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Comparison of endoscopic and open saphenous vein harvesting: Impact on postoperative in-hospital outcomes

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ABSTRACT

Objectives: This study aimed to investigate the cost-effectiveness, technical feasibility, and potential benefits associated with endoscopic saphenous vein harvesting.

Patients and methods: This study included a total of 122 patients who underwent coronary bypass surgery with saphenous vein grafts between January 2022 and March 2023. Fifty-six (44 males, 12 females; mean age: 62.5±8.6 years; range, 43 to 77 years) of the patients were assigned to the endoscopic harvesting group, while 66 patients (57 males, 9 females; mean age: 60.1±9.1 years; range, 42 to 81 years) were assigned to the open harvesting group. This study compares endoscopic saphenous harvesting and open technique in terms of clinical implications, including wound healing and clinical recovery and patients' pain experiences.

Results: Among the comorbidities evaluated, the prevalence of hypertension, type 2 diabetes mellitus, and chronic kidney disease did not show statistically significant differences between the two groups. There were no reported cases of graft branch complications, graft-related bleeding, or graft thrombosis in either group. However, the occurrence of wound discharge was significantly lower in the endoscopic group (0%) compared to the open group (13.6%). Patients who underwent endoscopic saphenous vein harvesting also experienced less pain and had a significantly lower incidence of keloid scar formation at the wound site. Both groups had comparable rates of debridement, while systemic infection was observed in 0% of the endoscopic group and 1.5% of the open group. Wound site infection was lower in the endoscopic group (0%) compared to the open group (4.5%). The length of hospital stay in the ward did not show a significant difference between the two groups. However, the time required for wound dressing was significantly shorter in the endoscopic group compared to the open group.

Conclusion: These findings suggest potential advantages of endoscopic surgery in terms of reduced postoperative complications and faster wound healing.

Keywords: Coronary artery bypass surgery, endoscopic saphenous vein harvesting, endoscopic vein harvesting.

Coronary bypass surgery is still the most common surgical procedure in cardiac surgery. It involves the use of vascular grafts, such as the left internal mammary artery, radial artery, and saphenous vein. Among these grafts, the saphenous vein is commonly used due to its lower tendency to spasm compared to radial grafts and its relatively straightforward harvesting process. However, the harvesting of saphenous vein grafts requires careful attention due to their varying lengths (usually 35 to 70 cm) and the presence of multiple branches.[1]

Traditionally, the harvesting of the vena saphenous magna involved open surgery, a practice that had persisted worldwide from the early days of coronary surgery until recent decades.[1] However, this open surgery approach often resulted in a painful experience for patients, sometimes leading to infections and prolonged hospital stays, decreased quality of life, and increased effort in wound care.[2,3] Fortunately, the introduction of video-assisted saphenous vein harvesting in 1996 brought about a significant shift.[4] Since the demonstration of the superior healing properties of the endoscopic method in 1999,[5] accumulating evidence continues to support the notion that endoscopic vein harvesting (EVH) surpasses open saphenous harvesting in terms of improved quality of

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life and outcomes at the surgical site. According to the EACTS (European Association for Cardio-Thoracic Surgery)/ESC (European Society of Cardiology) and ACC (American College of Cardiology)/STS (Society of Thoracic Surgeons) guidelines, experienced surgical teams have the option to utilize EVH, emphasizing its advantages in terms of patient recovery and reduced wound complications.[6,7] However, some concerns persist regarding cost-effectiveness and cardiac outcomes.[8] Hence, this study focuses on examining the experience of endoscopic saphenous harvesting and its clinical implications, including wound healing and clinical recovery, within a single surgical team at our center.

PATIENTS AND METHODS

This retrospective, single-center, nonrandomized study included 122 patients between January 2022 and March 2023. The patients met specific criteria from the all patient who had undergone elective isolated coronary bypass surgery performed by the same surgical team. The selection criteria were as follows: patients who underwent coronary artery bypass grafting with saphenous vein grafts and patients without any prior diagnosis of peripheral artery disease or venous insufficiency.

An endoscopic harvesting system was routinely used since the beginning of the program if the endoscope was available. However, the endoscope was in common use with other departments. If the system was not available, the open technique was employed for saphenous vein harvesting. There were no selection criteria between harvesting methods. Among the selected patient group, 56 individuals (44 males, 12 females; mean age: 62.5±8.6 years; range, 43 to 77 years) underwent EVH, while the remaining 66 patients (57 males, 9 females; mean age: 60.1±9.1 years; range, 42 to 81 years) underwent the traditional open harvesting technique.

Data collecting

Preoperative medical histories and demographic data of the patients were meticulously gathered from patient files and the hospital's electronic system. These records included information on variables such as the type of surgery, age, sex, body mass index, smoking prevalence, hypertension, type 2 diabetes mellitus, chronic kidney disease, and the average number of venous grafts utilized.

Additionally, perioperative details, including operative time, wound drainage, debridement, systemic infection, wound infection, length of hospital stay, and duration of wound dressing, were also extracted from patient files. To evaluate their pain status and the presence of keloid scar formation, patients underwent teleconsultation assessments. Wound illustrations were also collected (Figure 1). To assess the pain status, a singular binary question utilizing a yes/no response format was utilized.

Endoscopic harvesting

All patients underwent preoperative routine ultrasound imaging. The VirtuoSaph+ (Terumo, Corporation, Tokyo, Japan) system was utilized for endoscopic extraction in all cases. As a standard procedure, a 2 to 3 cm oblique incision was made from the sub-knee region at the medial tibial border. Under the guidance of a conical-tipped camera dissection catheter, the saphenous vein and its branches were explored using the system's 10-15 mmHg 3 L/min carbon dioxide insufflation support. A closed cavity was created and dissected up to the groin. Subsequently, the second component of the system, an electrocautery device, was introduced to separate the branches from distal to proximal, and the saphenous vein was secured within the locking mechanism at the system's end. The device was then used to remove the saphenous vein from its distal and proximal ends. Afterward, a minimal incision with a diameter of 0.5 to 1 cm was made at the most proximal end at the groin using an 11 scalpel, and the saphenous vein was grasped with a mosquito forceps, pulled out from the skin, and divided. The liberated saphenous was pulled out through the distal incision. The free part, held with the distal mosquito forceps, was ligated, clipped, and buried under the skin. The extracted saphenous vein's branches were tied and clipped outside. Finally, the distal end was closed with sutures or staples (Figure 2).

Open surgical harvesting

The open method involved a standard procedure of creating a longitudinal incision over the medial malleolus. The saphenous vein was carefully dissected and separated from the surrounding tissue, ensuring the removal was done without adipose or surrounding tissue. Subsequently, subcutaneous 2/0 Vicryl sutures were used for closure, followed by closure of the skin using staples or 3/0 Vicryl skin sutures.

