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Contents

ORIGINAL ARTICLES

CASE REPORTS

HOW TO DO IT?

Cardiovasc Surg Int 2022;9(3):141-146
http://dx.doi.org/DOI: 10.5606/e-cvsi.2022.1383
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Cardiovascular Surgery and Interventions

Original Article Open Access

Results of negative pressure wound therapy for deep sternal wound infections after cardiac surgery

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ABSTRACT

Objectives: The aim of this study was to present the outcomes of negative pressure wound therapy (NPWT) for deep sternal wound infection (DSWI) after cardiac surgery.

Patients and methods: Sixty-eight patients (35 males, 33 females; mean age: 60.1±10.1 years; range, 18 to 80 years) who underwent coronary artery bypass surgery or valvular heart surgery between January 2017 and December 2021 were retrospectively reviewed. Patients who underwent NPWT for DSWI after cardiac surgery were included in the study. Baseline and postoperative characteristics of the patients were presented. Previously claimed risk factors for mortality were investigated.

Results: The time interval between cardiac surgery and diagnosis of DSWI was 35.8±30.2 days. The mean duration of NPWT was 21.1±11.8 days. In-hospital mortality was 14.7%. Coagulase-negative staphylococci were the most frequently isolated microorganism (n=26, 38.2%), followed by *Klebsiella* spp. (n=10, 14.7%). The only factor associated with higher mortality was the female sex in our DSWI patients.

Conclusion: Negative pressure therapy is a safe and reliable treatment option in patients with DSWI with or without sternal dehiscence.

Keywords: Cardiac surgical procedures, negative pressure wound therapy, sternum, surgical wound infection.

Despite increasing experience and advancements in surgical techniques, sternal wound infection remains a challenging complication after cardiac surgery. Deep sternal wound infection (DSWI) following cardiac operations is relatively rare compared to other surgical site infections.[2] However, DSWI is life-threatening and difficult to treat, and its incidence is reported to be between 1 and 6%.[1,2] It is associated with prolonged length of stay and increased morbidity, mortality, and healthcare costs.[2,3]

Risk factors for DSWI reported in the literature include advanced age, diabetes, obesity, use of cigarettes, chronic renal disease, and chronic pulmonary disease.[2,4] The use of bilateral internal thoracic artery (BITA) is also an operation-related risk factor known to increase DSWI risk.[2] Rupprecht and Schmid[5] have classified sternal complications of cardiac surgery according to the associated clinical findings. Noninfected sternal instability can always be treated by primary sternal closure with or without debridement. In contrast, DSWI without sternal instability needs to be treated by surgical debridement with negative pressure wound therapy (NPWT) followed by wound revision and sternal closure.[4] Deep sternal wound infection with sternal instability is a more complex pathology and often needs advanced interventions such as muscle flaps.[4]

Treatment of DSWI is challenging, long-lasting, and lacks a standardized algorithm. Conventional treatment modalities are associated with increased mortality ranging from 19 to 25%.[2,6] Negative pressure wound therapy was first described in 1997 by Argenta and Morykwas[7] for enhanced wound

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healing. Since then, their technique has been applied for sternal wound infections after cardiac surgery and with improved outcomes.[8,9] The aim of this study was to present the outcomes of NPWT for DSWI after cardiac surgery.

PATIENTS AND METHODS

This retrospective study was conducted with at the Istanbul Medeniyet University, Göztepe Prof. Dr. Süleyman Yalçın City Hospital, Department of Cardiovascular Surgery between January 2017 and December 2021. Patient data were collected from hospital records in a high-volume cardiac center. Laboratory workups and microbiological culture results, including blood and wound culture, were recorded. Previously known risk factors, such as diabetes, advanced age, higher body mass index, active smoking, renal disease, and chronic pulmonary disease, were investigated. The outcomes of interest were the time of DSWI onset, length of hospital stay, and mortality. The study population was selected from patients who underwent coronary artery bypass surgery (CABG) or valvular heart surgery via median sternotomy. Patients with DSWI who required NPWT were included in the study. Patients who underwent aortic or cardiac surgery other than CABG or valvular heart surgery were excluded from the study. In addition, superficial sternal infections, which do not require NPWT therapy, minimal invasive cases (e.g., J-sternotomy), patients with infection of any site before the surgery, including emergency cases, and reoperations were excluded. The follow-up records of eight patients could not be reached, and they were excluded from the study. Among the patients who operated within the study period, 68 patients (35 males, 33 females; mean age: 60.1±10.1 years; range, 18 to 80 years) with DSWI after cardiac surgery who met the criteria were included in the study. A total of 8,221 open heart surgery patients were operated on within five years in our center. Thirteen DSWI patients who did not meet the inclusion and exclusion criteria were excluded from the study. Approximately 1% of patients were diagnosed with DSWI within the study period.

The diagnosis of DSWI was made according to the presence of at least one of the following criteria: isolation of microorganism from mediastinal tissue or fluid, presence of mediastinitis, or existence of sternal instability, chest pain, or fever (>38°C). Purulent drainage from the mediastinum in addition to the isolation of microorganisms from blood culture or mediastinal discharge, purulent mediastinal discharge, or widening mediastinum in radiological imaging was also considered DSWI.[10]

All patients took a preoperative bath with chlorhexidine. The staphylococcal colonization was checked with nasal swabs, and topical mupirocin was administered to patients with staphylococcal colonization. The patients were transferred to the intensive care unit following the operation, to the ward on the first or second postoperative day, and discharged from the hospital between the 7th and 10th postoperative day. If DSWI was observed, blood and wound cultures were performed. Perioperative prophylactic antibiotics were given to all patients, and empirical antibiotics were initiated upon the recommendation of the infectious disease department to patients with suspected infections. Antibiotherapy was revised according to culture antibiogram results. In patients with DSWI, NPWT (Confort C300 NPWT Therapy Unit, Eskişehir, Türkiye) in intermittent therapy mode with standard wound closure sets was applied after a sharp and satisfactory debridement of the necrotic and infected tissue. The NPWT set was replaced every 48 to 72 h. The sternal fixation by steel wires was performed in the presence of sternal dehiscence. Diagnosis of mediastinitis in patients with DSWI was made with positive wound cultures, symptoms of infection such as fever, angina, sternal instability, and radiological findings on the computer tomography.

Statistical analysis

Statistical analysis was performed using the Jamovi version 1.2.27 software (Sidney, Avustralya). Descriptive data were expressed as mean ± standard deviation for continuous variables and number (frequency) for categorical variables. Univariate logistic regression analysis was performed for variables that were previously reported as risk factors for in-hospital mortality. A p value of <0.05 was considered statistically significant.

RESULTS

The baseline characteristics of the patients are presented in Table 1. Forty-five (66.2%) patients had diabetes mellitus, and 43 (63.2%)

Table 1
Baseline characteristics

Variables	n	%	Mean±SD
Age (year)			60.1±10.1
Female sex	33	48.5	
Hypertension	42	61.8	
Diabetes mellitus	45	66.2	
Obesity	43	63.2	
Active smoking	34	50.0	
Chronic pulmonary disease	21	30.9	
Chronic kidney disease	30	44.1	

SD: Standard deviation.

had obesity. Sternal wound cultures were taken as soon as possible after detecting DSWI. Isolated microorganisms are presented in Table 2. Coagulase-negative staphylococci were the most frequently isolated microorganism (n=26, 38.2%) in our DSWI patients, followed by *Klebsiella* spp. (n=10, 14.7%), *Staphylococcus aureus* (n=9, 13.2%]), and *Acinetobacter* spp. (n=9).

Postoperative and follow-up data are shown in Table 3. The mean time interval from the time of surgery to the detection of DSWI was 35.8±30.2 days, and the mean duration of NPWT was 21.1±11.8 days. The patients with DSWI had a longer length of stay with a mean of 58.2±49.5 days. In-hospital mortality was observed in 10 (14.7%) patients.

The result of the univariate logistic regression analysis performed on known risk factors for DSWI and mortality is given in Table 4. None of the variables were found to be associated with higher mortality except for the female sex in our study group. Eight out of 33 female patients had in-hospital mortality. Except for the two deceased patients, the sternal wounds of the other patients healed. All patients were discharged with recovery. The follow-up of the patients after discharge was not included in our study.

Table 2
Isolated microorganisms in sternal cultures

Microorganism	n	%
Staphylococcus aureus	9	13.2
MRSA	4	5.9
MSSA	5	7.4
Coagulase-negative Staphylococci	26	38.2
Enterobacter spp.	5	7.4
Klebsiella spp.	10	14.7
Escherichia coli	1	1.5
Acinetobacter spp.	9	13.2
Candida spp.	6	8.8
Proteus spp.	2	2.9
Morganella spp.	1	1.5
Corynebacterium spp.	4	5.9
Serratia spp.	1	1.5
Stenotrophomonas maltophilia	2	2.9

MRSA: Methicillin-resistant *Staphylococcus aureus*; MSSA: Methicillin-susceptible *Staphylococcus aureus*.

DISCUSSION

Deep sternal wound infection is a severe complication after cardiac surgery and requires special attention. While the incidence of DSWI

Table 3
Postoperative characteristics of the patients

Variables	n	%	Mean±SD
Time from operation to detection of DSWI (days)			35.8±30.2
Time to eradication of pathogen (days)			24.3±19.3
Duration of NPWT (days)			21.1±11.8
Sternal dehiscence	17	25.0	
Reconstruction by a muscle flap	2	2.9	
Length of hospital stay (days)			58.2±36.3
In-hospital mortality	10	14.7	

SD: Standard deviation; DSWI: Deep sternal wound infection; NPWT: Negative pressure wound treatment.

Table 4
Logistic regression analysis of risk factors for DSWI in predicting mortality

		95% CI		
	HR	Lower	Upper	*p*
Age	1.003	0.938	1.070	0.927
Female gender	5.280	1.030	27.064	0.046
Diabetes mellitus	0.731	0.184	2.901	0.656
Active smoking	0.622	0.159	2.439	0.496
Obesity	2.629	0.512	13.502	0.247
Chronic kidney disease	1.320	0.344	5.062	0.686

DSWI: Deep sternal wound infection; CI: Confidence interval; HR: Hazard ratio.

after CABG is as low as 0.3 to 2.3%,[11,12] the associated mortality rate can be as high as 36%.[13] Early closure of the sternal wound following a sharp debridement in DSWI cases appears as a treatment option to prevent secondary infection. Still, it may also predispose to the spread of infection.[2,13] Sternal closure following NPWT, which provides a clean wound with granulation tissue, is a more reasonable option.[2] In DSWI cases after cardiac surgery, the mortality rate was quite higher before NPWT, and the mortality rate was noticeably decreased after the use of NPWT.[5,13] Morisaki et al.[13] reported that mortality in DSWI patients was 38% before NPWT use, and this rate decreased to 5% after NPWT use. The in-hospital mortality was 14.7% in our study population, which seems significantly lower than the mortality rates in previous studies.[13,14] The beneficial effects of NPWT on sternal wound healing could be listed as follows: it maintains chest wall stability, promotes granulation tissue, decreases wound edema, and provides drainage of excessive and infected fluid in case of a persistent infection. [11,15] Mobilization of the patient is also possible with NPWT that provides sternal stabilization.[15,16]

Deep sternal wound infection is often an early complication of cardiac surgery.[1,5] The time interval between cardiac surgery and diagnosis of DSWI is a valuable parameter in treatment outcomes. Delayed diagnosis may negatively affect the success of treatment, whereas early diagnosis may prevent the further spread of the infection.[1,11] Negative pressure wound therapy is recommended to be initiated as soon as possible, particularly if the sternal wound closure is expected to be delayed.[6,11] The DSWI study by Buğra et al.[1] reported 21.3% mortality, and the mean time between the diagnosis of DSWI after the first cardiac surgery was 50.4±172.5 days. In our opinion, relatively early detection of DSWI (35.8±30.2 days) in our study plays a vital role in the slightly better mortality rate (14.7%). In addition, NPWT was initiated as soon as possible in all patients diagnosed with DSWI, which could also explain the better outcomes in our study.

According to the study by Lepelletier et al.,[17] *Staphylococcus aureus (S. aureus)* is the most frequently isolated microorganism in DSWI patients (40%), followed by coagulase-negative staphylococci (30%). Similarly, in our study population, the most isolated microorganisms were coagulase-negative staphylococci (38.2%), *Klebsiella* spp. (14.7%), and *S. aureus* (13.2%). Although routine preoperative nasal swabs are obtained from all patients, and mupirocin ointment is given to eradicate staphylococcal nasal colonization as the guidelines recommend, these measures cannot prevent *Staphylococcus* spp. from being the most frequently isolated microorganism in the DSWI cases.[17,18] In methicillin-resistant *S. aureus* cases, it is necessary to perform extensive and sharp tissue debridement to prevent severe tissue destruction and inflammation due to antibiotic resistance.[19]

Female sex, hypertension, diabetes mellitus, obesity, active smoking, chronic pulmonary disease, and chronic renal disease, which are considered risk factors for DSWI in the literature,[2,4,15] were observed at very high rates ranging from 30.9 to 66.2% in our DSWI patients. Among these risk factors, the only risk factor that was shown to be associated with

increased mortality was the female sex in our study population. In the literature review article for DSWI patients presented by Phoon and Hwang,[15] female sex was considered an independent risk factor for DSWI. When we looked for the impact of female sex on mortality in DSWI patients, no evidence was found on the subject. Although we found female sex as a risk factor for mortality in our study population of DSWI patients, this issue needs to be supported by further prospective studies.

The management of DSWI, particularly with sternal instability, needs special care and attention, with further interventions often necessary. Sternal dehiscence may give rise to DSWI. The Robicsek sternal closure technique is beneficial and helps to provide sternal stability in case of multiple sternal fractures.[15,20] If the primary closure of the sternum cannot be achieved, reconstructive surgery by a tissue flap can be an alternative.[14,21,22] We used the Robicsek sternal closure technique to provide sternal stability in cases with multiple sternal fractures. In two of these patients, primary closure could not be achieved, so reconstructive surgery by a muscle flap was required.

Despite several studies and reviews, there are no clear guidelines for DSWI. Dr. Lazar has extensively studied the field of sternal wound infections.[6,11,23] According to these studies, DSWI patients should be managed with a multidisciplinary approach, and NPWT should be initiated as soon as possible. There are also several reviews that propose an algorithm for the management of DSWI.[4,15,20] However, a widely accepted algorithm does not exist.

The retrospective design of the study is a significant limitation. Since we present the outcomes of NPWT after DSWI, there is no control group to compare for morbidity and mortality in the study; however, we could compare our results with previously reported outcomes with DSWI. Two patients with BITA use were both nondiabetics; therefore, BITA use was not included in the statistical analysis considering its limited number. Although the single-center design of our study may be a limitation, our clinic is a high-volume center serving a large population, allowing us to share our experience with a high number of yearly cases.

In conclusion, cardiac surgery patients can be complicated with DSWI despite the increasing surgical experience and better outcomes. Negative pressure wound therapy is a safe and reliable treatment option in DSWI patients with or without sternal dehiscence and is recommended to be initiated as soon as possible. The most frequently isolated microorganisms were coagulase-negative staphylococci (38.2%), *Klebsiella* spp. (14.7%), and *S. aureus* (13.2%). Female sex was the only factor that was shown to be associated with increased mortality in our DSWI patients.

Ethics Committee Approval: Ethical approval was obtained from the hospital's academic review board and Haydarpaşa Numune Training and Research Hospital Clinical Research Ethics Committee (No: HNEAH-KAEK 2022/103-3681). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: Informed consent was waived due to the retrospective nature of the study, and the patient information had been anonymized before analysis.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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The treatment indication affects the time in therapeutic range

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ABSTRACT

Objectives: This study aimed to compare the efficacy and safety of the treatment in patients with deep vein thrombosis (DVT) and mechanical mitral valve replacement (MVR) who were treated with warfarin for different indications.

Patients and methods: A total of 536 patients (314 males, 222 females; mean age: 55.6±10.8 years; range, 18 to 89 years) were retrospectively reviewed between January 2016 and January 2020. The patients were evaluated in two groups: 273 DVT patients (149 males, 124 females; mean age: 56.7±11.3 years) who received long-term therapy (six months) and 263 mechanical MVR patients (165 males, 98 females; mean age: 56.2±9.4 years). Both groups were compared in terms of the percentage of time in the therapeutic range (TTR), the time to reach the target international normalized ratio (INR), and warfarin related complications.

Results: The number of total hospital visits and total INR measurements for six months in the MVR group was statistically significantly higher than in the DVT group ($p<0.001$). The duration and percentage of TTR in the first three and six months of the MVR group were statistically significantly higher than the DVT group ($p<0.05$).

Conclusion: More MVR patients remained in the therapeutic range than DVT patients due to the frequent hospital visits of these patients for various reasons; thus, it may be beneficial to increase the frequency of follow-up examinations or measurements of INR in patients who have started warfarin treatment for an indication other than valve replacement.

Keywords: Anticoagulants, deep venous thrombosis, heart valve prosthesis, therapeutic range, warfarin.

The most recognized way to measure the therapeutic effectiveness and quality of warfarin treatment over time is to measure the percentage of time in the therapeutic range (TTR).[1] It has been shown that high TTR rates are associated with a lower risk of complications in terms of bleeding in patients using warfarin.[2]

Deep vein thrombosis (DVT) patients often go to the hospital only for international normalized ratio (INR) control. However, patients with mechanical valve replacement (MVR) frequently apply to the hospital for wound evaluation and routine cardiac examinations, particularly in the first postoperative month. Therefore, this increases the number of clinical visits of patients. In this study, we predicted that the group with a higher number of hospital visits could potentially have better TTR rates.

When the literature was reviewed, there was no study comparing venous thrombus patients and patients who underwent mechanical valve replacement in terms of anticoagulation quality and complications. Hence, DVT and MVR patients were compared in terms of the percentages of TTR and supratherapeutic INR-related bleeding complications, aiming to compare the efficacy and safety of the treatment in patients who received warfarin for different indications.

PATIENTS AND METHODS

This retrospective study was conducted with 536 patients (314 males, 222 females; mean age: 55.6±10.8 years; range, 18 to 89 years) on oral anticoagulation with warfarin at the Katip Çelebi University, Faculty of Medicine, Department of Cardiovascular Surgery between January 2016 and January 2020. Data obtained from the hospital registry system. The patients were evaluated in two

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groups: 273 DVT patients (149 males, 124 females; mean age: 56.7±11.3 years) who received long-term therapy (six months) and 263 mechanical MVR patients (165 males, 98 females; mean age: 56.2±9.4 years). Both groups were compared in terms of the percentage of TTR, the time to reach the target INR, and warfarin-related complications. Both groups were followed up by our team in our anticoagulation clinic for the first six months. Data including the initial demographic and clinical characteristics of the patients, INR measurements, number of clinical visits over a six-month period, and the number of INR measurements performed over a six-month period were recorded. In line with the recommendations of the literature, the target INR range was accepted as 2.0 to 3.0 in DVT patients, and the target INR range was accepted as 2.5 to 3.5 in patients with mechanical MVR.[3,4] The TTR was calculated using the Rosendaal linear interpolation method.[5] Inclusion criteria were patients who received anticoagulant therapy by indication of isolated mechanical MVR or venous thromboembolism. Exclusion criteria were patients with chronic renal failure or hypercoagulability syndrome, and cancer patients receiving chemotherapy. Patients were excluded if the INR was measured less frequently than once every two months in both groups. In addition, patients who underwent redo surgery in the mechanical valve group were excluded.

The definition of the complication was patients hospitalized with Grade 2 or higher bleeding according to the World Health Organization (WHO) Bleeding Scale due to supratherapeutic INR.[6] Comparing the complications associated with the subtherapeutic INR was not suitable for this study as it was not fair to compare valve complications with recurrent DVT.

Blood product transfusion was decided according to previously published studies.[4,7,8] Accordingly, fresh frozen plasma and erythrocyte suspension replacement was performed in patients with supratherapeutic INR (INR >5) and bleeding higher than Grade 2 according to the WHO Bleeding Scale.

Statistical analysis

All analyses were performed using IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for baseline characteristics of patients. Kolmogorov-Smirnov and Shapiro-Wilk tests were employed to test the normality of data. Continuous variables were described as mean ± standard deviation, and categoric variables were presented as counts (percentages). We tested factors in univariate analyses (t-test and chi-square test). A p value <0.05 was considered statistically significant.

RESULTS

No statistically significant difference was found between the groups in terms of age, sex, smoking, arterial hypertension, diabetes mellitus, and prior cerebrovascular events (Table 1).