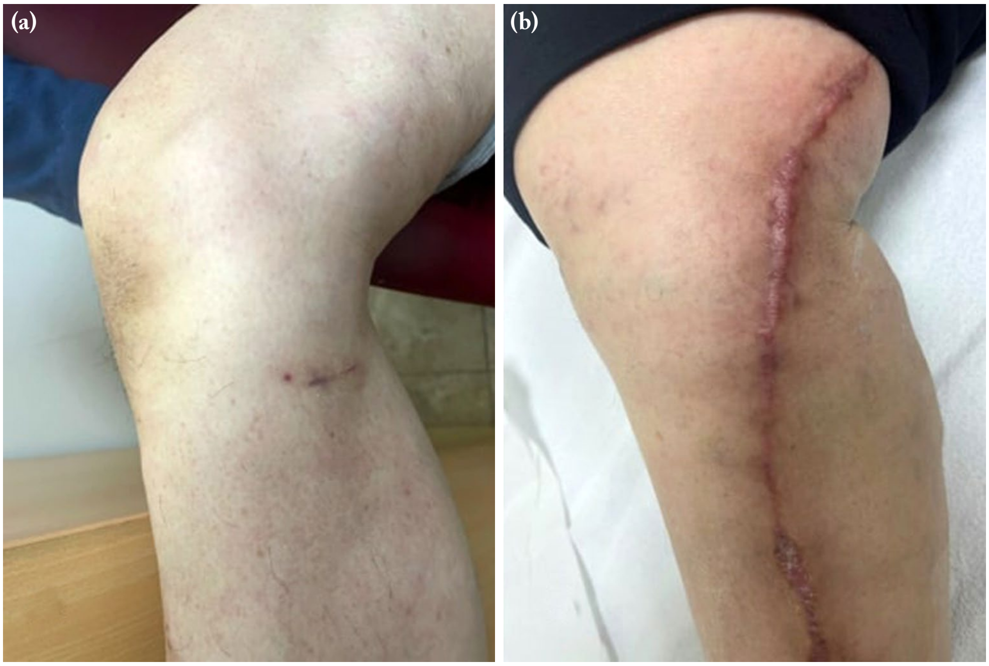

Figure 1. (a) Healed distal incision of a patient in the EVH group. **(b)** Healed incision of a patient in the open group.

EVH: Endoscopic vein harvesting.

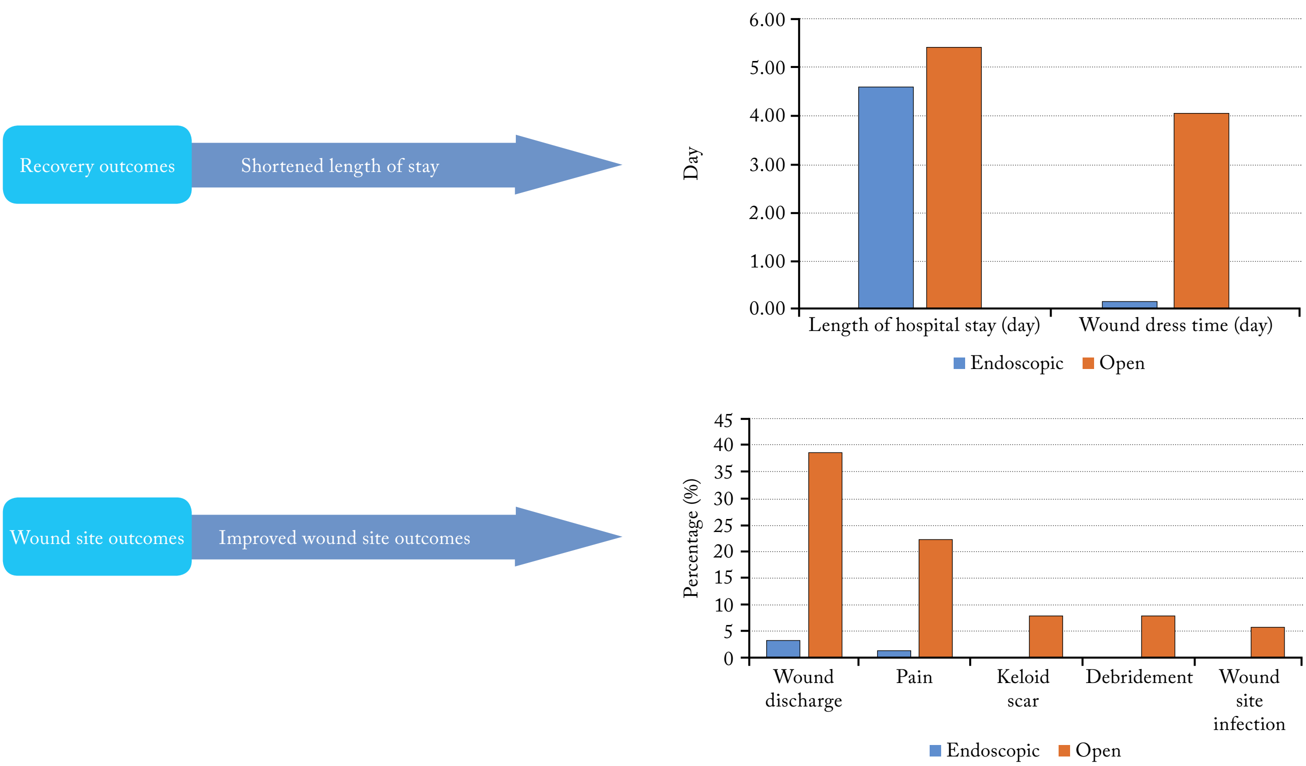

Figure 2. Central figure.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). The categorical data were analyzed using the chi-square test, Fisher exact test, and the Phi-Cramér test, which are suitable for examining associations and dependencies between categorical variables. The numerical data were analyzed using the analysis of variance F-test and Student's t-test, which are appropriate for comparing means between groups. In addition, post hoc power analysis was performed to determine the power of the study. A *p*-value <0.05 was considered statistically significant.

RESULTS

The results presented in Table 1 compare the demographic and clinical characteristics between patients who underwent EVH and those who underwent open surgery. The mean age of the EVH group and the open surgery group did not statistically significantly differ (p=0.758). The percentage of female patients was higher in the EVH group at 21.4% (n=12) compared to 13.6% (n=9) in the open surgery group, although the difference was not statistically significant (p=0.256). Both groups had similar mean body mass index values, with the EVH group averaging 28.1±4.1 and the open surgery group averaging 27.7±4.8 (p=0.879). The prevalence of smoking was 33.9% (n=19) in the EVH group and 51.5% (n=34) in the open surgery group, showing a trend toward significance (p=0.051). The percentages of patients with hypertension, type 2 diabetes mellitus, and chronic kidney disease were comparable between the two groups, with no statistically significant differences observed (p>0.387 for all). Furthermore, the mean number of venous grafts used was 2.4±0.7 in the EVH group and 2.3±0.8 in the open surgery group, with a *p*-value of 0.138, indicating no significant difference.

Table 2 presents the outcomes of the endoscopic and open approaches for the variable studied. The mean operation time was similar for both groups, with 280±52 min in the EVH group and 276±53 min in the open group (p=0.739). There were no reported cases of graft side branch complications, graft-related bleeding, or graft thrombosis in either group. However, there were significant differences observed in several variables. The incidence of wound discharge was significantly higher in the open group (n=24, 38.7%) compared to the EVH group (n=2, 3.4%; p=0.017). Similarly, the open group had a higher prevalence of pain (n=14, 22.6%) compared to the EVH group (n=1, 1.7%; p=0.001). Keloid scar formation was also more common in the open group (n=5, 8.1%) compared to the EVH group (n=0; p=0.026). However, there were no significant differences in the rates of systemic infection (n=1, 1.5% in open *vs.* n=0 in EVH; p=0.355) or wound site infection requiring debridement (n=4, 6.1% in open *vs.* n=0 in EVH; p=0.061). The

Table 1
Patient characteristics

	Endoscopic group			Open group			
Variables	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			62.5±8.6			60.1±9.1	0.758
Sex							
Female	12	21.4		9	13.6		0.256
Body mass index			28.1±4.1			27.7±4.8	0.879
Smoking	19	33.9		34	51.5		0.051
Hypertension	37	67.9		42	63.6		0.625
T2DM	27	48.2		37	56.1		0.387
Chronic kidney disease	3	5.4		4	6.1		0.868
Venous graft counts			2.4±0.7			2.3±0.8	0.138

SD: Standard deviation; T2DM: Type 2 diabetes mellitus.

Table 2
Outcomes of the procedures

	Endoscopic group			Open group			
Variables	n	%	Mean±SD	n	%	Mean±SD	*p*
Operation time (total)			280±52			276±53	0.7390
Graft side branch complications	0	0.0					-
Graft-related bleeding	0	0.0					-
Graft thrombosis	0	0.0					-
Wound discharge	2	3.4					**0.017**
Pain	1	1.7					**0.001**
Keloid scar	0	0.0					**0.026**
Debridement	0	0.0					**0.026**
Systemic infection	0	0.0					0.355
Wound site infection	0	0.0					0.061
LOS ward			4.6±0.9			5.4±3.0	**0.012**
Time of wound dress (day)			0.2±0.8			4.0±5.5	**0.002**

SD: Standard deviation; T2DM: Type 2 diabetes mellitus.

length of stay in the ward was significantly shorter in the EVH group (4.6±0.9 days) compared to the open group (5.4±3.0 days; p=0.012). Additionally, the time required for wound dressing was significantly shorter in the EVH group (0.2±0.8 days) compared to the open group (4.0±5.5 days; p=0.002). The post hoc analysis revealed that the study had a power of 0.99 for the wound discharge subject and 0.96 for pain assessment. However, the power was constrained to 0.47 in relation to the wound site infection.

DISCUSSION

Since its introduction in 1996, the video-assisted endoscopic method of saphenous harvesting has gained significant popularity in the coronary surgery.[4] Furthermore, by 2008, approximately 70% of saphenous harvesting in the UK was performed using this technique.[8] This rapid dissemination can be attributed to numerous benefits associated with endoscopic saphenous harvesting, as extensively documented in the literature.[8] These advantages include improved wound healing, reduced risk of infection, and shorter hospital stays. On the flip side, it is worth noting that some randomized controlled trials have reported poor cardiac outcomes associated with EVH compared to open saphenous harvest. These findings have raised certain concerns within the cardiac surgery community.[9,10]

Consistent with existing literature, our study demonstrated a significant reduction in wound dressing time and faster wound healing in the endoscopic harvest group.[11-13] Furthermore, the open group exhibited a significantly higher incidence of wound site discharge and requirement for debridement compared to the EVH group. However, contrary to the findings reported in the existing literature, we did not observe a statistically significant difference between the two groups regarding wound infection.[12,13] It is essential to acknowledge that although we did not experience any case of wound site infection in the EVH group, the limited sample size in our study might have contributed to the lack of a significant difference in wound infection rates. Additionally, it is worth highlighting that one patient in the open surgery group developed sepsis as a consequence of wound infection, underscoring the criticality of meticulous wound management in surgical procedures.

In our study, we rigorously implemented the enhanced recovery after surgery (ERAS) protocol, which is designed to optimize patient care and reduce hospitalization duration in both the endoscopic and open groups. Our efforts aimed to minimize hospital stays, particularly for patients undergoing multivessel coronary bypass surgery. This approach aligns with previous studies that have shown the benefits of shorter hospitalization periods for patients following ERAS protocols.[14,15] Remarkably, the EVH group exhibited significantly shorter hospitalization durations and dressing times, suggesting that endoscopic harvesting is not only more cost-effective but also facilitates faster patient recovery. These findings underscore the potential advantages of adopting endoscopic techniques in saphenous harvesting for coronary bypass surgery.

Our study findings align with existing literature in terms of quality of life outcomes. Specifically, we observed consistent results regarding pain levels in the postoperative period, where the EVH group exhibited significantly lower pain in the saphenous harvest area compared to the open group. Moreover, the incidence of keloid scar formation at the wound site was significantly lower in the EVH group. These outcomes highlight the clear superiority of endoscopic saphenous harvesting in terms of pain management and minimizing keloid scar formation, which are important factors influencing the quality of life for patients undergoing this procedure.

Neither group exhibited any occurrences of graft thrombosis, bleeding from graft branches, or structural deterioration in the graft, which are considered important graft-related adverse event outcome parameters. These findings suggest that the technique of saphenous vein harvesting, whether endoscopic or open, can be safely employed with regard to cardiac considerations.

While the study holds significant value, there are two limitations that need to be acknowledged and addressed: the retrospective design and the absence of long-term results. Despite these limitations, the study offers a comprehensive and insightful real-world view of endoscopic harvesting, particularly within a region where such techniques are rarely employed. Additionally, it is crucial to emphasize that the statistical analysis yields a substantial power level of over 95% for wound discharge and pain assessment. This high statistical power underscores the robustness and reliability of the study's findings in these aspects.

In conclusion, our study compared the outcomes of endoscopic and open saphenous vein harvesting methods. The EVH group demonstrated favorable wound site outcomes, including faster healing, reduced dressing time, and lower incidence of wound discharge. Although no significant difference was found in wound infection rates, the limited sample size may have influenced this result. Both groups had comparable recovery outcomes, likely due to adherence to the ERAS protocol. Endoscopic harvesting showed superior quality of life outcomes, with lower postoperative pain and fewer keloid scars. Importantly, neither group experienced cardiac complications, such as graft thrombosis or bleeding. These findings support the safety and benefits of EVH, contributing to the existing knowledge and guiding surgical decision-making for optimal patient outcomes.