The number of total INR measurements for six months in the MVR group was statistically significantly higher than in the DVT group (p<0.001, Table 2). In addition, the number of total

Table 1
Patient demographics and clinical features

	DVT group (n=273)			MVR group (n=263)			
	n	%	Mean±SD	n	%	Mean±SD	p
Age (year)			56.7±11.3			56.2±9.4	0.476
Sex							0.055
Female	124	45.4		98	37.3		
Male	149	54.6		165	62.7		
Smoking	67	24.5		58	22.1		0.496
Hypertension	55	20.1		63	24.0		0.287
Diabetes mellitus	22	8.1		23	8.7		0.774
Cerebrovascular events	9	3.3		13	4.9		0.989

DVT: Deep vein thrombosis; MVR: Mitral valve replacement; SD: Standard deviation.

Table 2
Three-and six-month follow-up results

	DVT group (n=273)			MVR group (n=263)			
	n	%	Mean±SD	n	%	Mean±SD	*p*
Total INR counts, in six months			4.40±0.72			5.06±0.91	***<0.001
Total hospital visit counts, in six months			4.41±0.71			5.20±0.88	***<0.001
TTR, in three months			46.6±18.3			49.7±16.8	*0.046
Percentage of TTR, in three months			51.8±20.3			55.6±18.8	*0.026
TTR, in six months			106.0±26.7			116.0±28.7	***<0.001
Percentage of TTR, in six months			58.9±14.8			64.8±16.0	***<0.001
Complication	54	19.8		49	18.6		0.736
WHO Bleeding Scale Grade ≥2	7	2.5		8	3.0		0.737
Blood transfusion	27	10.3		23	8.4		0.464
FFP (units)			3.0±1.6			2.8±1.7	0.420
ES (units)			2.7±1.4			1.7±0.6	0.061

SD: Standard deviation; INR: International normalized ratio; TTR: Time in Therapeutic Range; WHO: World Health Organization; FFP: Fresh Frozen Plasma; ES: Erythrocyte Suspension.

hospital visits for six months in the MVR group was statistically significantly higher than in the DVT group (p<0.001, Table 2).

The mean TTR in the first three months in the DVT group was 46.6±18.3 days. The percentage of TTR in the first three months was 51.8%. In the same group, the mean TTR in the first six months was 106.0±26.7 days, and the TTR percentage was 58.9%. The mean TTR and percentage of the first three and six months in the MVR group were 49.7±16.8 days, 55.6% and 116.0±28.7 days, 64.8%, respectively. Thus, the duration and percentage of TTR in the first three and six months of the MVR group were statistically significantly higher than the DVT group (p<0.05, Table 2).

When the DVT group (n=54, 19.8%) and MVR group (n=49, 18.6%) were compared in terms of hospitalization history due to supratherapeutic INR, there was no statistically significant difference between the groups (Table 2). When the patients hospitalized due to supratherapeutic INR were evaluated, Grade 2 and higher bleeding was detected according to the WHO Bleeding Scale in seven (2.5%) patients in the DVT group and eight (3.0%) patients in the MVR group, and no statistically significant difference was found between the groups (Table 2). Additionally, the blood transfusion rate and the number of transfused blood products did not differ significantly in both groups (Table 2).

DISCUSSION

Prior studies have reported strong associations between TTR and the efficiency and safety of the treatment.[1,9,10] One of the basic principles behind keeping the TTR percentage high is undoubtedly patient compliance.[11] Since the preoperative, operative, and postoperative processes for heart valve replacement patients are much more demanding than those for DVT patients, we designed this study based on the assumption that treatment compliance may be better in these patients. Therefore, to compare the efficacy and safety of warfarin treatment in DVT and prosthetic mitral valve patient groups were compared in terms of TTR percentage and complication rates.

It is a known fact that the demographic characteristics of the patients are associated with effective anticoagulation.[12,13] In our study, we evaluated both patient groups in terms of demographic data, and we could not find a statistically significant difference between the groups. The homogeneity of the demographic data made the results of the study valuable.

There are limited studies examining the TTR percentages of patients using warfarin for different indications. However, there are no comparisons of different indications in these studies. In one of these studies, the median TTR percentage in DVT patients using warfarin was reported as 71.1%.[14] In another study, the median TTR percentage was reported to be 60% in patients with mechanical prosthetic valves.[15] In our study, both the first three-and six-month TTR percentages in the MVR group were found to be statistically significantly higher than those in the DVT group. One of the main reasons is that the prosthesis valve operation process is much more demanding than the DVT treatment process, so patient compliance is likely to be higher. In our opinion, another reason is that MVR patients require more hospital visits than the DVT group. In our study, when patient groups were evaluated in terms of total hospital admissions during the six-month follow-up, there was a statistically significantly higher number of admissions in the MVR group. While DVT patients mostly went to the hospital for INR control alone, MVR patients were frequently admitted for wound site evaluation and cardiac routine examinations, particularly in the first postoperative month. In addition, it was understood from the outpatient clinic registry system that these patients were immediately admitted to the hospital even with noncardiac infectious or noninfectious symptoms.

There are reported results regarding the relationship between TTR and bleeding complications. It was reported that the rate of major bleeding complications was reported between 1.0 and 2.36 in 100 patients using warfarin.[14,15] In the study of Kavasoglu et al.,[16] which included 415 patients using warfarin, the rate of major bleeding was reported as 2.6%.

When evaluated in terms of bleeding and complications related to supratherapeutic INR in our study, there was no statistically significant difference between the groups. However, the mean TTR percentages of patients with bleeding complications in both groups were below 60% both in three months and six months, and these results were consistent with the literature.[9] Being outside of the TTR does not necessarily lead to complications. There are patients with high INR who were incidentally discovered in our follow-ups and did not have any symptoms or complications. Therefore, although there is a serious correlation between being out of TTR and the incidence of complications, this will not be an absolute relationship. We think that this is the reason there was no statistically significant difference between the groups in this sense.

When the groups were evaluated independently, it was observed that the TTR percentage in the first six months was higher in both groups compared to the first three months. This led us to think that the time elapsed since the initiation of treatment increased the TTR percentage. Therefore, these findings can be interpreted as indicating that the quality of warfarin therapy is largely dependent on the time elapsed since the initiation of therapy.

The number of INR measurements may have been effective in the emergence of the statistically significant difference regarding the TTR percentages stated above. In the WARFARIN-TR study conducted in our country, patients monitored for one year with an INR ≤8 (n=1,752) were reported to have statistically significantly lower TTR levels than those with an INR >8.[17] In our study, in accordance with the literature, the number of total INR measurements for six months in the MVR group was statistically significantly higher than in the DVT group.

One of the reasons for the better TTR percentage in the MVR group can be attributed to the knowledge of or familiarity with therapy, which are a large part of treatment compliance. It was reported that patients who had a low level of knowledge regarding warfarin therapy experienced more problems in terms of their adherence to the medication.[18] Although most of the MVR patients were discharged with the subtherapeutic INR, they were already on medication at discharge. In other words, this was not the first time they used warfarin when they left the hospital. When viewed from this aspect, this may have caused a difference in the patient groups in terms of acceptance of the disease and compliance with treatment.

There are several limitations to this study. The study group consisted of a relatively small sample size compared to large registers. The study was planned in a retrospective manner. Furthermore, we did not have enough data on possible confounder variables, such as educational status, personal income data, occupation, and caregiver availability, which may have affected our results.

In conclusion, we found that more MVR patients remained in the therapeutic range than

DVT patients due to the high awareness of therapy process influenced by the difficulty of the MVR procedure and the frequent hospital visits of these patients. Therefore, it may be beneficial to increase the frequency of follow-up examinations or measurements of INR in patients who have started warfarin treatment for an indication other than valve replacement. Studies with larger sample sizes, different warfarin usage indications, and expanded sets of sociocultural demographic data of patients will provide further clarification.

Ethics Committee Approval: The study protocol was approved by the Katip Çelebi University Faculty of Medicine Ethics Committee (Date/no: 19/11/2020-GOKAE-0609). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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The association of new atherosclerosis markers with coronary collaterals in chronic total occlusion patients

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ABSTRACT

Objectives: In the present study, we investigated the relationship between mentioned markers and chronic total occlusion collateral development.

Patients and methods: A total of 243 patients (210 males, 33 females; mean age: 63.3±11.5; range, 51 to 76 years) who underwent coronary angiography due to typical chest pain or myocardial ischemia detected in noninvasive stress tests and diagnosed with ≥1 major coronary artery occlusion between January and September 2020 were included in the cross-sectional observational study. The angiographic collateral index was determined according to the Cohen-Rentrop classification. The patients were divided into two groups according to the sufficiency of collateral development: the well-developed collaterals group (n=155) and the poor-developed collaterals group (n=88).

Results: Statistically significant parameters in univariate logistic regression analysis were evaluated with multivariate (stepwise) logistic regression analysis; as a result, presence of chronic total occlusion in left anterior descending artery (odds ratio [OR]=2.447; 95% confidence interval [CI], 1.160-5.162; p=0.019), total number of occlusions (OR=3.503; 95% CI, 1.445-8.494; p=0.006), left ventricular ejection fraction (OR=1.056; 95% CI, 1.022-1.091; p=0.001), and the atherogenic index of plasma (OR=0.017; 95% CI, 1.022-1.091; p<0.001) were independently associated with well-developed collaterals. Although the triglyceride-glucose index had statistical significance in the univariate analysis, it was not detected as an independent variable in the multivariate analysis. The monocyte-lymphocyte ratio was not significant in the univariate analysis.

Conclusion: Of the new atherosclerosis markers, only the atherogenic index of plasma had an independent association with poor collateral development.

Keywords: Atherogenic index of plasma, chronic total occlusion, coronary collaterals, monocyte-lymphocyte ratio, triglyceride-glucose index.

Coronary angiogenesis and collateral formation are adaptations that act protectively by supplying blood flow in the region where severe myocardial ischemia develops. Infarct size+, frequency of aneurysm formation, and major cardiovascular events are reduced owing to the adaptations.[1,2]

Dyslipidemia is a crucial factor contributing to vascular endothelial dysfunction.[2] Intact vascular endothelium is essential for coronary collateral development. Therefore, vascular endothelial dysfunction may disrupt collateral development. The fact that collateral development is impaired in diabetes mellitus and metabolic syndrome that causes vascular endothelial dysfunction supports this theory.[3-5]

Inflammation and abnormal glucose and lipid metabolisms are critical in atherogenesis and substantial risk factors for cardiovascular diseases.[6,7] Studies have shown that atherogenic index of plasma (AIP), triglyceride-glucose (TyG) index, and monocyte-lymphocyte ratio (MLR) are novel markers for atherosclerosis, insulin resistance, and inflammation, respectively.[8-10] Endothelial dysfunction plays a significant role in initiating the atherosclerosis process; in addition, it is the common ground of atherosclerosis risk factors. Considering the relationship between

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coronary collateral development and endothelial dysfunction, new biochemical markers indicate atherosclerosis may be associated with collateral development. In the present study, we aimed to evaluate the relationship of new atherosclerosis-related biochemical markers (AIP, TyG index, and MLR) with the coronary collateral development in chronic total occlusion (CTO) patients.

PATIENTS AND METHODS

The cross-sectional observational study included 243 consecutive patients (210 males, 33 females; 63.3±11.5; range, 51 to 76 years hospitalized in the cardiology department of the Rize Training and Research Hospital between January and September 2020. Patients diagnosed with stable coronary artery disease (CAD) according to the criteria recommended by the European Society of Cardiology and had total occlusion of ≥1 major coronary vessel detected with coronary angiography (CAG) were included in the study.[11] Patients with typical chest pain or with myocardial ischemia detected in noninvasive stress tests were included in the study. Coronary artery bypass grafting, acute coronary syndrome in the last three months, hematological disease, malignancy, severe kidney (estimated glomerular filtration rate <30 mL/min/1.73 m^2) or liver disease, ongoing infection or chronic inflammatory disease, and autoimmune disease were the exclusion criteria.

The presence of classical cardiovascular risk factors, such as age, sex, diabetes mellitus, hypertension, dyslipidemia, and smoking, was questioned. Patients underwent a transthoracic echocardiographic examination. Hypertension was defined as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg on repeat measurements or use of any antihypertensive drug. Diabetes mellitus was defined as a fasting plasma glucose level of ≥126 or ≥200 mg/dL at any measurement or use of any antidiabetic drug.

Peripheral venous blood samples were obtained from the patients on the day of hospitalization. The levels of blood biochemical parameters, including a lipid panel, fasting glucose, creatinine, and C-reactive protein levels, were measured. The TyG index was calculated as ln[fasting triglycerides (mg/dL) × fasting plasma glucose (mg/dL)/2]. The AIP was calculated by using the following formula: log10 (TG/HDL-C).[7,12] It can be classified according to the values obtained: −0.3 to 0.1 for low risk, 0.1 to 0.24 for medium, and more than 0.24 for high risk of CVD.[13] The MLR was calculated by dividing monocyte count by lymphocyte count.

Standard selective CAG was performed on all patients using the Judkins technique with at least four images for the left coronary system and at least two images for the right coronary artery. Images of CAG were reevaluated for analyzing collateral development by two experienced interventional cardiologists who were blinded to the study. Collateral grading was assessed concerning the vessel with the highest Rentrop grade in case of having more than one CTO-containing vessel. The degree of coronary collateral development was determined according to the Cohen–Rentrop method: Grade 0, no filling of any collateral vessels; Grade 1, side branch filling of the recipient artery without filling of the main artery; Grade 2, partial filling of the main epicardial artery by collaterals; Grade 3, complete filling of the main epicardial artery by collaterals.[14]

The patients were divided into two groups according to collateral development. Patients with Grade 0 to 1 Rentrope were included in the poor-developed collateral group, and patients with Grade 2 to 3 Rentrope were included in the well-developed collateral group. Coronary angiograms of 243 patients were analyzed, and according to the Cohen-Rentrop method, well-developed collaterals were observed in 155 (63.7%) patients, while poor-developed collaterals were observed in 88 (36.2%) patients.

Severe CAD was defined as stenosis of more than 50% in vessels greater than 1.5 mm in diameter. Coronary total occlusion was defined as lesions present for more than three months, in which the artery shows either the complete interruption of antegrade blood flow on angiography or minimal contrast penetration through the lesion without distal vessel opacification.[15]

Statistical analysis

Statistical analysis was performed using IBM SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were tested for normal distribution using the Kolmogorov-Smirnov test, the Shapiro-Wilk test, and visualization methods (histograms and probability plots). Data were expressed as mean±standard deviation (SD) for

Table 1
Baseline characteristics of the groups

Variables	Poor collateral flow (n=88)					Good collateral flow (n=155)					*p*
	n	%	Mean±SD	Mean	25th-75th percentile	n	%	Mean±SD	Mean	25th-75th percentile	
Age (year)			61.5±10.9					64.4±9.9			0.034
Body mass index (kg/m^2)			29.5±3.7					28.2±3.8			0.043
Sex											
Female	8	9.1				25	16.1				0.465
Previous PCI	33	37.5				50	32.3				0.408
Type 2 DM	37	42				44	28.4				0.022
Hypertension	63	71.6				97	62.6				0.099
Current smoking	35	39.8				44	28.4				0.047
Hyperlipidemia	38	43.2				54	34.8				0.125
LAD occlusion	14	15.9				57	36.8				<0.001
CX occlusion	19	21.6				48	31				0.076
RCA occlusion	60	68.2				87	56.1				0.104
Total occlusion number			1.07±0.31					1.3±0.5			0.002
Number of CAD			2.4±1.3					2.9±1.6			0.016
LVEF			47.1±10.3					50.1±10.1			0.027
Atherogenic Index			0.7±0.3					0.5±0.26			<0.001
WBC (10^3/µL)			9.1±2.7					8.6±2.8			0.206
Hemoglobin (g/L)			13.8±1.8					13.8±1.9			0.954
Glucose (Fasting) (mg/dL)			163.7±89.3					140.3±59.1			0.016
Serum creatine (mg/dL)			1.25±0.8					1.04±0.48			0.059
Total cholesterol (mg/dL)			207.1±55.1					201.1±51.6			0.365
LDL cholesterol (mg/dL)			129.8±47.1					128.1±43.1			0.762
HDL cholesterol (mg/dL)			40.7±16.1					43.4±10.1			0.099
Triglyceride (mg/dL)			229.5±162					156.3±92.1			<0.001
Triglyceride/glucose ratio			1.6±1.07					1.2±0.84			0.001
Monocytes/ lymphocyte ratio			0.3±0.2					0.3±0.14			
C-reactive protein				5.7	1.7-12.7				6	2.1-13.5	0.552
Medication						63	40.6				0.532
Acetylsalicylic acid	46	52.3				22	14.2				0.053
P2Y12 inhbitor	20	22.7				60	38.7				0.066
Beta blocker	38	43.2				45	29				0.495
ACE inhbitor	28	31.8				26	16.8				0.639
ARB	19	21.6				41	26.5				0.353
Calcium channel blocker	15	17				54	34.8				0.094
Statin	46	52.3				15	9.7				0.008
Insulin	13	14.8				37	23.9				0.232
OAD	29	33									0.126

SD: Standard deviation; PCI: Percutaneous coronary intervention; DM: Diabetes mellitus; LAD: Left anterior descending coronary artery; CX: Circumflex coronary artery; RCA: Right coronary artery; CAD: Coronary artery disease; LVEF: Left ventricular ejection fraction; WBC: White blood cell; LDL: Low-density lipoprotein; HDL: High-density lipoprotein; ACE: Angiotensin Converting Enzyme Inhb.; ARB: Angiotensin receptor blockers; OAD: Oral antidiabetic agents.

Table 2
Multivariate binary logistic regression analysis

	Univariate			Multivariate		
Variables	OR	95% CI	*p*	OR	95% CI	*p*
Age (year)	1.028	1.002-1.055	0.035			
Body mass index (kg/m^2)	0.932	0.870-0.999	0.047			
Type 2 diabetes mellitus	0.546	0.316-0.946	0.031			
Current smoking*	0.600	0.346-1.042	0.070			
Left anterior descending coronary artery occlusion	3.074	1.592-5.936	0.001	2.447	1.160-5.162	0.019
Number of total occluded vessel	3.362	1.488-7.600	0.004	3.503	1.445-8.494	0.006
Number of coronary artery disease	1.247	1.040-1.496	0.017			
Left ventricular ejection fraction (%)	1.029	1.003-1.056	0.029	1.056	1.022-1.091	0.001
Atherogenic index	0.035	0.011-0.119	<0.001	0.017	0.004-0.069	<0.001
Glucose (fasting)*	0.996	0.992-0.999	0.020			
Triglyceride (mg/dL)	0.994	0.991-0.997	<0.001			
Statin	0.488	0.286-0.832	0.008			
Triglyceride/glucose ratio	0.631	0.469-0.848	0.002			
Constant				0.026		0.001

OR: Odds ratio; CI: Confidence interval; * The marked parameters were not included in the multivariate logistic regression analysis. Forward conditional method was used in multivariate logistic regression analysis.

normally distributed continuous variables and median (interquartile range) for categorical variables. Variables of both groups were compared by the chi-square test, Mann-Whitney U test, and independent samples t-test, where appropriate. Univariate and backward multivariate logistic regression analysis was performed to identify independent predictors for well-developed collaterals. A two-tailed *p* value of <0.05 was considered statistically significant.

RESULTS

There were significant differences between the groups regarding age, body-mass index, diabetes, smoking, left anterior descending (LAD) artery occlusion, the total number of occlusions, number of coronary arteries with severe stenosis, left ventricular ejection fraction, AIP, fasting glucose, and triglyceride levels (Table 1). Although there were differences between the groups in terms of sex, hypertension, creatinine, and high-density lipoprotein cholesterol (HDL-C) levels, this difference was not statistically significant.

The parameters that reached statistical significance were tested with univariate logistic regression analysis, and factors other than smoking were found to be significant (Table 2). All statistically significant parameters in univariate logistic regression analysis were evaluated with multivariate (stepwise) logistic regression analysis; eventually, the presence of CTO in the LAD artery (odds ratio [OR]=2.447; 95% confidence interval [CI], 1.160-5.162; p=0.019), total number of occlusions (OR=3.503; 95% CI, 1.445-8.494; p=0.006), left ventricular ejection fraction (OR=1.056; 95% CI, 1.022-1.091; p=0.001) and AIP (OR=0.017; 95% CI, 1.022-1.091; p<0.001) were independently associated with good collateral development.

DISCUSSION

The present study identified that AIP, one of the new biochemical markers associated with atherosclerosis, has an independent inverse association with well-developed coronary collaterals. Although the TyG index differed significantly between the groups, it had no independent association with coronary collateral development.