Ethics Committee Approval: The study protocol was approved by the Koşuyolu High Specialization Hospital Ethics Committee (date: 04.07.2023, no: 2023111/703). 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: Concept, design, literature review, writing the article: M.M.O.; Control, supervision: M.A., T.O.; Data collection: A.M.O.; Materials: H.H.; Critical review: K.K.

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Cardiovascular Surgery and Interventions

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Acute mesenteric ischemia in the surgical intensive care unit: Analysis of clinical characteristics and risk factors for mortality

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ABSTRACT

Objectives: This study aimed to present the clinical characteristics of patients followed due to acute mesenteric ischemia (AMI) in the surgical intensive care unit and evaluate mortality-related prognostic factors.

Patients and methods: This retrospective study reviewed clinical records of 28 patients (19 males, 9 females; mean age: 67.5±17 years; range, 29 to 86 years) who were followed due to AMI in the intensive care unit between May 2016 and April 2023. We analyzed the clinical characteristics, risk factors, and prognostic factors of the patients. The Acute Physiology and Chronic Health Evaluation II (APACHE II) score was calculated in each patient to assess its prognostic value in AMI patients.

Results: Of the 28 patients, 19 had acute arterial occlusive mesenteric ischemia (AOMI), four patients had acute mesenteric venous thrombosis (MVT), and five patients had nonocclusive mesenteric ischemia (NOMI). Overall mortality was 60.7% (n=17). The mortality rate was 57.8% (n=11) in the AOMI group, 50.0% (n=2) in the MVT group, and 80.0% (n=4) in the NOMI group. Compared to survivors, the APACHE II score, shock incidence, arterial lactate concentration, specifically more prominent 24 h after diagnosis ($p<0.001$), acute renal failure, serum creatinine level, vasoactive agent consumption, and maximum vasopressor dose were significantly higher among nonsurvivors ($p<0.05$).

Conclusion: The clinical outcomes remain poor in AMI, and even in-hospital mortality is rather high. The death following AMI was mostly related to multiorgan failure, renal failure, elevated lactate level, and colon involvement. It appears that monitoring arterial lactate is helpful in identifying patients with poor prognosis. Early diagnosis, timely treatment, correction of shock, and renal protection are important to improve clinical prognosis.

Keywords: Acute mesenteric ischemia, arterial occlusive mesenteric ischemia, mesenteric venous thrombosis, nonocclusive mesenteric ischemia, prognostic factors.

Acute mesenteric ischemia (AMI) is a rare entity with high morbidity and mortality rate (30 to 100%), which frequently results in intestinal infarction due to acute impairment of intestinal perfusion.[1-5] It may develop as a result of arterial occlusivse mesenteric ischemia (AOMI), mesenteric venous thrombosis (MVT), and nonocclusive mesenteric ischemia (NOMI).[5]

Arterial occlusive mesenteric ischemia occurs following acute thrombosis or embolism of the superior mesenteric artery (SMA), accounting for approximately two-third of AMI cases.[5,6] Cardiac emboli due to causes such as heart valve diseases, bacterial endocarditis, myocardial infarction, and atrial fibrillation can readily pass SMA due to aortic outlet angle and large caliper and occlude the mesenteric artery, resulting in AOMI. Less commonly, atherosclerotic plaque or mural thrombus in an aortic aneurysm or aortic dissection can also lead to AOMI.[5-8]

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Mesenteric vein thrombosis is a rare cause of acute abdomen, accounting for 5 to 15% of all AMI cases.[6,7,9] Mesenteric vein thrombosis is classified as primary MVT, where underlying predisposing factors are lacking, and secondary MVT, where an etiological factor is detected. The secondary causes include previous history of abdominal surgery, malignancy, myeloproliferative diseases, medication, such as oral contraceptives, protein S and C deficiencies, antithrombin III deficiency, and prothrombin and factor V Leiden mutation, which may lead to hypercoagulability.[6,7,9] Cases of mesenteric artery and vein thrombosis due to COVID-19 (coronavirus disease 2019) were reported during the pandemic.[10]

Nonocclusive mesenteric ischemia accounts for 15 to 20% of all AMI cases.[11] Vasoconstriction due to factors such as severe cardiac failure, sepsis, or low cardiac output reduces splanchnic blood flow. The decreased blood flow often involves the ileocolic artery, resulting in proximal colonic ischemia and necrosis. It may occur after open heart surgery. Hypovolemia and vasoconstrictive use may exacerbate NOMI.[4,6,11]

Acute mesenteric ischemia can present as the primary diagnosis, it may also develop as a complication due to other comorbid conditions in intensive care unit patients as well. The AMI incidence is unclear. Diagnosis is generally made based on clinical suspicion and findings.[2,12] Computed tomography angiography is the gold standard diagnostic procedure due to noninvasiveness, accessibility, high sensitivity (91 to 96%) and specificity (95 to 99%).[3,7] It usually manifests with acute, severe abdominal pain without marked or specific symptoms and is generally diagnosed at an advanced state.[2] In most instances, early diagnosis cannot be made due to insufficient sensitivity and specificity of clinical features and biomarkers. Despite significant advances in diagnosis and management in recent years, the disease progresses into irreversible intestinal obstruction and gangrene if early diagnosis cannot be made, resulting in extremely high mortality. Thus, early diagnosis and timely treatment are of importance for prognosis.[1-3]

In AMI, management relies on early diagnosis, resection of necrotic intestine, diminishing intestinal ischemia by restoring blood flow, second-look laparotomy, and intensive care.[2,13] The use of single or hybrid interventional therapies with increasingly available experience and proven therapeutic efficacy tends to be a better choice.[5] This study aimed to define the characteristics of patients followed due to AMI in the intensive care unit and evaluate factors affecting mortality.

PATIENTS AND METHODS

This retrospective, observational, noninterventional study investigated 28 patients (19 males, 9 females; mean age: 67.5±17 years; range, 29 to 86 years) followed with the diagnosis of AMI in the intensive care unit of the Izmir Bakırçay University, Çiğli Training and Research Hospital between May 2016 and April 2023. The diagnosis of AMI was made using at least one of the following: computed tomography angiography or surgical procedure. In all patients, clinical characteristics, relevant risk factors, and prognostic factors were analyzed. Data regarding age, sex, comorbid conditions, medication, clinical findings, laboratory results, imaging findings, surgical procedures, and postoperative outcomes were recorded in all patients. The Acute Physiology and Chronic Health Evaluation II (APACHE II) score was calculated in each patient to assess its prognostic value in AMI patients.

Statistical analysis

Statistical analyses were performed using IBM SPSS version 19.0 software (IBM Corp., Armonk, NY, USA). Groups were compared using the independent samples t-test. Univariate analyses were performed using Fisher exact test. A p-value <0.05 was considered statistically significant.

RESULTS

Of the 28 patients, 19 had AOMI, four patients had MVT, and five patients had NOMI (Table 1). Overall mortality was 60.7% (n=17). The mortality rate was 57.8% (n=11) in the AOMI group, 50.0% (n=2) in the MVT group, and 80.0% (n=4) in the NOMI group.

In patients undergoing surgery, the choice of surgical technique was up to the discretion of the surgeon who decided the surgery based on intestinal viability. Intestinal viability was defined according to color, arterial pulsation, and peristalsis of the intestinal segment. Of 19 patients in the AOMI group, withholding treatment was preferred in three cases and no surgical intervention was performed. These three patients died in the intensive care unit. Explorative laparotomy (open and close procedure)

Table 1
The demographic and clinical data of the 28 patients

	Total (n=28)					AOMI (n=19)					MVT (n=4)					NOMI (n=5)				
	n	%	Mean±SD	Median	Range	n	%	Mean±SD	Median	Range	n	%	Mean±SD	Median	Range	n	%	Mean±SD	Median	Range
Age (year)				67.5	29-86				71.1	30-86				48.7	29-74				70.3	61-81
Sex																				
Male	19	67.9				13					2					4				
Female	9	32.1				6					2					1				
Previous history																				
Hypertension	18	64.3				16					1					1				
Coronary artery disease	14	50				9					-					5				
Atrial fibrillation	9	32.1				8					-					1				
Diabetes mellitus	6	21.4				4					-					2				
Hypercoagulable state	2	7.1				-					2					-				
Peripheral artery disease	16	57.4				14					-					2				
Laboratory data																				
Serum creatinine (mg/dL)				2.1	1.1-3.1				2.0	1.2-3				1.6	1.1-2.8				2.4	1.3-3.1
WBC ($\times 10^9$)			17.2±9.3					16.0±6.0					20.1±11.3					21.0±.8.1		
Blood Gas (PH)			7.31±0.12					7.32±0.11					7.39±0.13					7.30±0.10		
D-dimer			4601.2±4093.3					4599.7±4323.8					7278.6±3236.1					3851.7±2693.5		
Bowel ischemic region																				
Jejunum	9	32.1				5					2					2				
Ileum	12	42.9				9					1					2				
Colon	7	25.0				5					1					1				
Death number	17	60.7				11					2					4				
APACHE II scores			11.3±5.3					12.0±4.7					9.5±6.1					13.8±7.4		

AOMI: Arterial occlusive mesenteric ischemia; MVT: Mesenteric venous thrombosis; NOMI: Nonocclusive mesenteric ischemia; SD: Standard deviation; WBC: White blood cell; APACHE II: Acute Physiology and Chronic Health Evaluation II.

Table 2
Comparison of risk factors in the deceased group and the survival group

	Deceased group (n=11)				Survival group (n=11)				
	n	Mean±SD	Median	Range	n	Mean±SD	Median	Range	*p*
Age (year)			67	29-86			66.5	30-78	0.84
Serum creatinine (mg/dL)			1.6	1.1-2.8			2.1	1.3-3.1	0.014
Arterial lactate at diagnosis (mmol/L)			4.4	2.6-9.4			2.5	1.4-3.8	<0.001
Arterial lactate 24h after diagnosis (mmol/L)			7.9	3.3-15.4			1.7	1.3-2.3	<0.001
Shock	12				3				0.01
MODS	8				2				0.202
Respiratory failure	6				1				0.073
Renal failure	8				1				0.011
APACHE II score		13.5±5.1				8.3±4.3			0.013

SD: Standard deviation; MODS: Multiple organ dysfunction syndrome; APACHE II: Acute Physiology and Chronic Health Evaluation II.

was performed in three cases, all of which were nonsurvivors. Proximal colon resection was performed due to ileocolic artery involvement in 13 patients. Revascularization by embolectomy in SMA was feasible in only four patients. Mortality was 47% in the subgroup where revascularization was achieved by embolectomy.

Of the four patients in the MVT group, one patient underwent intestinal resection. Medical treatment (anticoagulant and antithrombotic therapy) was given to three patients.

Of five patients in the NOMI group, all patients had undergone open cardiac surgery. No surgical treatment was performed on any of the patients. The patients were treated for underlying causes in addition to supportive care. Majority of the patients had multiorgan dysfunction at the time of diagnosis. In the NOMI group, all patients needed inotropic support at admission to the intensive care unit.

The risk for hypertension and atrial fibrillation was higher in the AOMI group compared to the MVT and NOMI groups ($p<0.05$). Compared to survivors, APACHE II score, shock incidence, arterial lactate concentration, particularly more prominent 24 h after diagnosis ($p<0.001$), acute renal failure, serum creatinine level, vasoactive agent consumption, and maximum vasopressor dose were significantly higher among nonsurvivors ($p<0.05$) (Table 2).

DISCUSSION

There is no diagnostic method specific for the diagnosis of AMI; thus, diagnosis is challenging. The diagnosis is generally delayed, and the disease is already advanced at the time of treatment.[1-6] Given the low incidence and wide spectrum, there is limited number of studies on AMI, majority of which are retrospective.[1-15] In AMI, the mortality rate ranges from 30 to 100% in different studies.[1-6,16,17] In our study, the overall mortality rate was 60.7%.

The AOMI cases, caused by an arterial embolus or thrombus in SMA, are the cause of intestinal ischemia in 70 to 80% of cases. To a lesser extent, intestinal ischemia may occur as a result of MVT or NOMI.[5,6] In our study, there was AOMI in 67.8% of the patients, while MVT and NOMI were observed in 14.3% and 17.9%, respectively. The mortality rate was higher in the NOMI group (80%).

Nonocclusive mesenteric ischemia is mainly observed in patients with acute, severe, critical illness, such as heart failure and surgical patients.[11] Clinical presentation is often insidious and nonspecific, leading to delayed diagnosis.[11,18,19] The NOMI rate has been reported as 15% among AMIs in the literature, its incidence is unclear as diagnosis cannot be made in critically ill patients.[11,18,20] In our study, all patients with diagnosis of NOMI had history of major cardiovascular surgery.

In some studies, it has been reported that comorbid disease is one of the risk factors for mortality.[1,19,21] In our study, atrial fibrillation and arterial hypertension rates were significantly higher in the AOMI group ($p<0.05$). There was no history of arterial hypertension in the NOMI group. The reason for the speculative protective effect of arterial hypertension remains to be unknown; however, it may be associated with better preservation of autoregulation pressure gradient in the splanchnic region.[22] In our study, the presence of comorbid disease showed no significant effect on mortality.