The AIP is a new lipid index superior to low-density lipoprotein (LDL)-cholesterol (LDL-C),

HDL-C, total cholesterol, and triglyceride in predicting CAD.[24] Atherogenic index of plasma is a substitute for small dense (sd) LDL particles and is inversely proportional to LDL-C particle size.[25] The rise in AIP indicates a decrease in LDL particle diameter and an increase in sdLDL, which favors the formation of foam cells and atherosclerotic plaque development.[26] Atherogenic index of plasma is independently associated with CTO and is thought to predict the presence and severity of CTO.[27]

High-density lipoprotein cholesterol has cardioprotective effects and improves endothelial function through its anti-inflammatory and antioxidative effects; in addition, it modulates monocyte activation, adhesion, and migration.[28,29] In the present study, HDL-C level was found close to statistical significance in the well-developed collateral group. The HDL-C level might have contributed to well collateral development.

Studies have shown that the TyG index is superior to HOMA-IR (homeostatic model assessment for insulin resistance) in assessing insulin resistance and can be used to predict CAD and adverse cardiovascular events.[30-32] Insulin resistance can directly or indirectly contribute to ventricular and vascular dysfunction due to attenuated proinflammatory response and aggravated atherosclerotic plaque.[33,34] Furthermore, insulin resistance can alter systemic lipid metabolism, leading to dyslipidemia and even accelerating the rupture of fragile plaques by aggravating vascular endothelial damage and inflammation.[35] However, in the current study, although its relationship with collateral development was significant, it was not detected as an independent variable.

Monocyte-lymphocyte ratio, a novel marker of systemic inflammation, is an independent risk factor for CAD and predicts lesion severity.[36] Increased MLR favors body inflammation and oxidative stress, accelerates the formation of foam cells and endothelial damage, suppresses immune responses, and aggregates coronary plaque development.[37,38] In the present study, its relationship with collateral development had no statistical significance.

Melidonis et al.[39] more frequently detected third-degree collateral circulation following complete occlusion of the LAD and right coronary arteries. In the current study, well-developed collaterals were observed much more in the LAD artery CTO cases. We thought that this might be due to the size of the myocardial jeopardy area, which is influential in collateral development, and the ischemic stimulus that it created. We considered that the higher the total number of occlusions and the number of lesions above 50%, the greater the collateral development as a factor affecting the size of the myocardial jeopardy area.

The relatively small study population and the single-center design may limit the interpretation of results. The study's cross-sectional nature limits the direct relationship between cause and effect. More extensive and prospective studies are needed to confirm this relationship.

In conclusion, the use of AIP, one of the new biochemical markers associated with atherosclerosis in patients with CTO, should be at the forefront in predicting poor collateral development. Furthermore, the use of TyG would be beneficial, but MLR was not appropriate. Compared to these parameters, the AIP, which is noninvasive and easily accessible, can help predict the degree of collateral development the best, but more comprehensive randomized controlled studies are needed.

Ethics Committee Approval: The study protocol was approved by the Recep Tayyip Erdoğan University Faculty of Medicine Ethics Committee (Date/no: 18.05.2022/40465587-050.01.04-443). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Determination of predischarge learning needs of patients with myocardial infarction

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ABSTRACT

Objectives: This study aimed to determine the predischarge learning needs and influencing factors of patients with myocardial infarction.

Patients and methods: The study included 190 MI patients (156 males, 34 females; mean age: 60.2±12.7 years; range, 21 to 85 years) admitted with the diagnosis of myocardial infarction between February 2021 and February 2022. Data were collected using the Sociodemographic/Clinical Characteristics Form and the Turkish version of the Cardiac Patients' Learning Needs Inventory.

Results: The patients' symptom management, physical activity, anatomy and physiology of the heart, diet, psychological factors, lifestyle, and the mean total score on the scale were 27.45±2.64, 22.82±3.53, 20.56±3.15, 19.92±3.19, 15.45±2.81, 12.38±1.95, 155.21±17.11 points, respectively. It was found that there was a statistically significant difference in the general education need levels of the patients according to their education status, marital status, working status, exercise habit, cohabitants, additional chronic diseases, and history of heart attack/angiography and seeking information about heart attacks ($p<0.05$).

Conclusion: Predischarge learning needs levels of patients with myocardial infarction were relatively high. The primary learning need was for symptom management. Patients' learning needs levels varied according to sociodemographic and clinical characteristics.

Keywords: Cardiology nursing, learning needs, myocardial infarction, nursing care.

Myocardial infarction (MI) develops due to an atherosclerosis or thrombus.[1] It is among the leading causes of death in Türkiye,[2] as well as in the world.[3,4] Risk factors include the male sex, advanced age, coronary artery disease, hypertension, diabetes mellitus, and hyperlipidemia. The main purpose of the treatment and nursing care of these patients is to reduce the mortality/morbidity rate, prevent disabilities, create a healthy lifestyle, and increase the quality of life (QoL).[5,6] The learning needs of the patients should be evaluated to prevent recurrent severe symptoms and maximize their QoL.[7-11]

Patients' learning needs differ according to the prognosis of the disease and the cultural and spiritual traditions of the patient.[9] It is stated in the literature that the learning needs of patients with MI include the anatomy and physiology of the heart, psychological factors, lifestyle, correct drug use, correct diet, physical activity status, and symptom management.[8,12] With individualized nursing education planned in line with learning needs, it is easier for patients to cope with their diseases, and the rate of rehospitalization decreases. Thus, their QoL is positively supported. However, it is seen in the literature that the education given to the patients is mostly on specific subjects and is not structured in line with their learning needs.[13-15] Therefore, this study aimed to determine the learning needs and influencing factors of patients with MI.

PATIENTS AND METHODS

The population of this descriptive and cross-sectional study consisted of 190 MI patients (156 males, 34 females; mean age: 60.2±12.7 years; range, 21 to 85 years) who were admitted to the coronary intensive care unit and cardiology clinic of the Pamukkale University Faculty of Medicine between February 2021 and February 2022. Patients diagnosed with MI confirmed by a physician, able to speak and understand Turkish, who had no

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communication barriers, had mental competence, had no psychiatric disease, who was conscious, who was in stable condition, stayed in the hospital for at least two days, discharged by their physician, and willing to participate in the study were included in the study.

The face-to-face interview technique was used to collect the data. The data regarding the introductory information of the patients were obtained from the patients themselves, and the data containing the information about their medical conditions were obtained from the records in the patient's file. The Sociodemographic and Clinical Characteristics Form, developed by the researcher in line with the relevant literature, and the Cardiac Patients' Learning Needs Inventory (CPLNI) were used to collect the study data.

This form, developed in line with the relevant literature, consists of two sections: sociodemographic and clinical. The sociodemographic characteristics section includes 13 questions regarding the patient's protocol number, diagnosis, age, sex, marital status, education status, employment status, smoking status, sports status, body mass index, individuals they are living with, and place of residence. The clinical characteristics section includes 10 questions regarding having an additional chronic disease, the medication used regularly, history of a heart attack in family members, the reason for coming to the hospital, history of heart attack, angiography, and stent, the state of having regular check-ups, the status of receiving education about heart attack, and from whom this education was received.[9,12,15,16]

The CPLNI was developed by Gerard and Peterson.[8] The scale has been accepted as a short, simple, and understandable measurement tool for determining the learning needs of patients suffering from myocardial infarction. Turkish validity and reliability study was carried out by Uysal and Enç.[12] The Turkish Version of the CPLNI (TR-CPLNI) consists of eight subdimensions and 38 items. The TR-CPLNI includes five items to assess the anatomy and physiology of the heart, four items to assess psychological factors, three items to assess lifestyle factors, five items to assess drug information, five items to evaluate nutritional information, six items to evaluate physical activity, six items evaluate symptom management, and four items evaluating other issues. Scale scoring is calculated as follows: not important=1, somewhat important=2, moderately important=3, important=4, very important=5 , and not applicable=0. The phrase "not applicable" was accepted as 0 points so as not to affect the scoring. The score that can be obtained from the scale is between 38 and 190. The increase in the scale score indicates that the patient's learning need is increasing. The original CPLNI Cronbach's alpha value was 0.91.[8] In the Turkish validity and reliability study, Cronbach's alpha value of the overall scale was found to be 0.96. The Cronbach's alpha value of the subdimensions of the scale varies between 0.78 and 0.92.[12] In this study, Cronbach's alpha value of the overall scale was found to be 0.94. Cronbach's alpha value of the scale subdimensions ranges from 0.52-0.87.

Statistical analysis

The sample size was determined as 150 patients using the G*Power version 1.9.4 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany), with a medium effect size (d=0.15), error level of 0.05, and study power of 0.80.

The data were analyzed using IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ±standard deviation. Categorical variables were presented as numbers and percentages. Normality analysis was used to examine the relationship between dependent and independent variables. The normality analysis was calculated according to the kurtosis and skewness analysis. Normal distribution was accepted according to this result (skewness=0, kurtosis=±2).[17] In the comparison of the levels of the patients' learning needs according to sociodemographic/clinical characteristics, the data matching the normal distribution were evaluated by Student's t-test and one-way analysis of variance. For the data that did not fit the normal distribution, the Mann-Whitney U test or the Kruskal-Wallis test was used to compare the differences between the groups. A value $p<0.05$ was considered statistically significant.

RESULTS

The mean body mass index was 27.6±4.2, and 63.2% were hospitalized with a non-ST-elevation MI diagnosis. Of the patients, 81.0% were married, and 62.1% were primary school graduates. It was determined that 38.4% of the patients are employed, 36.3% are smokers, 55.3% did not exercise at all, 48.4% live in the city center, and 52.1% lived with their

Table 1
Sociodemographic characteristics of patients with MI

Variables	n	%	χ^2±SD
Age (year)			60.2±12.7
BMI (kg/m^2)			27.6±4.2
Diagnosis			
NSTEMI	120	63.2	
STEMI	70	36.8	
Sex			
Male	156	82.1	
Female	34	17.9	
Marital status			
Married	154	81.0	
Single	36	19.0	
Educational status			
Illiterate	9	4.7	
Literate	17	8.9	
Primary education	118	62.1	
Secondary education	33	17.4	
Undergraduate and postgraduate	13	6.8	
Working status			
Working	73	38.4	
Not working	117	61.6	
Smoking status			
Drinks	69	36.3	
Never drank	56	29.5	
Left	65	34.2	
State of doing sports			
Never played sports	105	55.3	
Occasional athlete	61	32.1	
Regular exerciser	24	12.6	
Living place			
Town center	92	48.4	
District	50	26.3	
Town/village	48	25.3	
Person living with			
Alone	21	11.2	
Spouse	99	52.1	
Spouse and kids	55	28.8	
Mother-father	4	2.1	
Son/daughter	11	5.8	

Table 1
Continued

Variables	n	%
Presence of chronic disease*		
Yes	143	75.3
No	47	24.7
Type of chronic disease #		
Hypertension	81	56.6
Coronary artery disease	73	51.0
Diabetes mellitus	63	44.1
Chronic obstructive pulmonary disease	12	8.4
Asthma	8	5.6
Peripheral artery disease	7	4.9
Chronic renal failure	7	4.9
Congestive heart failure	2	1.4
Other (onnamed)	23	16.1
Continuous drug use status		
Using	134	70.5
Not using	56	29.5
Presence of a relative who has had a heart attack		
Yes	97	51.1
No	93	48.9
The reason why the patient came to the hospital#		
Chest pain	181	95.3
Back pain	57	30.0
Pain radiating to the left arm	71	37.4
Stomach ache	48	25.3
Heart attack/angio history *		
Yes	74	38.9
No	116	61.1
Stent placement history *		
Yes	49	66.2
No	25	33.8
Regular check-ups		
Yes	74	38.9
No	116	61.1
Getting information about heart attack		
Yes	42	22.1
No	148	77.9
From whom did he get the information*		
Health personnel	20	47.6
Relative/friend	9	21.4
Social media	13	31.0

MI: Myocardial infarction; SD: Standard deviation; BMI: Body mass index; STEMI: ST-elevated myocardial infarction; NSTEMI: Non-ST elevated myocardial infarction; Onnamed: Hyperlipidemia, rheumatoid arthritis, bening prostatic hyperplasia, hypothyroidism, cerebrovascular disease, lung cancer, lymphoma glaucoma, gastritis /reflux, vertigo, gout; * The analyzes were calculated on patients with "history of chronic disease", "history of continuous drug use", "having angio" and "receiving information about heart attack"; # Patients gave more than one disease name.

Tablo 2
Distribution of the mean scores of the scale of learning needs of patients with MI

Scale sub-dimensions	Distribution of scale score averages	
	χ^2±SD	Min-Max
Symptom management	27.5±2.6	14.0-30.0
Drug information	23.0±2.1	12.0-25.0
Physical activity	22.8±3.5	12.0-32.0
Anatomy and physiology of the heart	20.6±3.2	12.0-25.0
Nutritional information	19.9±3.2	11.0-25.0
Psychological factors	15.5±2.8	8.0-20.0
Other topics	13.7±3.4	6.0-20.0
Lifestyle factors	12.4±2.0	5.0-15.0
Grand scale total	155.2±17.1	100.0-190.0

MI: Myocardial infarction; SD: Standard deviation.

spouses. It was determined that 75.3% of the patients had a chronic disease, 56.6% had hypertension, 70.5% regularly took medicines, and 51.1% had a relative who had a heart attack. It was determined that 95.3% of the patients applied to the hospital with chest pain, 38.9% had angiography, and 66.2% of them had a stent. It was determined that 38.9% of the patients had regular heart health checks, 22.1% had information about heart attacks, and 47.6% of them received information from health personnel (Table 1).

The distribution of the mean scores of the patients' learning needs with MI is given in Table 2. The overall mean score for the education needs of the patients was 155.2±17.1. It was observed that symptom management (27.5±2.6), drug information (23.0±2.1), physical activity (22.8±3.5), and anatomy and physiology of the heart (20.6±3.2) subdimensions were the subjects with the highest learning needs (in the first four ranks), while nutritional knowledge (19.9±3.2), psychological factors (15.5±2.8), other subjects (13.7±3.4), and lifestyle factors (12.4±2.0) subdimensions were the subjects with the lowest learning needs (in the last four ranks) (Table 2).

The relationship between the level of learning needs according to sociodemographic and clinical characteristics of patients with MI is given in Table 3. A statistically significant difference was found between the marital status (F=5.766, p=0.001), educational status (F=4.995, p=0.001), employment status (Z=-3.162, p=0.002), state of doing sports (F=5.136, p=0.007), and cohabitant (F=8.188, p=0.001) of the patients included in the sample and the total scale score (p<0.05). Similarly, it was found that there was a statistically significant difference between those who did not have a chronic disease (Z=3.000, p=0.003), who did not have a history of heart attack/angiography (t=-2.993, p=0.003), and those who received information about the heart attack (t=2.900, p=0.004) and the mean scale score (p<0.05) (Table 3). It was determined that the scale subdimension learning needs levels of the patients varied according to their sociodemographic and clinical characteristics (Table 3).

DISCUSSION

After cardiovascular diseases, particularly MI, patients experience many physical and psychological complications and need information about the disease process.[18,19] In this study, which aimed to determine the predischarge learning needs of patients with MI and influencing factors, the general learning needs of the patients were found to be quite high. Similar to the findings of this study, it was stated in the national and international literature that the learning needs of patients with MI are high.[16,18,19] The study findings are similar to the literature, and it can be stated that patients need information about the disease and the changes affecting the postdischarge process.

According to the results of this study, the learning needs of the patients are affected by their sociodemographic and clinical characteristics. Single

Tablo 3
The relationship between the learning needs scale score of patients with MI and the independent variables

Variables	Grand scale total	Symptom management	Drug information	Physical activity	Anatomy and physiology of the heart	Nutritional information	Psychological factors	Other topics	Lifestyle factors
Diagnosis	t=1.478	t=-0.372	t=-0.351	t=1.276	t=0.761	t=2.253	t=1.74	t=1.468	t=-1.708
	p=0.141	p=0.710	p=0.725	p=0.204	p=0.448	**p=0.025**	p=10.083	p=0.144	p=0.088
Sex	t=-0.541	Z=-1.120	Z=-0.491	t=1.141	Z=-0.718	Z=-1.429	Z=0.108	t=-1.563	Z=-1.768
	p=0.589	p=0.263	p=0.623	p=0.255	p=0.473	p=0.153	p=0.914	p=0.120	p=0.077
Marital status	F=5.766	KW=0.758	KW=3.029	KW=0.490	F=3.149	KW=6.629	KW=4.264	F=5.552	KW=9.854
	p=0.001	p=0.519	**p=0.031**	p=0.690	**p=0.026**	**p=0.001**	**p=0.006**	**p=0.001**	**p=0.001**
Educational status	F=4.995	KW=18.272	KW=19.021	F=3.386	F=2.858	KW=18.478	F=4.462	F=2.032	KW=23.883
	p=0.001	**p=0.003**	**p=0.002**	**p=0.006**	**p=0.016**	**p=0.002**	**p=0.001**	p=0.076	**p=0.001**
Working status	Z=-3.162	Z=-3.694	Z=-2.174	t=4.208	t=1.775	t=1.765	t=2.698	t=1.911	Z=-1.232
	p=0.002	**p=0.001**	**p=0.030**	**p=0.001**	p=0.077	p=0.079	**p=0.008**	p=0.058	p=0.218
Smoking status	KW=1.881	KW=1.881	KW=2.245	F=2.810	F=1.299	F=1.816	F=1.153	KW=0.871	KW=7.280
	p=0.155	p=0.155	p=0.325	p=0.063	p=0.275	p=0.165	p=0.318	p=0.420	**p=0.026**
Doing sports status	F=5.136	KW=4.306	KW=4.228	F=3.441	F=2.920	KW=6.613	F=4.856	KW=5.447	F=4.902
	p=0.007	p=0.116	p=0.121	**p=0.034**	p=0.056	**p=0.037**	**p=0.009**	p=0.066	**p=0.008**
Living place	KW=1.641	KW=0.660	KW=0.231	F=1.390	F=2.178	F=0.365	F=5.294	F=0.267	KW=5.361
	p= 0.440	p=0.719	p=0.891	p=0.252	p=0.116	p=0.695	**p=0.006**	p=0.766	p=0.069
Person living with	F=8.188	KW=10.264	KW=13.142	F=6.138	F=4.677	KW=27.982	KW=19.282	F=5.970	KW=37.569
	p=0.001	**p=0.036**	**p=0.011**	**p=0.001**	**p=0.001**	**p=0.001**	**p=0.001**	**p=0.001**	**p=0.001**
Presence of chronic disease	Z=-3.000	Z=-2.221	Z=-1.307	t=-3.672	t=-3.018	t=-1.332	t=-2.285	t=-2.328	Z=-2.053
	p=0.003	**p=0.026**	p=0.191	**p=0.001**	**p=0.003**	p=0.185	**p=0.023**	**p=0.021**	**p=0.040**
Continuous drug use status	t=-1.906	Z=-2.140	t=0.061	t=-2.862	t=-2.082	t=-0.349	t=-1.631	t=-1.908	Z=-1.529
	p=0.058	**p=0.032**	p=0.951	**p=0.004**	**p=0.037**	p=0.727	p=0.104	p=0.058	p=0.126
Presence of a relative who has had a heart attack	t=1.087	Z=-0.618	Z=-1.298	t=-0.128	t=1.008	t=1.631	Z=1.143	t=-0.403	Z=-1.230
	p=0.278	p=0.537	p=0.194	p=0.898	p=0.315	p=0.105	p=0.254	p=0.687	p=0.219
Heart attack/angio history	t=-2.993	Z=-3.341	Z=-2.033	t=-2.143	t=-2.553	Z=-1.945	t=-1.949	Z=-2.481	Z=-1.918
	p=0.003	**p=0.001**	**p=0.042**	**p=0.033**	**p=0.011**	p=0.053	p=0.053	**p=0.014**	p=0.055
Stent placement history	t=2.464	Z=2.464	Z=2.144	t=2.003	t=0.768	t=1.338	t=0.948	t=1.793	t=1.147
	p=0.092	p=0.092	p=0.342	p=0.142	p=0.468	p=0.269	p=0.392	p=0.174	p=0.324
Regular check up	t=1.862	Z=-0.111	Z=-0.476	t=0.096	t=2.083	t=2.197	t=1.301	t=3.086	Z=-0.844
	p=0.064	p=0.911	p=0.634	p=0.320	**p=0.039**	**p=0.029**	p=0.195	**p=0.002**	p=0.399
Getting information about heart attack	t=2.900	Z=0.047	t=1.136	t=2.291	t=2.742	t=2.316	t=2.266	Z=3.331	Z=-1.191
	p=0.004	p=0.963	p=0.257	**p=0.023**	**p=0.007**	**p=0.022**	**p=0.025**	**p=0.001**	p=0.234
From whom did he get the information?	F=1.799	F=0.293	F=1.266	F=1.491	F=3.653	F=0.774	F=1.537	F=1.454	F=1.921
	p=0.164	p=0.830	p=0.300	p=0.233	**p=0.021**	p=0.516	p=0.221	p=0.242	p=0.143

MI: Myocardial infarction.

patients, secondary school graduates, working individuals, those living with their parents, those who regularly exercise, those with a history of chronic disease/angiography, and patients who have information about heart attack have higher general education needs levels. It was stated in the literature that being a woman and having a high level of education has an effect on learning needs.[16,18,19] In this study, unlike in the literature, the majority of the patients were male and had graduated from secondary school. However, considering that the patients live with their parents, it can be stated that parental support increases the level of sharing their learning needs with healthcare professionals, and this is due to cultural differences.