In AMI, the poor prognosis and mortality were associated with organ dysfunction, renal failure, high APACHE II score, and elevated lactate level, which was more prominent during the first 24 h. Persistent elevation in the serum lactate level reflects continued splanchnic hypoperfusion or multiorgan failure. Particularly in patients requiring vasoactive agents, the role of vasoactive agents in enhanced splanchnic vasoconstriction might have an influence on mortality. In AMI, a serum lactate level >2 mmol/L was associated with irreversible intestinal ischemia.[1,23] It should be kept in mind that normal arterial lactate level does not necessarily exclude AMI and that high lactate concentration may indicate delayed diagnosis.[1,23]

D-dimer is a fibrin product that is generated by enzymatic degradation during intravascular coagulation, and in case of elevated lactate levels, it can be further increased in AMI and in other diseases.[24] D-dimer level was found to be significantly higher in the MVT group. In our study, it was found that serum lactate and creatinine levels were significantly higher in nonsurvivors compared to survivors ($p<0.05$).

It has been reported that age is a negative prognostic criterion in AMI.[1,19,25] However, age was not a risk factor for mortality in AMI in our study ($p>0.05$).

Although anticoagulation with heparin is the key treatment in MVT, no benefit was observed in arterial AMI.[26] Anticoagulant therapy was initiated in all MVT patients. It was thought that COVID-19 was the underlying reason in two patients who developed MVT during the pandemic. Both of these patients died.

Only a minority of patients benefit from revascularization.[27] In our study, mesenteric artery embolectomy was performed in three AOMI patients. Intestinal resection was required in the majority of patients who underwent surgery.

Delayed diagnosis and treatment, elevated lactate level, sepsis at the time of presentation, and colonic involvement, in addition to the small intestine, are poor prognostic factors for mortality. Thus, early diagnosis and effective treatment of sepsis may reduce the mortality rate. In AMI patients with involvement of the small intestines and colon, viscera revascularization techniques (embolectomy, thrombectomy, endarterectomy, or bypass) must be attempted before wide resection.[1,2,12,21,28] In our study, colon involvement was higher in the AOMI group.

This study has some limitations. Since the data analysis period was long and the study was conducted at a new institution, the changes in healthcare providers, surgeons, and approaches might have led to significant changes in the diagnostic procedures and treatment options. Additionally, the number of diagnosed NOMI patients was limited since the diagnosis of NOMI is more challenging.

In conclusion, clinical outcomes remain poor, with high in-hospital mortality in AMI. Younger patients had a similar mortality risk to older patients. Hypertension and atrial fibrillation were more common in the AOMI group and associated with larger intestinal ischemia. The number of patients with NOMI might have been underestimated as the diagnosis is more difficult in these patients. Acute mesenteric ischemia-related deaths were mostly associated with multiorgan failure, renal failure, elevated lactate levels, and colon involvement. Monitoring the arterial lactate level appeared helpful in identifying patients with poor prognosis. Early diagnosis, timely treatment, and renal protection are of importance to improve clinical prognosis.

Ethics Committee Approval: The study protocol was approved by the Izmir Bakırçay University, Çiğli Training and Research Hospital Ethics Committee (date: 30.03.2022, no: 546). 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, design, data collection, literature review, wrting the article: İ.K.; Control, crtitical review, literature review: A.D.; Data collection, references and fundings: A.Ş.; Data collection, materials; H.A.; Wrting the article, design, crtitical review: Ş.B.

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Conduction system abnormalities after isolated surgical aortic valve replacement

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ABSTRACT

Objectives: This study aimed to examine the predictive value of preoperative electrocardiogram (ECG) findings for postoperative fascicular and atrioventricular (AV) conduction system defects in patients undergoing surgical aortic valve replacement for isolated aortic stenosis.

Patients and methods: The retrospective study included a total of 74 patients (45 males, 29 females; mean age: 62.9±13.7 years; range, 27 to 82 years) who underwent isolated surgical aortic valve replacement for aortic stenosis between September 2009 and September 2011. Electrocardiogram sheets taken at four time points (before the operation, first postoperative hour, 48th postoperative hour, and before discharge) were evaluated. The primary outcome was the development of AV block of the second or third degree or any type of fascicular conduction defect. The requirement for a temporary or permanent pacemaker during the postoperative stay was a secondary outcome.

Results: Before aortic valve replacement, the three most common ECG findings were left ventricle hypertrophy in 35 (47.3%) patients, T-wave inversion in 29 (39.2%), and left septal fascicular block in 18 (24.2%). None of the study parameters significantly predicted the need for temporary pacemaker requirement after surgery. Patients with preoperative left ventricle hypertrophy (odds ratio [OR]: 2.38, p=0.07), ST segment depression (OR: 3.04, p=0.9), left septal fascicular block (OR: 1.66, 0.34), and right bundle branch block (OR: 4.77, p=0.30) tended to develop postoperative AV block or fascicular block. Preoperative left bundle branch block was the only significant risk for developing advanced conduction disturbances after surgery (OR: 8.60, p=0.009).

Conclusion: The presence of monofascicular, bifascicular, or bundle branch block on the preoperative ECG may predict the likelihood of developing AV block or fascicular conduction system disorders after surgical aortic valve replacement, which should be confirmed in further studies employing continuous ECG monitoring in a larger patient population.

Keywords: Aortic valve replacement, conduction system disturbances, pacemaker, surgery.

Surgical aortic valve replacement is the gold standard of treatment for critical aortic stenosis. Surgical aortic valve replacement continues to be performed today with increasingly favorable outcomes owing to advances in myocardial preservation, surgical technique, and prosthesis quality over the last few decades.[1] Although sutureless aortic valve prosthesis[2] and transcatheter aortic valve replacement[3] have increased in popularity in recent years, the technical imperfections of these procedures are still associated with the risk of significant complications. Aortic valve surgery appears to be on the horizon for a long time in the surgically eligible patient population.

Postoperative conduction system disturbances are one of the most serious complications of aortic valve replacement, whether surgical or transcatheter. According to conventional belief, this involvement is caused by suture trauma to the atrioventricular (AV) conduction fibers near the aortic annulus or by involvement of this segment during the natural course of the disease.[4,5] However, given the anatomical structure of the conduction system, which extends from the atria to the ventricular free wall, defects in different segments of the conduction system cannot be explained solely by suture trauma.[6] Furthermore, in the group of patients who have not undergone cardiac surgery, hypoperfusion and ischemia of the involved system

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are largely responsible for the pathophysiology of acquired conduction system disorders.[7]

Moreover, due to the progressive hypertrophy of the myocardium caused by aortic stenosis, myocardial preservation during cardiac surgery is of particular importance.[8] Effective myocardial preservation during cross-clamping should not only aim to decrease epicardial cooling and ventricular oxygen consumption but also achieve effective septal and subendocardial perfusion. The fascicular conduction system distal to the AV node resides in the septum and subendocardium of the ventricle. Therefore, effective myocardial cooling and cardioplegic preservation appear to be as significant as avoiding surgical suture trauma to preserve the conduction system.[9]

This study aimed to identify potential risk factors for postoperative conduction system disorders in aortic stenosis patients undergoing isolated SAVR. In addition, the association between postoperative conduction system disturbances and the need for a pacemaker and the structural and conduction system findings on the preoperative resting electrocardiogram (ECG) was investigated. As potential risk factors for disturbances in the conduction system, the study also included preoperative demographic characteristics, echocardiographic findings, and data collected during the operation of the patients.

PATIENTS AND METHODS

This retrospective study was conducted at the Kartal Koşuyolu Training and Research Hospital between September 2009 and September 2011. Patients aged 25 to 85 who had their first isolated aortic valve replacement for severe aortic stenosis were included in the study. Using archive records and the hospital's electronic database, patient information was accessed, and the data obtained from the information were retrospectively analyzed. Patients who had undergone aortic valve replacement for isolated aortic regurgitation or in combination with coronary artery bypass grafting, other valve surgery, or adult congenital heart surgery were excluded from the study. Patients with more severe aortic, mitral, or tricuspid regurgitation, a history of myocardial infarction, severe left ventricular dysfunction, neurological sequelae, uncontrolled diabetes, hypertension, advanced chronic obstructive pulmonary disease, obesity, permanent pacemaker, and end-stage chronic renal failure were also excluded from the study. Thus, 74 (45 males, 29 females; mean age: 62.9±13.7 years; range, 27 to 82 years) out of 80 patients who underwent isolated aortic valve replacement at our hospital during the specified time period were included. The primary outcome was the development of AV block of the second or third degree or any type of fascicular conduction defect. The requirement for a temporary or permanent pacemaker during the postoperative stay was a secondary outcome.

Archival records were searched for demographic parameters, clinical data, preoperative echocardiographic findings, operative details, intensive care data, and ECG sheets. Electrocardiograms were evaluated at four different time points: *(i)* ECGs taken in the last three days prior to surgery; *(ii)* ECGs taken within 1 h of surgery; *(iii)* ECGs taken 24 h after surgery; *(iv)* ECGs taken prior to discharge from the hospital. The current American Heart Association (AHA)/American College of Cardiology Foundation (ACCF)/Heart Rhythm Society (HRS) Recommendations for the Standardization and Interpretation of the Electrocardiogram Part III: Intraventricular Conduction Disturbances guideline was used for the analysis of ECGs.[10]

Beta-receptor antagonists were stopped in patients with preoperative ECGs showing left bundle branch block but continued in patients with normal preoperative ECGs or fascicular block until 24 h before surgery. Beta-receptor antagonists were started in all patients on the first to second postoperative day unless there was bradycardia or any conduction disturbance.

Surgical and anesthetic considerations

Patients were administered 5 mg of oral diazepam the night before surgery. In the operating room, the patients were monitored with an electrocardiogram and pulse oximetry, and peripheral venous and radial artery catheters were inserted. Anesthesia was induced using 30 to 50 g/kg of fentanyl. As a muscle relaxant, 0.1 mg/kg of pancuronium was used. When necessary, 3 g/kg/min fentanyl infusion and isoflurane inhalation were administered during maintenance. Patients who were intubated were ventilated with 100% oxygen. A pulmonary artery catheter was then inserted through the internal jugular vein. A midline sternotomy was performed. The pericardium was subsequently divided in the shape of an inverted Y and suspended. Before cannulation, 300 to 400 U/kg of heparin was administered, and the activated clotting time was maintained at above 450 sec. The cardiopulmonary bypass (CPB) was initiated. According to the surgeon's preference, retrograde blood cardioplegia was administered from the wall of the right atrium into the coronary sinus. Following the initiation of CPB, the systemic body temperature dropped to 28 to 32°C. After aortic cross-clamping, an initial dose of 10 mL/kg isothermal blood cardioplegia was administered from the aortic root. During CPB, nonpulsatile perfusion was achieved with a hematocrit of 23 to 28%, a pump speed of 2.0 to 2.5 L/min/m, and an arterial mean pressure of 50 to 80 mmHg. Depending on the surgeon's preference, myocardial protection was maintained by administering antegrade or continuous retrograde blood cardioplegia every 15 to 20 min.

An oblique aortotomy was performed, directed towards the noncoronary sinus, to perform a root enlargement procedure on patients with a narrow aortic root. After the aortic valve was exposed, suspenders were placed on all three commissures, and the valve was raised upwards. First, the right aortic leaflets were resected, then the left leaflet was resected. Finally, the noncoronary leaflets were resected. Calcific debris was removed down to the annulus ring. After irrigating and aspirating the interior of the ventricle, valve measurements were taken. In cases where patient prosthesis mismatch was anticipated, the aortotomy incision was extended to the noncoronary sinus annulus, and the root expansion procedure was carried out. According to the preference of the surgeon, 2.0 Ti-Cron™ sutures (Covidien, Mansfield, MA, USA) were prepared with or without a pledget. Depending on the surgeon's preference, the pledgets were placed above or below the annulus when placing the sutures in the annulus. The valve was inserted into the annulus, and the sutures were tied. The incision for the aortotomy was closed. The cross clamp was removed. In the case that pacemaker support was required, inotropic support and epicardial pacing wires were provided. When the patient's temperature returned to normal, the CPB was discontinued by decreasing the flow. Heparin was neutralized by protamine sulfate in a 1:1 ratio. Following the removal of the arterial and venous cannulas and the control of bleeding, a 36-Fr drain was placed in the mediastinum. In all patients, the sternum was closed by inserting a temporary epicardial pacing wire.

Statistical analysis

Data were analyzed using IBM SPSS version 15.0 software (SPSS Inc., Chicago, IL, USA). Categorical variables were expressed as numbers and percentages, while continuous variables were expressed as mean±standard deviation (SD). To compare categorical data, the chi-square test and Fisher exact chi-square test were used, and the odds ratio was calculated for risk calculations. The statistical significance level was determined to be $p<0.05$.