When the mean score of the general learning needs of the patients included in the study was examined, it was determined that symptom management was in the first rank. In their study to determine the learning needs of patients with MI, Sultana et al.[18] reported that the learning needs of patients related to symptom management are quite high. Symptom management is an effort to control the risks associated with the disease. Patients who have undergone MI experience a fear of death during the crisis and want to know how to deal with a similar situation after discharge.[20] In this study, it was determined that the learning needs of patients who are secondary school graduates, employed, living with their spouses and children, who do not have additional chronic diseases, do not use drugs continuously, and have no previous history of heart attack and angiography were higher than the other patients. According to these results, contrary to the literature,[20] those without a history of chronic disease have higher learning needs related to symptom management. Thus, it can be interpreted that individuals who do not have a chronic disease experience more fear during MI and need more information to cope with the process compared to patients who have experienced angina before. However, the fact that this group of patients did not experience any conditions related to acute coronary syndrome before may have increased the need for information about the symptoms.

The secondary learning needs of the patients included in the study is drug knowledge. Drug information is an important variable for patients to comply with their treatments and to reduce the problems that may be experienced regarding the irregular use of drugs.[18] The long duration of treatment after MI increases the patients' learning needs about drugs.[21] In this study, similar to the literature,[9,16,18,21] all patients had high learning needs about drugs. It was stated in the national and international literature that drug information is among the top three topics demanded by patients who have undergone MI.[9,16,18,21] In this study, patients who are married, graduated from secondary school, employed, living with their parents, and who do not have a history of heart attack and angiography have a higher desire to get information about medications. However, no similar study was found in which all these variables were compared. Although no statistically significant difference was found in the drug knowledge subdimension of the learning needs according to sex in this study, it was stated in the literature that females expressed their drug knowledge learning needs more than males, and the difference was statistically significant.[19,21] This is explained by the fact that females, by their very nature, are more careful to ask for information about medication and control appointments than males.[19,21] Cultural structure is considered to be another reason why the level of learning needs varies according to sex. Considering that Almaskari et al.[19] conducted their study in Oman, whereas Alsaqri et al.'s[21] study was conducted in Saudi Arabia, sociocultural differences and sample differences between these countries explain the sex differences in findings. In other words, patient characteristics may vary from patient to patient and from culture to culture. Another reason affecting the high level of learning needs of patients on drug information in this study and other studies is that these patients may have positive or negative experiences with the drugs they constantly use. When these results are evaluated, it is seen that information about drugs cannot be ignored in the discharge training of patients after MI.

According to the findings of this study, one of the priority issues that patients need to learn is physical activity. However, it is stated in the literature that the learning needs about physical activity in patients with cardiovascular disease are not a priority.[9,19] Huriani[9] explain this situation with the necessity of restricting physical activity in the acute and subacute periods, which is the recommendation of the American Heart Association. According to the findings of this study, patients who have graduated from secondary school, are employed, exercise occasionally, live with their spouses and children, do not have additional chronic diseases, do not use medicines continuously, do not

have a history of heart attack and angiography, and know about heart attack have higher learning needs regarding the physical activity subdimension. Contrary to the findings of the current study, Almaskari et al.[19] determined that patients with higher education levels (undergraduate/graduate) have a higher desire to learn about physical activity. As can be seen, sociodemographic characteristics can affect learning needs related to physical activity. Almaskari et al.[19] interpreted this situation as sociodemographic characteristics, country conditions, cultural differences, and climate changes affecting individual priorities for learning needs.

Another issue that patients feel the need to learn primarily after MI is the anatomy and physiology of the heart (in the fourth rank). Patients are eager to receive information about the anatomy and physiology of the heart. Similar to the results of the current study, it is stated in the literature that patients who had an MI or cardiovascular disease have high learning needs about the anatomy and physiology of the heart.[18,19] Knowing the structure of the heart and the MI process makes it easier for patients to understand their disease and adapt to the treatment/care process and lifestyle change.[18] According to the findings of the current study, patients who are single, secondary school graduates, living with their spouses/children, who do not have a chronic disease, who do not have a history of angiography, who do not use medications continuously, who have regular health check-ups, who have information about heart attack, and who receive information from health personnel have higher levels of learning needs about the anatomy and physiology of the heart. Contrary to the findings of the current study, it is reported in the literature that patients with a history of comorbidity and acute coronary syndrome have a higher need for learning about the anatomy and physiology of the heart. Nur'aeni et al.[14] explained this situation with the theory of common sense. According to the common sense theory, the high severity of the disease and the threat factors perceived by the individual, and the fear of death increase the patients' learning needs. The finding of the current study that patients without chronic disease and acute coronary syndrome have higher learning needs regarding the anatomy and physiology of the heart can be interpreted as the acute coronary syndrome picture being perceived as a significant threat by the patients, which increases the learning needs.

It is reported in the literature that creating behavior change related to diet is the most significant step in developing healthy lifestyle behavior.[18,22,23] Unhealthy diets, particularly those containing fats, carbohydrates, and sugars, increase the risk of cardiovascular disease. However, for the patients participating in this study, the learning need regarding nutrition was not on their priority list. The high body mass index of the patients included in the sample group suggests that their eating habits and healthy lifestyle behaviors are not adequate. However, in this study, it was determined that learning needs about nutrition were more important than some variables. It was determined that patients who are diagnosed with ST-elevation MI, who are married, who have graduated from secondary school, who exercise occasionally, who live with their spouse/children, who have regular health checks, and who receive information about heart attack have a higher level of learning needs regarding nutrition compared to other patients. This situation can be interpreted as the sociodemographic and clinical characteristics of the patients affecting their learning needs regarding nutrition. Particularly the patient group that develops healthy lifestyle behavior has higher learning needs regarding the correct diet. It was stated that the risk of morbidity/mortality is higher in this patient group.[22,23] Therefore, it is thought that patients who are trying to develop high-minded, healthy lifestyle behaviors included in this study may have needed to learn more about heart-protective nutrition to avoid experiencing acute coronary syndrome again.

The learning needs of patients are affected by physiological and clinical processes as well as psychological factors. In this study, it was determined that the psychological factors are not a priority for participants. However, it was stated in the literature that the desire of MI patients to get information about psychological factors is at the forefront. In addition, according to the literature, patients need information about coping with stress after discharge the most.[18,19] It is considered that physiological problems are at the forefront since the patients in the study group are in the acute post-MI period. Another reason is cultural differences. This difference may have been because the patients in the study group were in the acute post-MI period, they focused on physiological symptoms rather than psychological factors, or they may have been the result of cultural differences. When the relationship between the psychological factors subdimension and

some variables were examined, it was determined that the patients who are single, have undergraduate and higher education, are employed, exercise regularly, live in the city center, live with their parents, do not have a chronic additional disease, and have information about heart attack have high learning needs about psychological factors. Hence, it can be suggested that patients who are educated, have healthy lifestyle behaviors, such as regular exercise, and do not have additional chronic diseases experience more stress during a heart. From a different perspective, the fact that the patients in this group were employed and living in the city center may have created another stress factor. Moreover, the fact that these people are also single and have taken responsibility for their parents may have increased their psychological burden as well as their physiological burden. Therefore, this may have increased the need for psychological support.

In this study, the learning needs of the patients about other subjects are in the last place. Other issues include the service to get support at discharge, the tests to be performed, and informing family members about heart-lung resuscitation or where and how to get support for family members. The reason why patients' learning needs for this subdimension are at the back of the line compared to other dimensions can be considered as the desire of patients to prioritize their individual needs rather than family during the acute illness period. When the relationship between the subdimension of other issues and some variables was examined, it was determined that the learning needs of patients who were single, living with their parents, who did not have a history of chronic disease/heart attack/angiography, who had regular check-ups, and who had information about heart attack were higher. Therefore, it can be interpreted that patients who do not have a history of chronic disease and heart attack but have knowledge about it want to act more cautiously during a possible acute coronary condition.

In this study, the learning needs of the patients related to lifestyle ranked last. However, contrary to the findings of this study, it was stated in the literature that the efforts of patients diagnosed with MI to develop healthy lifestyle behavior in the early post-MI period are at the forefront.[14] Although the general learning needs of the patients regarding a healthy lifestyle were low, it was found that it varies according to some sociodemographic and clinical characteristics. Patients who are single, have a high education level, smoke, exercise regularly, live with their parents, and do not have a chronic disease are more willing to reorganize their lifestyle, suggesting that patients with higher education levels are more willing to create healthy lifestyle behaviors. However, the fact that these patients experienced a major acute condition and at the same time have the knowledge in this area may have increased their learning needs towards protective lifestyle behaviors for themselves and their families.

In conclusion, the general predischarge learning needs of patients undergoing MI are high. Among the topics that require education, the first four are symptom management, drug information, physical activity, and the anatomy and physiology of the heart. The learning needs levels of the patients regarding the scale subdimensions vary according to their sociodemographic and clinical characteristics. Accordingly, assessing the learning needs of patients with MI before discharge, providing individual structured training for the patients in line with their learning needs, providing standard spontaneous education in cases where structured patient education cannot be done, conducting similar studies with larger and multicenter sample groups, in which qualitative and qualitative-quantitative study designs are used together, and obtaining broader and more detailed information on the subject is recommended.

Ethics Committee Approval: The study protocol was approved by the Pamukkale University Faculty of Medicine Ethics Committee (Date/no: 05.02.2021-E.14437). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: The study designed and completed, design, literature review, writing the article: T.S.M., F.G.; Idea/concept, critical review: T.S.M.; Data collection and/or processing: T.S.M.; Control/supervision, analysis and/or interpretation, final approval of the manuscript: F.G.

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Defining early right ventricular failure during left ventricular assist device implantation: Retrospective analysis of intraoperative management

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ABSTRACT

Objectives: In this study, we aimed to share the intraoperative anesthesia management of left ventricular assist device (LVAD) implantation and our approach to right ventricular failure (RVF) that developed in this process, and our results.

Patients and methods: A total of 82 patients (71 males, 11 females; mean age: 49.4±9.4 years; range, 18 to 71 years) who underwent LVAD implantation between February 2013 and June 2020 were included in the retrospective study. Preoperative echocardiography, cardiac catheterization findings, and intraoperative records were reviewed. In light of the preoperative hemodynamic, echocardiographic, and preoperative echocardiographic findings of the patients, RVF levels were preoperatively determined, and a medical and mechanical support therapy algorithm for RVF was created. The postoperative outcomes were evaluated within the framework of this algorithm.

Results: The mean preoperative left ventricular ejection fraction was 19.6%, and the mean right ventricular ejection fraction was 37.4%. According to our algorithm, eight (9.7%) patients developed severe, 12 (14.6%) moderate, and 48 (58.5%) mild RVF. No RVF was present in 14 (17.2%) patients. The vasoactive inotrope score was 25.7±1.3 in the advanced RVF group and compatible with the severity of RVF. Extracorporeal membrane oxygenation use was required in three (37.5%) patients who had severe RVF. Right ventricular assist device was implanted in one of the three patients with extracorporeal membrane oxygenation due to advanced RVF in the postoperative period. Mortality was observed in two (25%) patients in the advanced group, one (8.3%) in the moderate, three (6.25%) in the mild, and two (14%) in the normal RVF group.

Conclusion: A standardized method for defining the RVF severity and a well-defined treatment protocol according to its degree of severity is lacking. Considering hemodynamic and echocardiographic data, grading of RVF in patients is vital for determining the treatment protocol. Treatment for RVF should be converted into standard universal algorithms.

Keywords: Assist device, heart failure, left ventricle, right ventricle.

Left ventricular assist devices (LVADs) are increasingly used in advanced heart failure to provide adequate organ perfusion and improve quality of life. Perioperative management of LVAD implantation requires a multidisciplinary approach. In the presence of right ventricular failure (RVF), it is necessary to determine the degree of failure, start right inotropic therapy on time, and use short-term mechanical support systems if sufficient flow cannot be achieved.[1]

The incidence of RVF after LVAD implantation ranges from 5 to 44%.[2] Female sex, INTERMACS (Interagency Registry for Mechanically Assisted Circulatory Support) level 1, preoperative end-organ disorder, preoperative RVF, high pulmonary vascular resistance (PVR), nonischemic cardiomyopathy as etiology, history of a previous cardiac operation, and severe tricuspid insufficiency have been described as risk factors for the development of RVF after LVAD.[3] Right ventricular failure may develop immediately after LVAD implantation, during the early intensive care period, or late during follow-up after discharge.[4] Right ventricular failure in the operative or early postoperative period after implantation carries a significant mortality risk.[3]

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Management of RVF in LVAD implantation is challenging and there is no generally accepted common RVF definition.[5] In the studies performed, the definition of severe RVF is given on the basis of mechanical treatment and inotrope necessity. There are different clinical practices for managing intraoperative RVF, focusing on medication and mechanical support but not discussing a stepwise management protocol according to the degree of severity of RVF.

In this study, we aimed to present our algorithm for defining RVF, the management approach for RVF after LVAD implantation.

PATIENTS AND METHODS

Eighty-two patients (71 males, 11 females; mean age: 49.4±9.4 years; range, 18 to 71 years) who underwent LVAD implantation due to end-stage heart failure at the Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital between February 2013 and June 2020 were included in the retrospective study. The patients were evaluated by the advanced heart failure team per the protocol. Patients who underwent biventricular assist device (BIVAD) or total artificial heart (TAH) implantations were excluded. All patients received the standard preoperative management and treatment protocols decided by the advanced heart failure team. For the management of RVF, the algorithm defined by the team was applied. Preoperative demographic data, preoperative echocardiography, intraoperative cardiac catheterization findings, and intraoperative data were recorded.

None of the patients had mitral, tricuspid, or aortic stenosis of any degree. Patients with moderate or severe aortic regurgitation were not included in the LVAD program. Commonly, patients in the LVAD program have moderate to severe mitral regurgitation due to cardiomyopathy. As a routine approach, neither repair nor replacement of the mitral valve is performed during LVAD surgery as the LVAD unloads the left ventricle effectively. For tricuspid regurgitation tricuspid annuloplasty is performed only in the presence of severe regurgitation.

Standard open heart surgery monitoring was performed in each patient. A pulmonary artery catheter was used for mixed venous saturation, central venous pressure (CVP), and pulmonary arterial pressure measurement. External defibrillator pads were placed before anesthesia induction. After preoxygenation, anesthesia induction was ensured with midazolam (0.1 mg/kg), fentanyl (1-2 mg/kg), and rocuronium (1 mg/kg); anesthesia was maintained with volatile anesthetics (sevoflurane), fentanyl, and a propofol infusion. A transesophageal echocardiogram (TEE) probe (Vivid 7; GE Vingmed Ultrasound AS, Horten, Norway) was placed in all patients after intubation.

All operations were carried out with standard median sternotomy. Before cannulation, 300 IU/kg of heparin was administered. Arterial cannulation was performed using the ascending aorta or, in redo cases, the femoral artery. Venous cannulation was performed with the bicaval (in patients who will undergo tricuspid valve intervention) or two stage single atrial venous cannula technique. Cardiopulmonary bypass was initiated with an activated clotting time >400 sec. Left ventricular assist device implantations were performed on a normothermic beating heart.

A comprehensive perioperative TEE examination was performed in all patients undergoing LVAD implantation. The correct placement of the inflow cannula, toward the mitral valve and away from the

Table 1
Intraoperative TEE evaluation parameters before and after LVAD implantation and after weaning

Before LVAD implantation
Atrium and ventricle dimensions
Valvular functions
Ejection fraction
ASD, PFO
TAPSE
Intracardiac thrombus
Apical inflow cannulation location *vs.* mitral valve position
After LVAD implantation and before/after weaning
Apical inflow cannulation location *vs.* mitral valve position
Outflow and ascending aorta evaluation
Deairing
Interventricular septum position and shift
Ventricular contraction evaluation
Valvular functions
Flow and ventricular unloading

TEE: Transesophageal echocardiogram; LVAD: Left ventricular assist device; ASD: Atrial septal defect; PFO: Patent foramen ovale; TAPSE: Tricuspid annular plane systolic excursion.

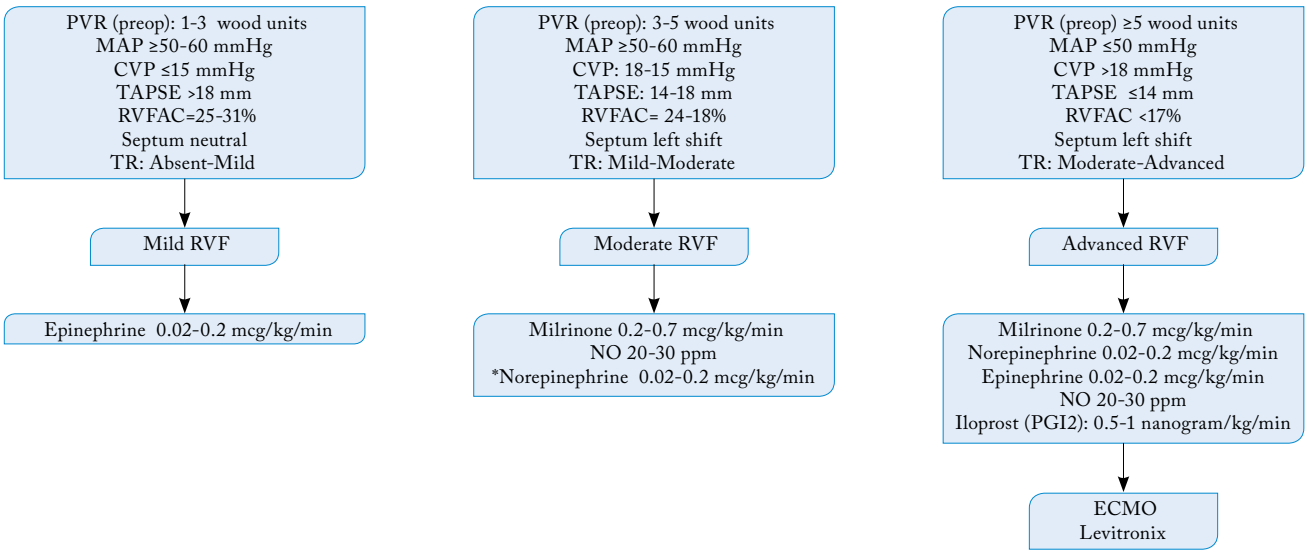

Figure 1. Right ventricular failure identification and management algorithm used in the intraoperative period.

RVF: Right ventricular failure; MAP: Mean arterial pressure; CVP: Central venous pressure; TAPSE: Tricuspid annular plane systolic excursion; RVFAC: Right ventricular fractional area change; TR: Tricuspid regurgitation; RVF: Right ventricular failure; ECMO: Extracorporeal membrane oxygenation; * If MAP ≤50 mmHg when milrinone was started, norepinephrine was added to the treatment.

ventricular septum, was assessed with intraoperative TEE. Our targets for TEE evaluation are given in Table 1.

The arterial blood gas parameters (pH, PCO_2 [partial pressure of carbon dioxide], PO_2 [partial pressure of oxygen], lactate, blood glucose, HCO_3, sodium, potassium, calcium, and chlorine) and hemodynamic parameters (heart rate [HR], mean arterial pressure [MAP], CVP, SPO_2 [peripheral capillary oxygen saturation]) were optimized before weaning off from cardiopulmonary bypass (CPB) and switching to full support by the LVAD device. Under optimal conditions (36-37˚C, HR: 80-100/min, mixed venous oxygen saturation ≥70%, arterial pH: 7.35-7.45, PO_2 and PCO_2 within normal limits, Hct [hematocrit]: 25-30%, potassium: 4.0-5.0 mEq/L, MAP ≥50 mmHg, CVP: 8-12 mmHg), CPB was terminated and LVAD was adjusted with adequate flow. Inotrope and pulmonary vasodilator therapy were initiated according to the RVF protocol. In Figure 1, the algorithm for the inotropic support and pulmonary vasodilator therapy used for weaning intraoperatively after LVAD implantation is displayed. The grade of the RVF was defined according to the group in which the majority of the criteria were matching (the group in which three or more criteria met among the seven parameters).

The vasoactive inotrope score (VIS) that reflects the sum of the inotropes were calculated for each patient after completion of LVAD implantation in the operating room. Vasoactive inotrope scores of patients on inotropes was calculated using the formula: dopamine dose (μg/kg/min)+dobutamine dose (μg/kg/min) + 100 × epinephrine (μg/kg/min) + 10 × milrinone dose (μg/kg/min) + 10000 × vasopressin doses (unit/kg/min) + 100 × norepinephrine doses (μg/kg/min).

Additional mechanical support was considered in patients with advanced RVF refractory to medical treatment. After CPB was terminated, the activated clotting time was neutralized with a heparin-protamine ratio of 1:1. After decannulation, bleeding control was achieved, and the sternum was closed. The patients were followed in the intensive care unit.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 28.0.1 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed as mean ± standard deviation, median (min-max), or number and frequency. The groups were compared using the chi-square and Kruskal-Wallis tests. A p value <0.05 was considered statistically significant.

RESULTS

The mean preoperative left ventricular ejection fraction was 19.6±4.6%, and the mean right ventricular ejection fraction was 37.4±9.7%. Preoperative mechanical support was necessary in 15 patients: left ventricular Levitronix Centri Mag (Levitronix LLC, Waltham, MA, USA) in seven (8.53%) patients, Venoarterial ECMO (Sorin Group STOCKERT SCPC, Munich, Germany) in four (4.87%) patients, and IABP (Datascope System 98 Datascope Corp., Fairfield, CT, USA) in four (4.87%) patients. Twenty-nine (35.3%) patients were on inotropes preoperatively, and nine (10.97%) patients were on mechanical ventilation before the operation. The mean preoperative tricuspid annular plane systolic excursion (TAPSE), pulmonary vascular resistans

Table 2
Demographic data (n=82)

	n	%	Mean±SD	Mean	Min-Max
Sex					
Female	11	13.4			
Male	71	86.6			
Mean age (year)			49.4±9.4		18-71
Diabetes mellitus	26	31.7			
Hypertension	31	37.8			
Body mass index (kg/m^2)			27.1±5.2		
Etiology of heart failure					
Dilated cardiomyopathy	42	51.21			
Ischemic cardiomyopathy	40	48.78			
INTERMACS Classification					
INTERMACS 1	7	8.53			
INTERMACS 2	8	9.75			
INTERMACS 3	14	17.07			
INTERMACS 4	38	46.34			
INTERMACS 5	15	18.29			
ECMO	4	4.87			
Levitronix	7	8.53			
IABP	4	4.87			
Preoperative hemodynamic					
Preoperative inotrope support	29	35.36			
Preoperative TAPSE (mm)				16.5	25-7
Preoperative PVR (WU)*				3.13	8-1
Preoperative CI (L/min/m^2)				1.195	2.4-0.95
Preoperative PCWP (mmHg)				17.90	41-10
Preoperative LVEF		19.6			
Preoperative RVEF	16	37.4			

ECMO: Extracorporeal membrane oxygenation; TAPSE: Tricuspid annular plane systolic excursion; PVR: Pulmonary vascular resistance; WU: Wood unit; CI: Cardiac index; PCWP: Pulmonary capillary wedge pressure; LVEF: Left ventricular ejection fraction; RVEF: Right ventricular ejection fraction.

(PVR), cardiac index (CI) and pulmonary capillary wedge pressure (PCWP) were 16.5 (7-25), 3.13 (1-8) wood units, 1.195 (0.95-2.4) L/min/m^2, and 17.90 (10-410) mmHg, respectively (Table 2).

Only two patients had severe tricuspid regurgitation before the operation, and concomitant tricuspid annuloplasty was performed. Both patients were in the severe RVF group. HeartMate II (HMII; St. Jude Medical, Inc. [Thoratec Corporation], Pleasanton, CA) was implanted in 31 patients (37.80%), Heartmate III (HMIII; St. Jude) Medical, Inc. [Thoratec Corporation], Pleasanton, CA) in 27 patients (32.92%), and Heartware HVAD Ventricular Assist System (HeartWare, Framingham, MA) in 24 patients (29.26%). Wood unit. According to our algorithm, eight (9.7%) patients developed severe, 12 (14.6%) moderate, and 48 (58.5) mild RVF. No signs of RVF were detected in 14 (17.2%) patients. Inotrope and vasodilator therapy were started according to this RVF classification. Among the seven patients who underwent surgery at the INTERMACS level 1, three patients developed severe, two patients moderate, and two patients mild RVF. Among all patients, the mean VIS values were 25.7±1.3 in the eight patients with advanced RVF, 19.5±1.5 in the 12 patients with moderate RVF, and 10.8±1.6 in the 48 patients with mild RVF. In 14 patients without RVF, the mean VIS was 3.6±1.1.

The mean duration of inotrope requirement was longer in patients with advanced RVF. Postoperative venoarterial extracorporeal membrane oxygenation (ECMO) was used in all patients who developed advanced RVF. The mean intubation time, renal replacement therapy requirement, and bleeding revision rates were higher in patients with advanced RVF (Table 3). As the degree of RVF increased, the INTERMACS level, need for inotropes, VIS value, need for ECMO and renal replacement therapy, and prolonged intubation time were found to be higher ($p<0.05$).

Although the overall patient number in the study was 82, the number of patients and morbidities were not sufficient to make a comparative analysis of each group. Instead, the study aimed to share our criteria for RVF after LVAD implantation as a contribution to further studies. A right ventricular assist device (RVAD) was implanted in the first postoperative week in one of the three patients who could not be weaned off the required support with an ECMO due to advanced RVF in the postoperative

Table 3
Patient profiles according to the degree of perioperative RVF after implantation

	Advanced RVF (n=8)			Moderate RVF (n=12)			Mild RVF (n=48)			Normal RV (n=14)		
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD
INTERMACS I	3	37.5		2	16.6		2	4.1		0	0	
Preoperative mechanical support	4	50		4	33.3		6	12.5		1	7.1	
Preoperative inotrope support	8	100		12	100		6	12.5		3	21.4	
Postoperative inotrope requirement (days)			9.8±2.8			6.6±1.4			4.4±1.2			1.7±0.9
VIS average (per patient)			25.7±1.3			19.5 ±1.5			10.8±1.6			3.6±1.1
Postoperative ECMO use	3	37.5		0	0		0			0	0	
Renal replacement therapy	3	37.5		1	8.3		0			0	0	
Intubation (days)			6±1.8			3.2±1.2			1.6±0.7			1.1±0.4
Reoperation for bleeding	2	25		0	0		2	4.1		0	0	
Mortality	2	25		1	8.3		3	6.25		2	14.2	

RVF: Right ventricular failure; RV: Right ventricul; VIS: Vasoactive inotrope score; ECMO: Extracorporeal membrane oxygenation.

period. Two patients with advanced RVF died due to prolonged intubation, infection, and sepsis. Two patients with normal right ventricular function died due to a major cerebrovascular event.

DISCUSSION

In LVAD patients, a postoperative process that will provide adequate LVAD flow and tissue perfusion can be ensured with careful intraoperative anesthesia management, and patient hemodynamics will be less affected by the underlying pulmonary and right ventricular dysfunction.[6,7] The first step in patient management during anesthesia preparations is advanced hemodynamic monitoring. In patients with advanced heart failure, a decrease in left ventricular preload or an increase in left ventricular afterload can cause rapid hemodynamic decompensation.[8] These patients require large amounts of circulating catecholamines to maintain vasoconstriction.[9,10] Suppression of the sympathetic system during induction or maintenance of anesthesia may cause severe decompensation in this patient group.[11-13] In patients undergoing LVAD implantation, TEE is a useful diagnostic and monitoring tool that provides insight into the position of the access cannula, ventricular contraction, filling pressures, and valve functions.[14-16] In our patient series, all patients underwent perioperative a TEE examination.

Evaluation of right ventricular functions is of particular importance.[17] Right ventricular function is affected by preload, PVR, and contractility. Upon initialization of the LVAD device, right ventricular preload increases, and left ventricular afterload can be optimized by adjusting the device flow. After the LVAD is implanted, the ventricular septum should be in a neutral to left position with the left ventricle moderately decompressed. Insufficient left ventricle decompression causes rightward septal shift and a decrease in LVAD flow, while excessive ventricular decompression causes the septum to deviate to the left and the device to suction, compromising the contractility of the right ventricle.

The interventricular septum may deviate to the left, impairing the septal contribution to right ventricular contraction and causing RVF. When RVF develops, it will increase left ventricular failure due to the septal compound system.[18] Therefore, visual control with TEE gains importance during the termination of CPB to assess the need for fluid and inotropic support during the incremental raising of the LVAD flow. The presence and degree of RVF can be successfully defined with monitoring and TEE examination.

Although various definitions of RVF and risk scoring systems have been defined, there is no standard accepted classification that guides treatment algorithms.[19] Existing definitions are generally based on the treatment of RVF. High dose and duration (more than two weeks) inotropic support RVAD, ECMO, and long-term use (two to 14 days) of inhaled nitric oxide are indicated as RVF treatment.[20-22]

Clinical differences are common in the detection and management of intraoperative RVF. Although the general strategies are known, the literature on treatment combinations, timing, and doses is limited. In our algorithm, patients were classified as mild, moderate, and advanced RVF by evaluating postoperative hemodynamic parameters (MAP, CVP, and PCWP), echocardiographic parameters (TAPSE, right ventricular fractional area change [RVFAC], interventricular septum position, and tricuspid valve function) and preoperative echocardiographic findings. Patients were managed according to this evaluation of RVF. The main purpose of the treatment algorithm was to optimize preload, afterload, and contractility using pulmonary vasodilators and inotropes. The requirement of inotropes or mechanical support was determined according to these parameters.

Inotropes, such as milrinone, or pulmonary vasodilators, such as nitric oxide and iloprost (PGI2 analogue), support the right ventricle by reducing afterload and optimizing preload.[23] Inhaled nitric oxide can produce a 43% reduction in PVR and decrease transpulmonary gradient (TPG).[24] In our patients, 20-30 ppm nitric oxide was used in 38 (46.34%) patients. In addition, hypoxia, hypercarbia, and acidosis should be avoided to minimize PVR.[18] Right ventricular failure after LVAD is encountered in 5 to 44% of operated patients across studies that use varying definitions of RVF.[25] Advanced RVF was detected in three (3.6%) of our patients, moderate RVF in 12 (14.6%) patients, and mild RVF in 48 (58.5%) patients. Due to varying definitions of RVF, no comparison with other studies could be made in this respect. The vasoactive inotropic scoring system is an objective indicator of inotrope therapy. Many studies have shown a correlation between high VIS values and poor outcomes.

Albeit, cut-off values for VIS vary greatly between studies.[26] In a study conducted in adult cardiac surgery patients, one-year mortality was higher in patients with a VIS ≥30.[27] In a study on the prognostic value of VIS after LVAD implantation,[28] high postoperative VIS (≥20) was associated with adverse in-hospital outcomes and was a good predictor of in-hospital mortality. In our study, the mean VIS value was 25.7±1.3 in patients with advanced RVF, 19.5±1.5 in moderate RVF, 10.8±1.6 in mild RVF, and 3.6±1.1 in patients without any RVF. Both RVF and mortality are more frequent with high VIS values. The necessity of using RVAD after LVAD is reported as 2.6%.[29] In The European Association For Cardio Thoracic Surgery, (EACTS) expert opinion statement, it was revealed that RVAD was required at a rate of 6 to 28% in patients using LVAD.[30] In our series, RVAD was used in one (5%) of 20 patients with moderate and severe RVF. Two patients with advanced RVF could not be weaned from RVF, and RVAD, which is the next treatment step, could not be used due to sepsis and multi-organ failure. Right ventricular failure after LVAD implantation is associated with high mortality and morbidity.[22] The RVF development rate is 9 to 42% after LVAD implantation,[22] and the mortality rate is stated to be 8%.[30] In our patient series, the mortality rate was 25% in patients with advanced RVF and 8.3% in patients with moderate RVF. When RVF is excluded from grouping, mortality is 9.7% in all patients.

The limitations of this study include its retrospective data collection and the relatively limited number of cases. Due to the limited number of patients with different grades of RVF, a statistically significant comparison was challenging. However, we believe it is important that the same treatment algorithm is applied to all patients, and thus we aimed to share our intraoperative patient management to form a basis for prospective studies.

In conclusion, intraoperative management during LVAD implantation requires a multidisciplinary approach and is crucial in the presence of RVF. A standardized method for defining the RVF severity and a well-defined treatment protocol according to its degree of severity is lacking. Defining the degree of RVF is essential to provide optimal treatment. We suggest our definitive criteria for evaluating mild, moderate, and severe RVF after LVAD implantation, which is helpful for a stepwise approach to management. The clinical criteria proposed here can be helpful for future studies aiming at a universal algorithm for defining the management of RVF after LVAD implantation.

Ethics Committee Approval: The study protocol was approved by the Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital Ethics Committee (Date/no: 08-03-2021/E-28001928-604.01.01). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Early-term outcomes of simultaneous carotid endarterectomy and coronary revascularization

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ABSTRACT

Objectives: This study was designed to evaluate the early-term results of the safety and effectiveness of simultaneous applications of coronary revascularization and carotid endarterectomy.

Patients and methods: In the sectional descriptive study conducted between December 2010 and December 2014, 32 patients (22 males, 10 females; mean age: 66±1.6 years; range, 49 to 85 years) with coronary artery disease and carotid artery stenosis were evaluated. All patients underwent simultaneous carotid endarterectomy and coronary artery bypass grafting. They were followed at the median for three months. Demographic characteristics of the patients and a history of previous myocardial infarction, hypertension, diabetes mellitus, hyperlipidemia, renal disease, peripheral arterial disease, and smoking were recorded.

Results: Hospital mortality was encountered in two (6.3%) patients. One (3.1%) patient had a postoperative major stroke, whereas two patients had a transient ischemic attack. Postoperative myocardial infarction was observed in one patient.

Conclusion: Synchronous carotid endarterectomy and coronary artery bypass grafting may be safe and effective in the management of patients with concomitant carotid artery stenosis and coronary artery disease.

Keywords: Carotid artery stenosis, carotid endarterectomy, coronary artery bypass grafting, coronary artery disease.

The coexistence of coronary artery and internal carotid artery obstructive disease is quite prevalent.[1] Significant internal carotid artery stenosis is detected in 8 to 14% of patients undergoing coronary artery bypass surgery.[1] Significant internal carotid artery disease poses a high risk for stroke after coronary bypass surgery. Therefore, carotid endarterectomy (CEA) is recommended for stroke prevention before coronary artery surgery.[1,2]

Surgical options applied in the coexistence of coronary and carotid artery disease are as follows: *(i)* staged approach, where endarterectomy is initially performed, followed by coronary artery bypass grafting (CABG); *(ii)* simultaneous approach, in which both procedures are done in one session; *(iii)* reversed approach, where CABG is performed first and CAE is performed later, which has a high cerebrovascular event rate. The overall risk of death, stroke, and myocardial infarction has been reported to be 10 to 12% after staged or simultaneous CEA and coronary bypass.[3] In this study, we aimed to present our results of CEA and myocardial revascularization performed simultaneously in a single center.

PATIENTS AND METHODS

Thirty-two patients (22 males, 10 females; mean age: 66.8±1.6 years; range, 49 to 85 years) who underwent simultaneous CAE and CABG using cardiopulmonary bypass (CPB) at the Turgut Özal University Faculty of Medicine Hospital between December 2010 and December 2014 were included in the sectional descriptive study. The patients were followed up for three months after the CABG. Surgical indications for CAE were as

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follows: *(i)* ≥50% internal carotid artery stenosis in a symptomatic patient, *(ii)* ≥70% internal carotid artery stenosis in an asymptomatic patient, and *(iii)* ≥70% bilateral internal carotid artery stenosis in an asymptomatic patient. Reoperation or emergency operations, patients with preoperative inflammatory or infective lung disease, patients with a left ventricular ejection fraction <40%, patients with chronic liver disease, and those using preoperative steroids were excluded from the study. All patients were operated by the same surgical team. Preoperative carotid artery evaluation of our patients was routinely performed with carotid Doppler ultrasonography. Computed tomography was performed in six patients (18.75%) as the rate of carotid stenosis could not be determined clearly who underwent carotid Doppler ultrasonography.

Surgical technique

The carotid artery was reached by passing the medial fascia of the sternocleidomastoid muscle. After the common carotid artery, internal carotid artery, and external carotid artery were fixed with nylon tapes, heparin was applied as a standard procedure. An incision was made in the carotid artery extending from the common carotid artery to the internal carotid artery. A carotid shunt was applied to all patients, and then CEA was performed. After the procedure was completed, the incision was repaired with primary or a continuous suture technique using a carotid patch. Acetylsalicylic acid was routinely added to the treatment on the first postoperative day in all patients.

Median sternotomy was performed, the left internal mammary artery was prepared. Moderate hypothermic CPB was applied during the operation. Myocardial protection was started with cold crystalloid cardioplegia, followed by cold blood cardioplegia. The aortic clamp was removed after all distal and proximal anastomoses were completed. We believe that the anastomosis quality is better under cross-clamp.

Statistical analysis

All data were collected and analyzed using IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Descriptive data are reported as median with interquartile range or frequencies as appropriate. We performed a Student t-test or Mann-Whitney U test as appropriate. Categorical variables were expressed as numbers (percentages) and compared using Pearson's chi-squared tests. Clinical data were presented as mean ± standard deviation (SD). A p value <0.05 was considered statistically significant.

Table 1
Clinical characteristics of the patients

	n	%	Mean±SD	Range
Age (year)			66.8±1.6	49-85
Sex				
Male	22	68.8		
Female	10	31.3		
Neurological history				
Asymptomatic	23	71.9		
Transient ischemic attack	4	12.5		
Stroke	5	15.6		
Cardiac history (myocardial infarction)	15	46.9		
Chronic obstructive pulmonary disease	6	18.8		
Hypertension	26	81.3		
Diabetes mellitus	18	56.3		
Chronic renal failure	4	12.5		
Smoking	13	40.6		
Hyperlipidemia	10	31.3		
Peripheral artery disease	7	21.9		

SD: Standard deviation.

Table 2
Preoperative data

	n	%	Mean±SD	Range
Aortic cross-clamp time (min)			99.7±5.7	38-193
Cardiopulmonary bypass time (min)			125.6±7.6	60-259
Number of coronary grafts			3.5±0.1	2-5
Intensive care duration (h)			24.3±2.6	14-76
Length of stay in hospital (days)			6.6±0.5	4-14
Surgical technique primary	1	3.1		
Patchplasty	31	96.9		

SD: Standard deviation.

RESULTS

Preoperative demographic data are given in Table 1. In the preoperative evaluation, most of the patients were asymptomatic (23 patients, 71.9%). Four (12.5%) patients had a transient ischemic attack, and five (15.6%) patients had a history of stroke. Two patients with a history of stroke had right lower and right upper extremity weakness, two patients had left lower and left upper extremity weakness, and one patient had a complete motor deficit on the left side.

Unilateral stenosis was detected in 25 (78.1%) patients, and bilateral stenosis was detected in seven (21.9%) patients. Fifteen (46.9%) patients had a history of coronary artery disease (myocardial infarction). Two of four (12.5%) patients with chronic kidney disease were continuing the hemodialysis program.

The preoperative data of the patients are given in Table 2. All patients were followed in the intensive care unit on the first day of operation. The carotid artery was repaired with a patch in 31 (96.9%) cases, and primary closure was preferred in only one (3.1%) patient due to the large diameter of the carotid artery.

Postoperative data of the patients are given in Table 3. Early mortality occurred in two (6.3%) patients due to cardiac events. One was deceased while hospitalized on the seventh postoperative day, and sudden death was observed in the other patient after discharge in the first postoperative month. Permanent hemiplegia developed in one patient, who was referred to physical therapy and rehabilitation after discharge. A transient ischemic attack developed in two patients. Myocardial infarction was observed in one patient after the operation.

Table 3
Postoperative data

	n	%
Early mortality	2	6.3
Neurological event persistent		
Hemiplegia	1	3.1
Transient hemiparesis	0	0
Transient ischemic attack	2	6.3
Postoperative MI	1	3.1
Atrial fibrillation	3	9.4
Heart failure	2	6.3

MI: Myocardial infarction.

DISCUSSION

One of the most common and feared complications after myocardial revascularization is a perioperative neurological event. In addition to having a significant effect on morbidity and mortality in the early and late periods, it prolongs the stay in the intensive care unit and the duration of discharge. It causes loss of workforce and reduced quality of life.[4-6]

It has not yet been clarified whether carotid artery disease causes perioperative stroke in individuals who have undergone coronary bypass operations. It has been suggested that some of the strokes may occur from residual carotid plaques during or after the operation, as well as from the harmful effects of the CPB, particularly the loss of pulsatile flow and the decrease in systemic perfusion pressure during CPB, which causes ischemia and related stroke distal to the carotid stenosis.[2,6] However, Reed et al.[7] also reported that more than 50% of strokes occur in the

postoperative period. This indicates that there are other mechanisms as well. More research is needed on this topic.[2,7]

Discussions are still ongoing about the surgical sequencing of patients with both CABG and CEA indications.[8] Surgical strategies such as staged, reverse staged, or simultaneous approaches were reported to minimize perioperative neurological and cardiac complications in these patients.[9] In patients with significant carotid artery stenosis who underwent CABG alone, the perioperative neurologic event rate was reported between 7.4 and 20.3%, and the mortality rate was between 6.9 and 13.8%.[10,11] In addition, a high morbidity rate of 7 to 8% was reported in patients requiring CABG but undergoing isolated CEA, and this is mostly the result of perioperative myocardial infarction.[11] Therefore, simultaneous operation in which both CEA and CABG are performed is recommended.[12,13] Trachiotis and Pfister[14] and Akins et al.[15] reported that combined CEA and CABG surgery were very effective in reducing neurological and myocardial complications. In addition, Takach et al.[16] stated in their study that the simultaneous approach is as safe as the staged approach even in the high-risk patient group. However, the discussion of how the simultaneous approach will be conducted has continued since Bernhard et al.[17] reported the simultaneous operation for the first time. The incidence of stroke is high (10%) in patients who initially underwent CABG and then CEA under cardiopulmonary bypass. In patients who underwent CEA and then coronary bypass operation, the incidence of perioperative myocardial infarction was found higher, and it has been reported that 25 to 30% of death rates are due to myocardial infarction.[18,19] Evagelopoulos et al.[20] performed combined surgery in 313 patients in which the carotid artery was prepared first and performed CEA after cooling to 30°C with median sternotomy, systemic heparinization, standard cannulation, and CPB. The early mortality rate with this technique was found to be 8.9% (4.2% cardiac origin). Khaitan et al.[21] reported that cerebral protection could be safely applied with 25°C hypothermia. In our series, we found that major neurological morbidity was 3.1% and mortality was 6.3% in our patients. In addition, 6.3% of our patients developed a transient ischemic attack.

Although there is no consensus on the ideal mean blood pressure for cerebral protection in CPB, Tufo et al.[22] reported that the risk of neurological events increased fourfold when the blood pressure remained below 50 mmHg for more than 10 min. In the simultaneous surgical technique used in our study, CEA is performed first, and then CABG is performed. Cerebral perfusion was maintained by the routine use of carotid shunts in all patients during CEA. In addition, we aimed to prevent cerebral hypoperfusion by keeping the perfusion pressure above 70 mmHg during CPB.

It has been reported in various publications that cardiopulmonary bypass and aortic and carotid cross-clamp time are the most important determinants of perioperative stroke development in CABG surgery. Each of these two periods is of particular importance in combined surgery. In a study of 2,211 patients undergoing coronary artery surgery, it was reported that pump time exceeding 120 min was a predictor of perioperative stroke.[23] In our series, the mean aortic cross-clamp time was 99.7±5.7 min, and the mean CPB time was found 125.6±7.6 min.

The main limitation of this study is that it included a single center. Therefore, the number of patients and the follow-up period are limited. Long-term follow-up results are needed.

In conclusion, combined CEA and CABG intervention may be recommended in the presence of severe carotid stenosis with coronary artery disease. When evaluated together with the literature, it can be said that the results of the simultaneous approach will be satisfactory.

Ethics Committee Approval: The study protocol was approved by the Turgut Özal University Ethics Committee (Date/no: 12.01.2011/03). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept: Y.N.; Design: Ö.N.A., Y.N; Control/supervision: Y.N.; Data collection and/or processing, analysis and/or interpretation: Ö.N.A., Y.N.; Literature review: Ö.N.A.; Writting the article: Ö.N.A.; Critical review: Y.N.

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Cardiovascular Surgery and Interventions

Case Report Open Access

A rare and challenging mitral valve replacement in a child with Hurler syndrome

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ABSTRACT

Mucopolysaccharidoses are progressive inherited lysosomal storage disorders, and early cardiac involvement is common. Valvular involvement of mucopolysaccharidoses usually causes regurgitation, most commonly affecting the left heart and mitral valve. In this case, we discuss the treatment and perioperative management of mitral valve degeneration in a child with Hurler syndrome by performing mitral valve replacement.

Keywords: Hurler syndrome, valvular disease, mucopolysaccharidosis.

Mucopolysaccharidoses (MPSs) are progressive inherited lysosomal storage disorders caused by the absence of enzymes involved in glycosaminoglycans' (GAGs) degradation. Mucopolysaccharidosis causes multiorgan system dysfunction and clinical implications that vary according to the specific GAG accumulated and the specific enzyme mutations present.[1] There are seven subtypes of MPS defined in the current literature. Early cardiac involvement is common, particularly in patients with MPS type 1 (Hurler syndrome).[2] There are very rare pediatric cases published on valvular surgery in patients with Hurler syndrome in the current literature. In this case, we discuss the treatment and perioperative management of mitral valve degeneration in a child with Hurler syndrome by performing mitral valve replacement.

CASE REPORT

An 11-year-old female diagnosed with MPS type 1 when she was seven-year-old presented to our clinic. Phenotypically short stature, thickening of the face, short and stiff neck, claw hand, and wide abdomen were observed (Figure 1). The patient had a history of frequent respiratory tract infections and multiple intensive care unit hospitalization, and a tracheostomy was performed two years ago. The patient had been undergoing enzyme replacement therapy (Laronidase; Genzyme Europe B.V, Amsterdam, Netherlands) since the age of eight. The patient, who was admitted to the emergency department with a pneumonia attack 15 days ago, received intensive antibiotherapy treatment in the intensive care unit. On physical examination of the patient, a holosystolic murmur extending to the axilla was heard upon listening. Crepitant rales were heard in the bilateral lower zones of her lungs. The patient had hepatomegaly and 2+ pitting edema in both lower extremities. Transthoracic echocardiography revealed moderate mitral stenosis and severe mitral regurgitation. The mitral valve area was 0.95 cm^2, the peak gradient was 24 mmHg, the mean gradient was 10 mmHg, and the regurgitant fraction was 46% (Figure 2). Subvalvular involvement, thickened leaflets, and commissural fusion were detected. The left atrium bulged to the right, and marked left atrium dilatation (4.6×5 cm) was observed. The patient was discussed in the pediatric cardiology and cardiac surgery council, and a decision for mitral valve replacement was made.

The patient was taken to the operating room. A median sternotomy was performed. The patient had a

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Figure 1. Phenotypic appearance of the patient with short stature, prominent smallness of the jaws, cervical shortness, rough facial features, claw-like hands, and umbilical hernia.

large thymus tissue covering the entire mediastinum. The thymus was completely removed. It was observed that the mediastinum was quite narrow. Aortic bicaval cannulation was performed. The procedure was initiated under moderate hypothermia. Antegrade blood cardioplegia was used for diastolic arrest. Left atriotomy was performed through the Sondergaard groove. Mitral valve leaflets were in dysmorphic appearance, and both leaflets were markedly thickened. Chordae tendineae were shortened, and papillary muscles were thickened. Diffuse involvement of the subvalvular apparatus impaired the mobility of the leaflets. There was thickening in the mitral annulus due to dense deposit accumulation, and the tissue was fragile (Figure 3).

Mitral valve leaflets were resected. It was not possible to preserve the subvalvular apparatus structures in this patient as it was obvious that it would adversely affect the opening of the mechanical valve leaflets. The annulus was tight and flimsy. Therefore, the annular structure was strengthened by crossing pledget-supported single sutures. Bileaflet size 20 supra-annular mechanical mitral valve (Open Pivot AP; Medtronic, Minneapolis, MN, USA) was used for replacement. Mechanical valve opening was checked with intraoperative transthoracic echocardiography. Cross-clamp time was 112 min. The patient was weaned from cardiopulmonary bypass with a low-dose dopamine infusion. In the third postoperative hour, the intubation tube was replaced with a tracheostomy cannula. The patient's need for positive pressure ventilation continued for six days due to early pulmonary atelectasis. The patient, who was applied respiratory physiotherapy during the intensive care period, was taken to the clinical service on the 15th day. During this whole process, enzyme replacement therapy treatment was continued without interruption. The patient was discharged on the 19th postoperative day without any complications.

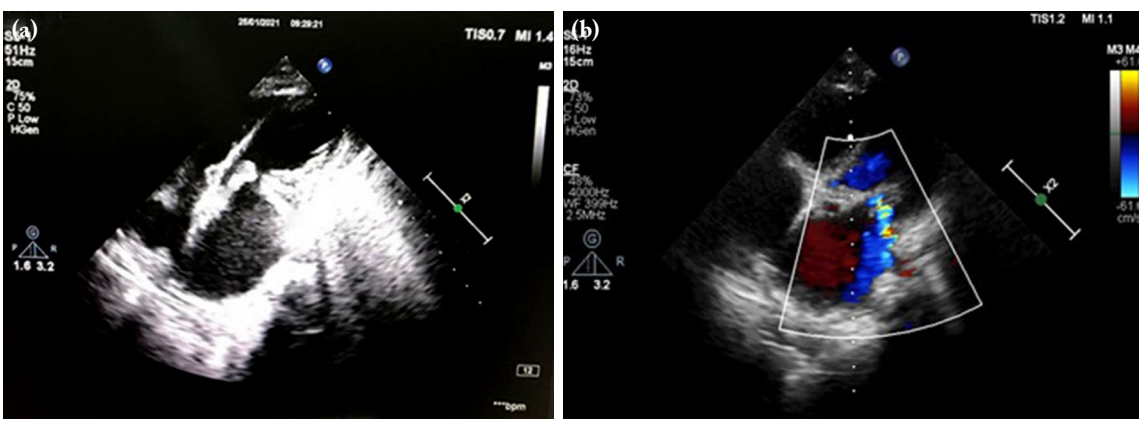

Figure 2. Transthoracic echocardiography demonstrates thickened mitral valve leaflets, **(a)** thickened and fused subvalvular apparatus, and **(b)** eccentric failure jet.

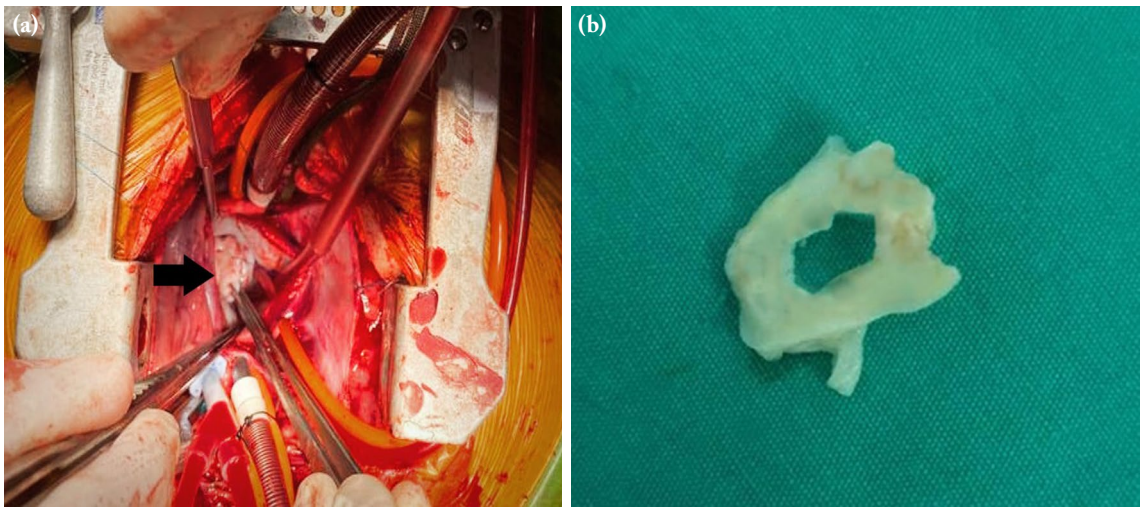

Figure 3. **(a)** The intraoperative view of the patient (the mitral valve is seen through the left atriotomy) and **(b)** the mitral valve removed in a single piece.

DISCUSSION

Mucopolysaccharidosis can affect all tissues that develop due to genetic mutation of lysosomal enzymes and where deposits accumulate. Phenotypes such as growth retardation, skeletal and joint deformities, vision and hearing problems, spinal cord compression symptoms, and hepatomegaly may be encountered. Cardiac involvement is observed at a high rate in this patient group. Previous studies have shown that the causative subtypes (MPS types 1, 2, and 4) are more commonly associated with cardiovascular pathologies, particularly with dermatan sulfate catabolism defects.[1,3] In the current literature, it is seen that the valvular involvement of MPS usually causes regurgitation, most commonly affects the left heart, and the most frequently affected valve is the mitral valve. The positive effects of medical treatment on valvular involvement in patients with an early diagnosis are controversial. After the administration of enzyme replacement therapy, myocardial and ventricular function improved in patients with MPS, myocardial deposit accumulation decreased, and progression slowed. However, poor vascularity of heart valves limits enzyme replacement therapy's effect on valvular degeneration.[4]

There are procedural difficulties in valvular replacement surgery in patients with MPS. As the mediastinum and heart chambers are tight, this situation makes surgical manipulation and retraction difficult in patients with MPS. Besides, periprosthetic annular tissue has a narrow and tight structure due to deposit accumulation. However, the annular tissue is not structurally durable enough. The use of pericardial pledget and felt pledget has been reported in the literature.[5,6] We preferred to use Teflon felt to increase durability. Additionally, due to annular stenosis, we preferred a supra-annular prosthetic valve. Placing the prosthesis in a supra-annular position appears to be a good alternative in patients with MPS, where traditional annular implantation is often not possible.

The positive effects of preserving the subvalvular apparatus on postoperative myocardial functions in mitral valve replacement are already known. However, in the patient we operated on, there was a mass effect due to the severe thickening of the papillary muscle, and the chordae tendineae were severely shortened. We think that aggressive excision of papillary muscles and chordae tendineae will prevent the need for reintervention due to complications such as a stuck prosthetic valve. Kitabayashi et al.[5] reported in their case report in 2007 that they resected the chords and papillary muscles.

We think that myocardial protection during cardiopulmonary bypass is essential in these patients. Since diffuse intimal proliferation and coronary arterial stenosis/occlusion in epicardial coronary arteries due to GAG storage were detected in two studies.[7,8] In addition, subvalvular apparatus excision for valve replacement in these patients may cause myocardial dysfunction. Therefore, we tried to overcome this

problem by adhering to the full-dose cardioplegia protocol, applying topical cold saline, and venting the left heart chambers.

In the postoperative period, a restrictive lung disease with reduced compliance, predisposition to upper and lower respiratory tract infections, short tracheal length, macroglossia, and neck deformities make these patients' extubation process difficult. We applied intensive respiratory physiotherapy to our patient during the preoperative period. Besides, since the patient had a tracheostomy, we performed intraoperative intubation procedures and postoperative respiratory management more efficiently. However, our patient had a prolonged intensive care period due to the development of atelectasis. The literature observed that patients with MPS who underwent valve surgery had an extended intensive care period, and pulmonary complications were frequent. Therefore, when the decision for valve replacement is made for these patients, it is necessary to be prepared for lung complications during the intensive care unit stay.

In conclusion, cardiac involvement in patients with Hurler syndrome may further impair already poor pulmonary function. The elimination of valve pathology prolongs the patient's life. Good perioperative preparation is vital in this patient group. The surgeon should know that they will encounter a narrow and structurally challenging annulus in the intraoperative period and take precautions against this situation.

Patient Consent for Publication: A written informed consent was obtained from the patient's parents for the publication of this case report and accompanying images.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, data collection and/or processing, analysis and/or interpretation, writing the article: I.M., F.D.; Design: I.M., M.C., M.A.; Control/supervision: O.I., M.A.; Literature review: M.C., M.A., O.I.; Critical review: I.M., F.D., M.C., M.A., O.I.; References and funfings: O.I., M.A., I.M.; Materials: M.A.

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Cardiovascular Surgery and Interventions

Case Report Open Access

Robotic atrial septal defect closure with valved pericardial patch in a pulmonary hypertensive patient

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ABSTRACT

Atrial septal defect (ASD) is the most common congenital anomaly in adults after bicuspid aortic valve. Atrial septal defect closure should be carefully considered in the setting of elevated pulmonary artery systolic pressure. Patients with borderline pulmonary vascular resistance may be candidates for closure with careful hemodynamic evaluation, even after pulmonary hypertension therapy. Herein, we present the surgical closure of the ASD with a valved pericardial patch after medical therapy for pulmonary hypertension via the da Vinci robotic system in a 30-year-old female patient.

Keywords: Pulmonary hypertension, robotic atrial septal defect surgery, valved pericardial patch.

Atrial septal defect (ASD) is the most common congenital anomaly in adults after bicuspid aortic valve.[1] Although it may be asymptomatic until adulthood, potential complications of an undetected ASD include arrhythmias, paradoxical embolizations, right ventricular failure, and pulmonary hypertension, which is associated with high morbidity and mortality rates.[1,2]

Pulmonary arterial hypertension (PAH) may develop approximately in 3 to 10% of patients with congenital heart disease, known as pulmonary hypertension-congenital heart disease (PH-CHD).[1] The decision to close an ASD in the presence of elevated pulmonary artery systolic pressures is difficult. In such patients, a cardiac team experienced in congenital heart anomalies must decide the ASD closing surgery. Atrial septal defect closure is contraindicated in patients with Eisenmenger physiology and in patients with pulmonary vascular resistance (PVR) ≥5 WU, while it is controversial in patients in the range of 4-5 WU.[1] In these patient groups, ASD may be crucial for decreasing right ventricle overload by allowing right-to-left shunt as a valve, particularly in pulmonary hypertensive attacks. Therefore, in patients with high pulmonary arterial pressure (PAP), the closing of ASD should be carefully considered after an individualized assessment of patients about potential benefits and risks. A valved pericardial patch could be a good choice in such patients who are not suitable for interventional techniques with fenestrated ASD closure devices.[1,2]

In this case report, we present robot-assisted ASD closure with a valved pericardial patch, which allows only a right-to-left shunt, in a patient who had PAH.

CASE REPORT

A 30-year-old female patient with no other known disease was admitted to the cardiology department with reduced functional capacity without any other symptoms. Chest X-ray revealed right atrial enlargement while electrocardiogram demonstrated rightward axis deviation. Transthoracic echocardiography revealed right ventricular dilation, a large ASD, elevated systolic pulmonary artery pressure (85 mmHg), and moderate tricuspid valve insufficiency. Right heart catheterization (RHC) showed an elevated PAP and PVR of 71/31 mmHg

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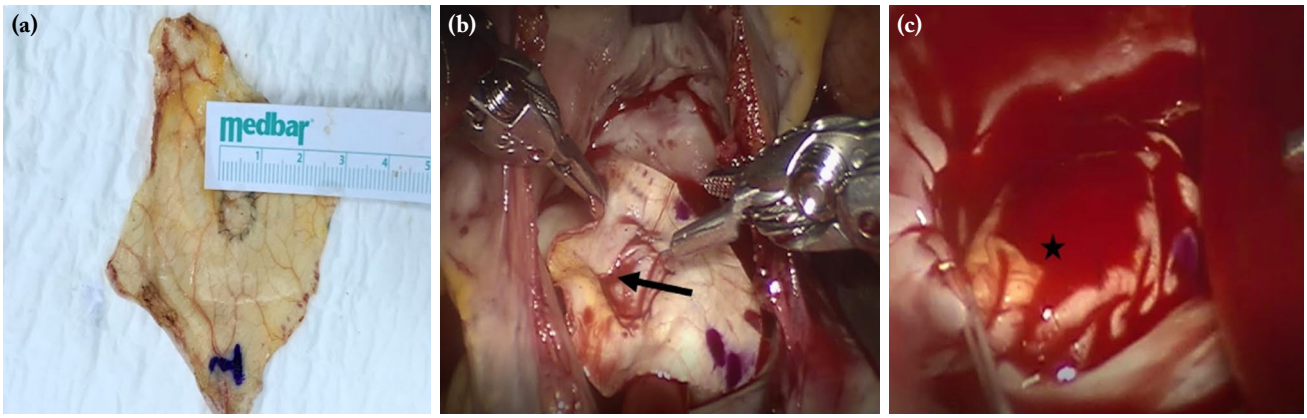

Figure 1. The view of the valved pericardial patch **(a)** A 1 cm second pericardial patch was sewn onto the hole of the main pericardial patch. **(b)** The pericardial patch was sutured onto the atrial septal defect. The black arrow shows the direction of the tunnel passing through the inferior vena cava to the superior vena cava. **(c)** Final version of the valved pericardial patch. Black star indicates the tunnel and the location of the valve).

(mean pressure: 48 mmHg) and 4.74 WU, respectively. The fraction of pulmonary perfusion (Qp)/fraction of systemic perfusion (Qs) ratio was 2. Other likely causes of pulmonary hypertension were excluded. We decided to reevaluate ASD surgery after pulmonary hypertension-specific therapy. Macitentan was started 10 mg once daily. Right heart catheterization revealed a slight improvement in PAP (60/33 mmHg [mean pressure: 43 mmHg]) and PVR (3.65 WU) at the three-month follow-up. The Qp/Qs ratio was also elevated to 2.85. Although improvements in catheterization parameters, pulmonary hypertension was ongoing. We decided to close the ASD with a valved pericardial patch, which allows only a right-to-left shunt in case of high pressure in the right atrium due to ongoing PAH. Standard surgical procedure was performed via da Vinci robotic system as we detailed in our previous reports.[2,3] The pericardial patch was excised and treated with glutaraldehyde as usual. Different from standardized ASD surgery, a 1 cm oval defect was created in the middle of the patch. Then, it was repaired with another small pericardial patch with a running polypropylene suture except for one side of the intended defect, which will create a tunnel (as foramen ovale in neonatal life) to allow a right-to-left shunt in case of elevated PAP (Figure 1a). Afterward, the patch was sutured onto the atrial septal defect. At this time, it is important that the small patch stays on the left atrial surface, allowing a right-to-left atrial shunt when it is necessary. Furthermore, a tunnel passing through the inferior vena cava to the superior vena cava was created (Figure 1b). After the de-airing protocol, the operation was terminated with standardized techniques. Figure 1c demonstrates the final version of the patch. Total cross-clamp time and total perfusion time were 63 and 128 min, respectively. The patient was discharged on the fifth postoperative day without any complications. Macitentan treatment was planned for six months, and a control right heart catheterization was also planned for the six-month follow-up.

DISCUSSION

Atrial septal defect can remain undiagnosed until adulthood. In most asymptomatic patients, symptoms occur after the fourth decade, including reduced functional capacity, exertional shortness of breath, palpitations, and less frequently right heart failure. If pulmonary hypertension has not developed, surgical repair has low mortality and good long-term outcome. However, if pulmonary hypertension has developed, these patients must be carefully evaluated. Atrial septal defect closure is contraindicated in patients with Eisenmenger physiology, a PVR ≥5 WU (despite targeted PAH treatment), or desaturation on exercise.[4] Nonetheless, there is a gray zone where it is still controversial to close ASD, particularly in patients whose PVR is in the range of 4-5 WU.

According to the European Society of Cardiology guidelines for the management of adult congenital heart disease, patients who have ASD with a significant

shunt (signs of right ventricular volume overload), PVR <5 WU, and Qp/Qs >1.5 should undergo ASD closure regardless of symptoms.[5] If PVR is ≥5 WU, fenestrated ASD closure may be considered when PVR falls below 5 WU after targeted PAH treatment and a significant shunt is present (Qp:Qs >1.5). The guidelines also conclude that a decision regarding lesion correction should be based upon individual patient evaluation at a tertiary center with expertise in PH-CHD.[5] In our case, although the first measured PVR was 4.74, we assessed that it would be risky to completely close the ASD in this patient after hemodynamic evaluation.

There are three commonly used classes of medications that have shown efficacy in PAH treatment: phosphodiesterase-5 inhibitors, prostanoids, and endothelin receptor antagonists. These medications have different pathway targets, mechanisms of action, indications, delivery routes, and side-effect profiles.[6] In our patient, we chose macitentan (as an endothelin receptor antagonist) for this purpose.

Percutaneous fenestrated ASD closure is undoubtedly an alternative in these patients. However, if it is not feasible to implant the device secondary to a lack of rims (even if it is complete or fenestrated), a surgical valved pericardial patch could be a good choice.

There are some papers about unidirectional valved patch closure of septal defects with good results.[7,8] With this option, most of the patients who had high surgical risk secondary to complete closure of the ASD could be operated. Rosic et al.[7] reported their surgical technique with a Dacron patch, which was similar to our technique. It is well-known that autologous pericardium has a stronger ability to resist calcification without any foreign or synthetic material. In our center, we primarily choose autologous pericardium whenever possible, and in this case, we used an autologous pericardium patch instead of a bovine or Dacron patch.

There are several options available to patients for ASD surgery. Percutaneous interventions are less invasive; however, in patients with an insufficient rim of defect, these techniques cannot be used. Shunt recurrency, infections, and occluder dislodgment are other complications of percutaneous techniques.[9] Therefore, surgeons should continue to prefer safe and feasible surgical procedures while utilizing less invasive, less traumatic, and most cosmetically appealing techniques. In our center, we do most of the ASD closure surgery with the da Vinci robotic system or minimally invasive techniques. Merits of robotic surgery are mainly less pain, complication, and trauma as in all minimally invasive techniques, with surgeon-friendly instruments' improved mobility and visualization capability.[9,10] In this regard, robot-assisted valved pericardial ASD closure can be preferred as a cosmetically compelling and effective method for patients with borderline PAH after good hemodynamic evaluation and appropriate medical therapy in a tertiary center.

In conclusion, robot-assisted ASD closure with a valved pericardial patch is an effective and feasible method in pulmonary hypertensive patients after a good hemodynamic evaluation and patient management.

Patient Consent for Publication: A written informed consent was obtained from the patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Acquisition, analysis, and interpretation of data. Drafting and revising the manuscript: M.K.; Acquisition, analysis, and interpretation of data. Drafting and revising the manuscript: G.E.; Drafting and revising the manuscript: E.K.; Acquisition of the data. Drafting and revising the manuscript: M.E.İ.; Acquisition, analysis, and interpretation of the data. Drafting and revising the manuscript: T.D.; Acquisition of the data: C.B.

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Cardiovascular Surgery and Interventions

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Right ventricular pseudoaneurysm repair and fibrin pericardiectomy after a fall from height in a young male patient

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ABSTRACT

Right ventricular pseudoaneurysms are rare in the literature. Patients may have complaints such as shortness of breath, fatigue, and palpitations, as well as signs such as ventricular arrhythmias and hypotension. In addition to a good physical examination and anamnesis, transthoracic echocardiography, transesophageal echocardiography, computed tomography, computed tomography angiography, magnetic resonance imaging, magnetic resonance angiography, scintigraphy, and ventriculography can also be used for diagnosis. The certain treatment of right ventricular pseudoaneurysms is surgical aneurysmectomy and repair. Herein, we present the diagnosis and management of a 32-year-old male patient with a right ventricular pseudoaneurysm, which was diagnosed 20 years after a fall from height.

Keywords: Aneurysm, blunt trauma, pericardiectomy, pseudoaneurysm, surgery, ventricular.

Right ventricular (RV) pseudoaneurysms are rare, particularly due to traumatic events, but could be fatal for patients,[1,2] Ischemic heart diseases are the most common reason; additionally, infections, previous cardiac operations, blunt traumas, pericardiocentesis, epicardial lead extraction, and transcatheter valve replacement are among other causes.[1-5] Right ventricular aneurysms are only encountered in 1 to 3% of all cardiac aneurysms in pathological series. In addition, most of these RV aneurysms occurred in the RV outflow tract due to prior congenital operations.[6] Ventricular aneurysms usually arise in the left ventricle, and there are few reports of RV pseudoaneurysms.[4,6] It is difficult to determine by physical examination as there is no typical sign for pseudoaneurysms. Ventricular arrhythmias, hypotension, shortness of breath, fatigue, and palpitation can be observed. In addition to a good physical examination and anamnesis, transthoracic echocardiography (TTE), transesophageal echocardiography, computed tomography (CT), computed tomography angiography (CTA), magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), scintigraphy, and ventriculography can be useful for diagnosis. Although surgical treatment is required for large true cardiac aneurysms, pseudoaneurysms are frequently narrow-necked and usually can be percutaneously closed. Herein, we present the management of a patient with an RV pseudoaneurysm and constrictive pericarditis, which was diagnosed 20 years after a fall from height.

CASE REPORT

A 32-year-old male patient was admitted to our clinic with the diagnosis of an RV pseudoaneurysm. There was no significant comorbidity in the medical history except for a fall from the second floor when he was 12 years old. The patient had lost his consciousness after the event but was not admitted to any hospital. It was learned that the patient had complaints of fatigue and weakness for about one week after falling. Afterward, he continued his life without a complaint for 20 years; however, the patient had developed palpitation, fatigue, weakness, and shortness of breath in the last year. A 1.5×2.5 cm pseudoaneurysm with Doppler activity at the apex of the right ventricle and an ejection fraction of 45% was detected on TTE. The pericardium was thickened,

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and other TTE findings consistent with constrictive pericarditis were also present. The pericardium was fibrotic, thickened (more than 2 mm), and a ventricular septal diastolic shudder and respiration-related shift in the interventricular septum was present. Respiratory change in the mitral valve E/A (early to late diastolic transmitral flow velocity) was more than 25%. A coronary angiography was performed in another center, which was normal. Pulmonary arterial pressure, right heart chambers, and functions were normal. An aneurysmatic appearance of approximately 30×18 mm was observed at the RV apex with a narrow neck of approximately 2 to 3 mm in the CTA (Figure 1). The electrocardiogram was in sinus rhythm. Routine blood tests were completely normal. We started the operation with a median sternotomy approach. The pericardium completely consisted of a fibrinous structure (Figure 2). Aortic and right atrial cannulation was performed, but the cardiopulmonary bypass was not started. A complete pericardiectomy was done. Afterward, the primary repair was performed by excising the aneurysmatic tissue from the apex of the right ventricle by the off-pump procedure (Figure 3). A pathological sample was taken from the pseudoaneurysm sac and pericardiectomy material. It was reported as fibrosis and compatible constrictive pericarditis (Figure 4).

Figure 2. The material extracted from fibrin pericarditis.

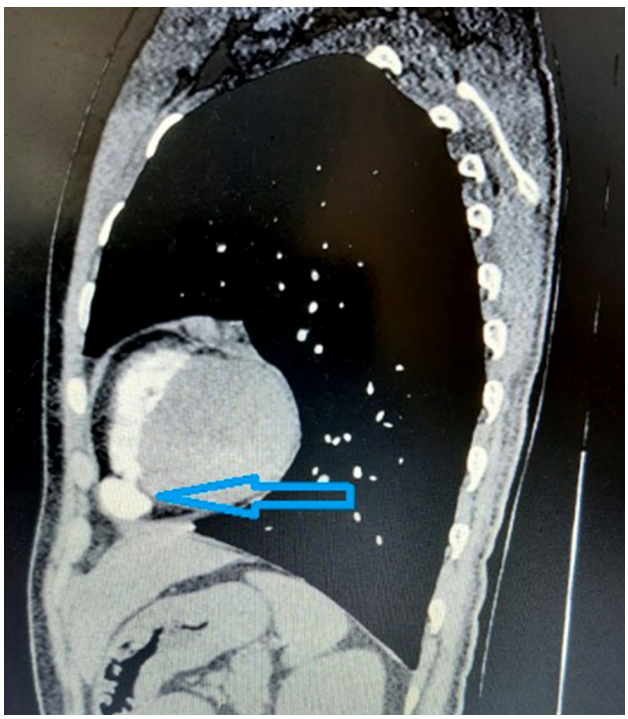

Figure 1. Computed tomography angiography image of the aneurysm emerging from the apex of the right ventricle with a thin neck.

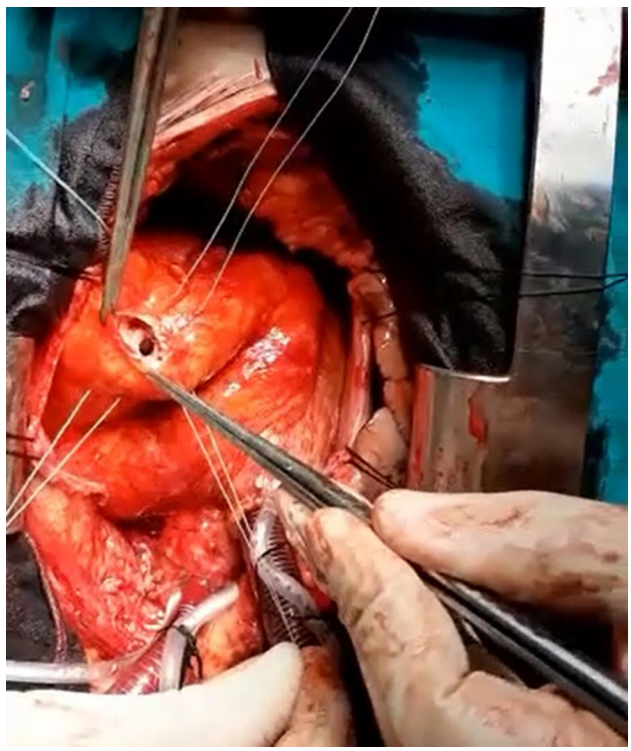

Figure 3. Aneurysmal region at the apex of the right ventricle.

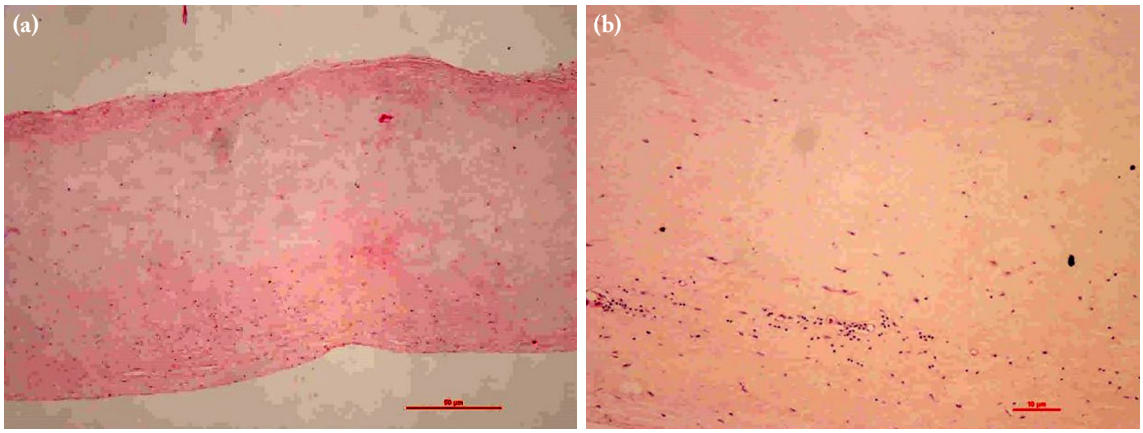

Figure 4. Hematoxylin & eosin-stained preparations of the pericardium revealing fibrosis and lymphocyte-dominant inflammation on light microscopy. No significant calcification was observed. **(a)** Thickened fibrotic pericardium (H&E, ×40). **(b)** Lymphocyte-dominated inflammation (H&E, ×100).

The patient was discharged on the seventh day without any complications, and there were no issues in a three-year follow-up.

DISCUSSION

Loss of myocardial integrity is the main cause of cardiac rupture. Free intrapericardial rupture usually results in cardiac tamponade and death. If a cardiac rupture is not containing whole cardiac layers, pseudoaneurysm formation occurs.[2] Noninvasive tests such as two-dimensional echocardiography and, more recently, three-dimensional echocardiography may be useful for detecting Doppler activity, or the same can be accomplished by echocardiographic contrast. Transesophageal echocardiography could be more beneficial for the evaluation of posterior cardiac segments due to its increased sensitivity compared to TTE. Cardiac MRI and CT can be performed to assess the structural relationships of the cardiac aneurysms or pseudoaneurysms detected in the echocardiography.[2,4]

The majority of ventricular aneurysms occur in the left ventricle.[4] In addition, RV aneurysms are more frequently located in the RV outflow tract due to prior congenital heart operations.[4,7] While some of the RV aneurysms are clinically diagnosed, some of them are diagnosed postmortem, and most of these are pediatric cases.[8-11] While transmyocardial infarcts, trauma, congenital, and cardiomyopathies are among the causes, some may be idiopathic.[12] Iatrogenic cases have also been reported.[13] A fatal RV aneurysm case was reported in a patient who underwent transcutaneous radiofrequency ablation for Wolff-Parkinson-White syndrome.[13] In addition, cases of RV aneurysm developing after postinfarct ventricular septal rupture have also been reported.[14-16] Cardiac pseudoaneurysms are treated with Amplatzer septal occluder devices and introduced under fluoroscopic and angiographic guidance.[4]

Diagnosis of constrictive pericarditis and its differentiation from restrictive cardiomyopathy is important but usually difficult. Transthoracic echocardiography is the initial and sometimes the only affordable test for the diagnosis of this condition. As per Hancock,[17] septal bounce, ventricular septal shift with respiration, and biatrial enlargement are the three basic signs of TTE in constrictive pericarditis. In our case, the ejection fraction of 45% was detected on TTE. The pericardium was fibrotic, thickened (more than 2 mm), and ventricular septal diastolic shudder and respiration-related shift were present in the interventricular septum. Respiratory change in the mitral valve E/A was more than 25%. Significant respiratory variation in mitral and tricuspid inflow velocities represents ventricular interdependence and is an important pathophysiologic feature in constrictive pericarditis.[18]

Right ventricular aneurysms may be isolated or may be accompanied by some congenital anomalies. A case of a double-chambered left ventricle-associated RV aneurysm and another case with hypertrophic cardiomyopathy associated with

RV aneurysm have been reported.[19,20] As with left ventricular aneurysms, the most common cause of an RV aneurysm is myocardial infarction. Aneurysm development time after myocardial infarction may take years, or it may develop within the first week. An RV aneurysm that developed on the sixth day postinfarction is available in the literature.[21] The most sensational study of RV aneurysms was done by Antonelli Incalzi et al.[22] In their study, they found the rate of aneurysm development in the right ventricle after acute myocardial infarction to be 8.8%. This rate represents a significant public health problem. Nonetheless, the incidence of aneurysms is lower in patients followed up after acute myocardial infarction in the clinic. Due to blunt traumas and aortic dissections, ruptures in the heart cavities and pseudoaneurysms can develop.[23] The symptoms of patients with an RV aneurysm are nonspecific and have a wide range. The most common symptoms are fatigue, shortness of breath, collapse, and palpitation.[24,25] Along with these, hypotension and hypotensive attacks may be the first signs.[26] It may manifest as syncope attacks due to malignant arrhythmias.[27] The most severe symptom in our patient was fatigue. Transthoracic echocardiography, transesophageal echocardiography, CT, CTA, MRI, MRA, and direct ventriculography are used in diagnosis.[1,28] In our case, TTE and CTA were utilized. Right ventricular aneurysms that cause ventricular dysrhythmias, heart failure, and pulmonary embolism are indicated for surgery.[6] In the treatment of pseudoaneurysms, aneurysmectomy or device closure can be performed.[23] Pseudoaneurysms requiring additional surgical procedures can be easily closed with open-heart surgery. In our patient, the ejection fraction was decreased due to constrictive pericarditis, and therefore, pseudoaneurysm repair was performed on a beating heart together with surgical pericardiectomy. Cardiac complications of injuries, such as blunt traumas and falling from heights, may not be noticed in the early period and manifest in the long term. Therefore, careful anamnesis of patients can provide some clues to the physicians. Rare diseases should also be kept in mind in young patients describing cardiac symptoms.

In conclusion, a detailed medical history and physical examination are crucial in cases with an atypical presentation and should not be overlooked.

Patient Consent for Publication: A written informed consent was obtained from the patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Design, writing the article and, analysis: F.A.; Literature review and references: V.P.

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Cardiovascular Surgery and Interventions

Case Report Open Access

Left main coronary artery osteoplasty with pulmonary autograft in a child with familial hypercholesterolemia

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ABSTRACT

Familial hypercholesterolemia is a disease characterized by mutations in the low-density lipoprotein receptor. Total cholesterol levels >500 mg/dL and low-density lipoprotein levels >350 mg/dL are associated with early atherosclerosis. In these patients, the incidence of coronary artery disease is high in the first decade of life, and it often emerges in adolescence. Herein, we present a 14-year-old female with familial hypercholesterolemia who underwent left main coronary artery osteoplasty with a pulmonary autograft due to an incidentally detected osteal stenosis of the left main coronary artery. The patient was discharged without any problems, and no problems were detected during the follow-up.

Keywords: Familial hypercholesterolemia, left main coronary osteal stenosis, pulmonary autograft.

Coronary artery disease in childhood is rarely observed. Today, advances in detecting the presence of myocardial ischemia have led to the expansion of coronary revascularization indications in childhood. The most common cause is Kawasaki disease and there are few studies on other causes.[1] These include the ALCAPA (abnormal origin of the left coronary artery from the pulmonary artery) syndrome, which is not suitable for the reimplantation technique; left main coronary artery (LMCA) atresia, iatrogenic injuries and complications, and premature atherosclerosis, particularly during surgeries requiring coronary manipulation, such as arterial switch operations and Ross operations.[2] Coronary artery disease is observed in 10% of patients with familial hypercholesterolemia (FH), and coronary revascularization has been reported in the literature only as a case report.[3] Here, we present a patient with FH who underwent osteoplasty with a pulmonary autograft due to LMCA osteal stenosis.

CASE REPORT

A 14-year-old girl was scheduled for liver transplantation due to FH. The patient was referred to our clinic for preoperative evaluation. On physical examination, widespread xanthomas were observed in the joint regions. Heartbeats were rhythmic and normal. Electrocardiography was normal, and echocardiography demonstrated left ventricular hypertrophy and mild aortic regurgitation. Coronary angiography was planned for the patient, who had a history of rapid fatigue and exertional dyspnea and a family history of early death due to coronary artery disease. Angiography revealed LMCA osteal stenosis (Figures 1). The decision to operate was made with consensus. After median sternotomy, bicaval cardiopulmonary bypass was established in mild hypothermia (32°C), and cardiac arrest was achieved by del Nido cardioplegia (homemade). Myocardial protection was performed with retrograde cardioplegia. The ascending aorta and the pulmonary artery trunk were separated, and the LMCA was identified. An oblique incision was initiated on the anterior aspect of the aorta above the commissures and was extended across to the left lateral wall toward the LMCA. The anterior aspect of the LMCA was

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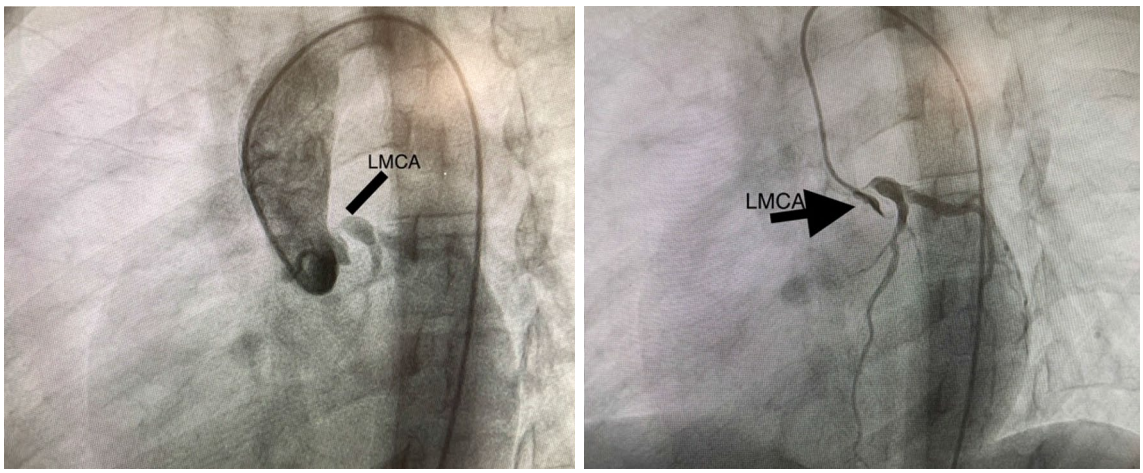

Figure 1. Preoperative angiographic images.
LMCA: Left main coronary artery.

opened for approximately 1 cm beyond the ostial lesion. During surgery, it was observed that the patient's aortic wall was extremely thick and plated. The patch was prepared from a fresh pulmonary artery. Left main coronary artery osteoplasty was performed with the anterior transaortic approach using the pulmonary autograft. The pulmonary artery defect was reconstructed with an autologous pericardial patch. The surgery was successfully finished. The patient was discharged without an issue on the seventh postoperative day, and no pathology was observed in the follow-up angiography at six months (Figure 2). The patient underwent a successful liver transplant eight months postoperatively.

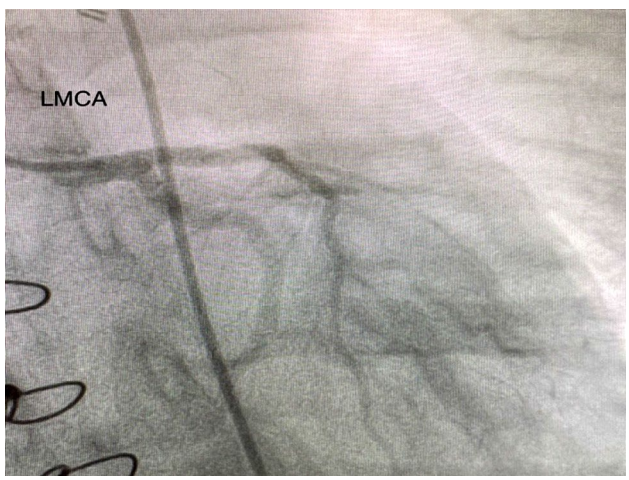

Figure 2. Postoperative angiographic image.

DISCUSSION

Guidelines for surgical indications for children with coronary artery disease have been developed in Japan. Indications for pediatric coronary revascularization are the same for children as for adult cases and include ischemic signs and symptoms. Unlike adults, however, children can be asymptomatic until the late term. Specifically, surgery is indicated if any of the following four conditions are present: *(i)* LMCA lesions, *(ii)* stenotic lesions of the multiple proximal coronary, *(iii)* proximal left anterior descending artery lesion, and *(iv)* collateral development.[4] Although our patient was asymptomatic, surgery was performed due to the presence of a severe proximal LMCA lesion.

Coronary artery surgery for children should be handled differently than that for adults as it involves some technical difficulties. These include the size of the coronary arteries, the difficulty of exposure, and the accessibility of the appropriate graft. Another problem is the long-term patency of the graft as children develop rapidly and their ability to lead a normal life depends on it. In 1966, Cooley et al.[5] first reported revascularization with an autologous saphenous vein graft in a baby with an abnormal left coronary artery. Later, with the use of the internal mammary artery and its long-term patency and growth potential, arterial grafts were preferred.[6] The patency of arterial grafts has been shown to be 3.5 times higher than that of venous grafts, even in children younger than three years old. Yatsunami et al.[7] reported that even in the majority of the neonatal population, the

coronary artery diameter is greater than 1 mm and the use of arterial grafts is appropriate.

The surgical technique to be applied in cases of proximal LMCA stenosis is controversial. The traditional surgical treatment for isolated LMCA osteal stenosis is coronary artery bypass grafting (CABG). Although this approach is effective, CABG can cause competition and steal phenomena. In addition, in cases of isolated osteal stenoses, retrograde perfusion to a large myocardial area is provided only with the graft.[8] Mavroudis et al.[1] stated that the combination of LMCA-plasty and CABG can be effective in this patient group. However, in the follow-up of their patients, string-sign findings were observed in the grafts in almost half of the cases. It was reported that only osteoplasty is sufficient for these patients. We preferred LMCA osteoplasty instead of CABG since our patient had a history of FH and would need to use long-term immunosuppressants after liver transplantation.

Although surgical osteoplasty was defined for adult patients by Effler et al.[9] and Sabiston et al.[10] in 1965, it was not preferred due to high mortality rates. Hitchcock et al.[11] obtained good results in 1983 with a posterior approach and Dion et al.[12] with an anterior approach in 1997. Finally, Liska et al.[13] suggested the transaortic approach, in which the aorta is transected and anteriorly mobilized to better visualize the coronary ostium and its distribution and facilitate patch reconstruction. We also prefer the transaortic approach during osteoplasty in our clinic. It allows the lesion to be better visualized, and it provides convenience while suturing the patch during repair.

The biggest advantages of surgical angioplasty in the pediatric population are that it does not require bypass material and provides antegrade flow. It has been used in cases of LMCA atresia, occlusion, and inflammatory arteritis.[14] However, there are few studies on proximal coronary artery patch-plasty. Prêtre and Turina[15] reported successful results in patients with LMCA osteal stenosis after surgical angioplasty. Successful reconstruction of both LMCA and RCA osteal stenosis with an autologous pericardium prepared in a "pantaloon" shape was also performed in another study.[16] This technique achieved good results in some selected cases of atherosclerotic lesions.[17] The success rate is high for lesions in the proximal half of the isolated noncalcified coronary trunk. However, an increased risk of thrombosis has been demonstrated for patients requiring extension of osteoplasty to the LMCA branches.[18] The use of autologous pericardium also has risks of fibrotic thickening, contraction, calcification, and late aneurysm formation due to exposure to systemic pressure. Its advantages are that it is flexible, resistant to infection, and nonimmunogenic.[19] Another material used in LMCA osteoplasty is the autologous pulmonary artery. It contains the intima, media, and adventitia layer. Long-term results of arch constructions with autologous pulmonary artery patches have been reported.[20] However, there are no definitive results about their use in osteoplasty in the literature. Ma et al.[21] reported positive early-and mid-term outcomes after LMCA-plasty. Ischemia was not observed in any of their patients. The pulmonary autograft had advantages due to material thickness, ease of manipulation, genetic homogeneity, and potential for somatic growth. Moreover, there was no risk of ectasia seen with pericardial patches. The use of pulmonary artery patches is thought to be more appropriate in our clinic. Pulmonary artery defects are also reconstructed with autologous pericardium to prevent the risk of pulmonary stenosis.

In conclusion, although patients with FH are asymptomatic, the risk of early atherosclerosis should not be forgotten. In cases of isolated LMCA osteal stenoses, osteoplasty may be a good option. The use of pulmonary autografts may be advantageous.

Patient Consent for Publication: A written informed consent was obtained from the parent of the patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Cardiovascular Surgery and Interventions

How to do it? Open Access

Penetrating gluteal trauma managed by surgical treatment with an added value of digital subtraction angiography

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ABSTRACT

Penetrating traumas to the gluteal region can occur via vascular injury, nerve injuries, or damage to the perineal organs. Vascular injuries are usually life-threatening injuries in gluteal penetrating traumas. Therefore, the use of angiograms may be necessary for the management of penetrating traumas to assess the bleeding focus. Herein, the case of a 24-year-old male who applied to the emergency department with a penetrating stab wound injury to the gluteal region is presented. Digital subtraction angiography (DSA) was performed for urgent vascular evaluation, which showed a pulsatile bleeding from the femoral left circumflex lateral artery, whereupon the vascular surgeon proximally ligated the type 3 lateral circumflex artery. However, the control DSA taken due to continued bleeding after the procedure revealed that the flow of the ligated lateral circumflex artery was interrupted, but the bleeding continued in the same region with the blood supply of the collateral coming from the iliolumbar branch of the internal iliac artery. Thereupon, a peripheral 5×60 mm balloon was inflated in the internal iliac artery, and whether the bleeding stopped was evaluated. Afterward, the patient was taken back to surgery by the vascular surgeon, and the bleeding was stopped by collateral ligation. In this case, we showed with a demonstrative case that vascular imaging may be required not only before but also after the procedure in vascular injuries due to penetrating trauma and that treatment can be provided by closure of the feeding artery in both directions in dense collateral areas.

Keywords: Angiography, imaging, penetrating trauma.

Penetrating traumas constitute up to 3% of all injuries in the gluteal region.[1] The penetrating injury to the buttock is not a common condition, and it is present in up to 3% of all penetrating injuries.[2,3] In the systematic review, it was shown that penetrating traumas can be associated with severe diagnostic and clinical problems and a mortality rate of up to 2.9%.[1] Therefore, a stab wound to the gluteal region might be considered potentially life threatening, and every effort should be made to locate possible injuries. In penetrating traumas to the posterior abdomen region, the death rate is 0 to 2%.[2] In the abdomen, this rate is between 0 and 4.4%, whereas it is 2.5 to 5.6% in the thorax.[2,3] The gluteal injury mortality rate is 2.9%, which is quite high concerning the other areas of the body.[2,3]

Penetrating vascular traumas may require urgent surgical treatment, and mortality may occur despite appropriate intervention.[1-3] Gluteal region blood supply is provided by both common femoral, deep femoral, and internal iliac arteries.[1-3] We aimed to report a case with a gluteal stab wound trauma managed by a multidisciplinary team.

CASE REPORT

A 24-year-old male patient was admitted to the emergency department with the presence of bleeding after a penetrating injury to the gluteal region. At the time of admission, the patient's blood pressure was 112/73 mmHg, hemoglobin value was 14 mg/dL, and heart rate was 110 bpm. The patient was alert and agitated, and there was a stab wound over the left gluteal area; no additional injury was observed in the

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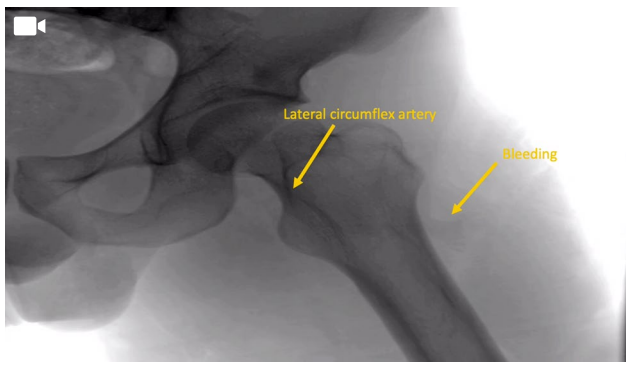
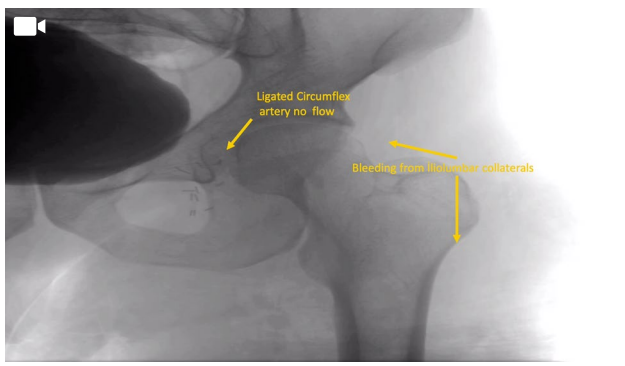
abdominal ultrasonography. A catheter of the urine bladder was placed, and no macroscopic bleeding was found. No anomaly was observed in the digital rectal examination.

As the gluteal hemorrhage was pulsatile on admission, computed tomography angiography (CTA) was planned to evaluate the source of the hemorrhage, but invasive imaging was decided since the patient was agitated (since motion artefact might be present), and invasive vascular imaging was also possible. On the vascular imaging with digital subtraction angiography (DSA), the left common femoral artery (CFA) was visualized with a contrast injection from the common iliac artery. On the imaging, significant bleeding was observed from the type 3 left lateral circumflex artery (LLCA), which branched from the left CFA (Video 1). After DSA, a surgical approach was planned. In the operation, the LLCA was ligated with a surgical intervention from the left groin region.



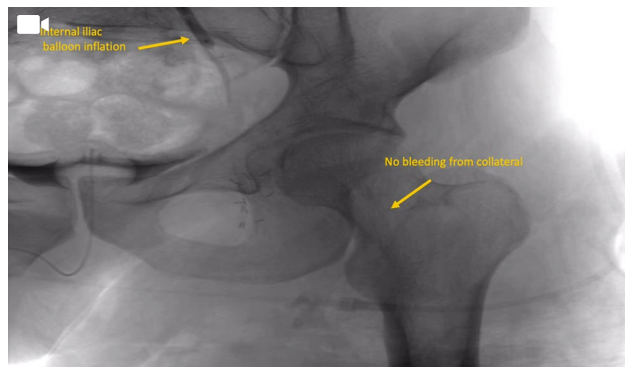
Video 1. The first digital subtraction angiography showing bleeding from the lateral circumflex artery.



Video 2. The second digital subtraction angiography, conducted after the first surgery, revealing bleeding from the iliolumbar collateral and the ligation of the lateral circumflex artery.

In the operation, the LLCA was hard to reach directly; therefore, it was ligated from the origin with a surgical intervention from the left inguinal region. Due to the persistence of the bleeding after the surgical ligation, the patient was taken into the angiography unit again. On the repeat angiogram we have seen that the bleeding was not originated from LLCA, instead the origin of the Bleeding was iliolumbar branch of the internal iliac artery (IIA) (Video 2). To confirm this, a 0.35 hydrophilic wire was sent to the left IIA via the destination sheath; it was observed that the bleeding stopped when the image was taken again by giving a contrast material from the left common iliac artery after a 5×60 balloon inflation. It has been confirmed that there is no additional collateral to cause bleeding (Video 3).

This time, collateral from the iliac branch of the iliolumbar artery was ligated. Exploring the



Video 3. The third digital subtraction angiography displaying no bleeding from the lateral circumflex artery and the iliolumbar collateral with balloon inflation in internal iliac artery.

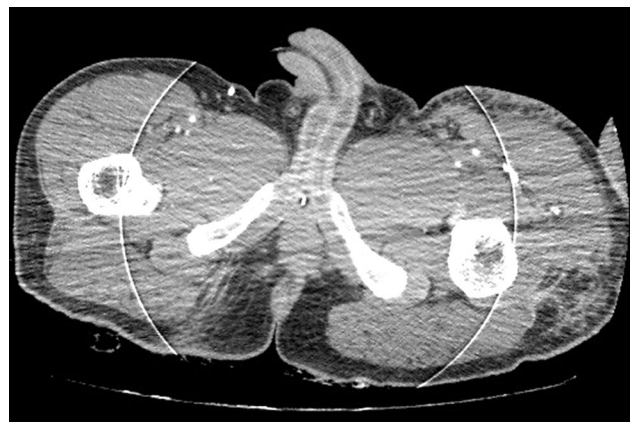


Figure 1. Computed tomography angiography section demonstrating no bleeding after the second operation.

iliolumbar collateral artery between gluteal muscles, the bleeding source was directly ligated with a 5-0 Prolene suture. No bleeding was observed in the CTA taken after the second procedure (Figure 1). The patient's postoperative course was uneventful, and the surgeons recommended conservative management of the symptoms.

DISCUSSION

In this case, we showed that vascular imaging might be better not only before the procedure but also after the procedure in areas with dense collaterals. Endovascular intervention was not performed as there was no coil at our hospital at the time of the patient's admission; however, if the coil had been made from the proximal lateral circumflex artery, it would not have been successful due to bleeding from the iliolumbar artery.

The gluteal area has complex anatomical characteristics. This morphology is associated with the likelihood of pelvic or abdominal penetration following gluteal injury. Penetrating injuries account for up to 90% of vascular injuries, and vascular injuries often occur between the ages of 20 and 40.[4,5] Surgical exploration and repair are carried out as fast as feasible in individuals with "hard" symptoms of vascular injury, such as refractive hypotension and apparent limb ischemia. Moreover, the authors advise that CTA should be confirmed with DSA if the CTA is not sufficient at the time of the accident with suspicion of heavy vascular injury.[6] At the discretion of the surgeon, arteriography can be conducted preoperatively.[7,8] Only 12 patients undergoing interventional radiology treatment were utilized to control bleeding or target ballot in 12 individuals as the sole method in the systematic review.[7,8] Laparotomy and prolonged gluteal operation were conducted in 207 (33.7%) subgroup patients out of 615 individuals with gunshot or stab trauma.[7,8]

The LCA is the biggest branch of the deep femoral artery. It is 1.5 cm from the origin of the CFA in 67% of the instances and is directly derived by the CFA in 14 to 20%.[9] The iliac branch of the IIA travels laterally into the iliac fossa to supply the iliac muscle and the iliac bone. This branch also forms anastomoses with iliac branches of the obturator artery, the deep circumflex iliac artery, the LCA, and the superior gluteal artery.[9] In addition, the modern techniques including angiographic imaging accompanied by internal balloon occlusion provided us the opportunity to localize bleeding source. After the detection of the bleeding source, we had an opportunity to guide re-operation procedure and appropriate management.

In conclusion, successful initial surgical ligation with DSA guidance may not be sufficient in the dense collateral region, particularly in a group of patients with vascular injury, in which there is no standard recommendation after the surgery. Reimaging might be necessary for detailed bleeding control after the procedure in case of suspicion.

Patient Consent for Publication: A written informed consent was obtained from the patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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