RESULTS

Table 1 shows the baseline characteristics of the patients, while Table 2 demonstrates the preoperative echocardiography parameters. Nineteen (25%) patients were receiving beta-receptor antagonists prior to surgery. None of these patients had a bundle branch block on their preoperative ECG, but six patients had a left septal fascicular block, and four patients had a left anterior fascicular block. There were no in-hospital deaths. The mean duration of aortic cross-clamping was 73.38±21.76 min, the mean duration of CPB was 99.52±23.90 min, the mean time to extubating was 16.05±41.85 h, and the

Table 1
Baseline characteristics

Variables	n	%	Mean±SD
Age (year)			62.9±13.7
Sex			
Male	45	60.8	
Body mass index (kg/m²)			27.8±4.8
Concomitant diseases			
COPD	15	20	
Carotid artery disease	3	4	
Cerebrovascular disease	4	5	
Coronary artery disease	4	5	
Diabetes mellitus	15	20	
Peripheral artery disease	1	1	
Hypertension	30	40	
Dyslipidemia	4	5	
Tobacco use	16	20	
Preoperative medications			
ACE inhibitor	18	20	
ARB	10	13	
Statins	14	18	
Beta receptor antagonists	19	25	
Bronchodilators	14	18	

SD: Standard deviation; ACE: Angiotensin converting enzyme; ARB: Angiotensin receptor blockers; COPD: Chronic obstructive pulmonary disease.

Table 2
Preoperative echocardiography

Variables	Mean±SD
Maximum aortic transvalvular gradient (mmHg)	90.66±27.56
Mean aortic transvalvular gradient (mmHg)	60.13±18.79
Velocity (m/s)	4.25±1.22
Interventricular septum (cm)	1.42±0.27
Posterior wall thickness (cm)	1.35±0.22
Ejection fraction (%)	61.95±5.54
Left ventricle end-diastolic diameter (cm)	4.96±0.64
Left ventricle end-systolic diameter (cm)	3.28±0.76

SD: Standard deviation.

mean postoperative bleeding was 419.59±287.26 mL. Eight (1.8%) patients underwent early surgical revision due to bleeding or tamponade.

Table 3 shows the preoperative and postoperative ECG findings at three different time points. Before aortic valve replacement, the three most common ECG findings were left ventricle hypertrophy in 35 (47.3%) patients, T-wave inversion in 29 (39.2%), and left septal fascicular block in 18 (24.2%).

In the first postoperative hour, left ventricle hypertrophy findings remained unchanged in 35 (47.3%) patients, inverted T waves were observed in 27 (36.5%) patients, left septal fascicular block developed in six patients, and left septal fascicular block was present in a total of 24 (32.4%) patients. While left bundle branch block was not present preoperatively, it developed in 19 patients during the first postoperative hour and was observed in 24 (32.4%) patients. While right bundle branch block was not present preoperatively, it developed in five patients during the first hour of recovery and was observed in nine (12.2%) patients.

Table 3
Pre- and postoperative ECG findings

	Preoperative		1st hour		24th hour		Discharge	
Postoperative ECG finding	n	%	n	%	n	%	n	%
Left ventricle hypertrophy	35	47.3	35	47.3	35	47.3	35	47.3
Inverted T waves	29	39.2	27	36.5	29	39.2	26	35.1
Left septal fascicular block	18	24.3	24	32.4	13	17.6	10	13.5
Right ventricle hypertrophy	14	18.9	14	18.9	14	18.9	14	18.9
Left anterior fascicular block	7	9.5	6	8.1	4	5.4	4	5.4
Left bundle branch block	5	6.8	24	32.4	8	10.8	9	12.2
Right bundle branch block	4	5.4	9	12.2	10	13.5	11	14.9
Left posterior fascicular block	3	4.1	4	5.4	2	2.7	1	1.4
Incomplete left bundle branch block	3	4.1	2	2.7	4	5.4	3	4.1
Atrial fibrillation	2	2.7	2	2.7	2	2.7	2	2.7
Incomplete right bundle branch block	-	-	1	1.4	-	-	1	1.4
Atrial flutter	-	-	3	4.1	1	1.4	-	-
Sinus tachycardia	-	-	8	10.8	3	4.1	-	-
Junctional tachycardia	-	-	1	1.4	-	-	-	-
1st degree AV block	-	-	3	4.1	1	1.4	-	-
2nd degree Mobitz type 2 AV block	-	-	4	5.4	2	2.7	-	-
3rd degree AV block	-	-	2	2.7	3	4.1	3	4.1
Atrial escape r27 rhythm	-	-	1	1.4	-	2.7	-	-
Accelerated atrial rhythm	-	-	-	-	1	4.1	-	-
Accelerated junctional rhythm	-	-	-	-	4	5.4	-	-
Bifascicular block	-	-	8	10.8	3	4.1	-	-

ECG: Electrocardiogram; AV: Atrioventricular.

At the 24th postoperative hour, left ventricle hypertrophy persisted in 35 (47.3%) patients, and inverted T waves persisted in 29 (39.2%) patients, while left septal fascicular block findings disappeared in 11 patients and were observed in 13 (17.6%) patients. Left bundle branch block resolved in 16 patients and persisted in eight (10.8%). While rates of left ventricle hypertrophy and inverted T waves persisted in discharge ECGs, septal fascicular block disappeared in eight patients who had it prior to surgery and regressed to a total of 10 (13.5%) patients. Left bundle branch block persisted in nine (12.2%) patients at discharge. In addition, other ECG abnormalities developed in a small number of patients and gradually returned to normal. Nine (12.1%) patients underwent root enlargement procedure, six of these had septal fascicular block, and two had left bundle branch block in the postoperative period.

Ten (13.5%) patients required a temporary pacemaker after surgery. Pacemaker indications included slow atrial fibrillation in two, sinus bradycardia and first degree AV block in one, Mobitz

Table 4
Comparison of study parameters between patients receiving and not receiving temporary pacemaker support after isolated aortic valve replacement

	TPM (+) (n=10)		TPM (-) (n=64)				
	n	%	n	%	OR	95% CI	*p*
Age (>60 year)	6	60.0	47	73.4	0.543	0.136-2.160	0.381
Sex							
Male	8	80.0	37	57.8	2.91	0.574-14.853	0.181
BMI (<29 kg/m²)	4	40.0	23	35.9	1.188	0.304-4.650	0.804
IVS (>1.3)	8	80.0	37	57.8	2.91	0.574-14.853	0.181
Mean gradient (>60 mmHg)	5	50.0	29	45.3	1.207	0.318-4.580	0.782
HCT decline (>10%)	4	40.0	32	50.0	0.667	0.172-2.589	0.556
Duration of aortic clamping (>90 min)	0	0.0	14	21.9	0.397	0.046-3.404	0.100
Duration of CPB (>100 min)	3	30.0	28	43.8	0.551	0.131-2.325	0.412
Hypothermia (<31°C)	2	20.0	21	32.8	0.512	0.100-2.626	0.416

TPM: Temporary pacemaker; OR: Odds ratio; CI: Confidence interval; BMI: Body mass index; IVS: Interventricular septum; HCT: Hematocrit; CPB: Cardiopulmonary bypass.

Table 5
A comparison of the frequency of preoperative ECG abnormalities in patients who had or did not have postoperative atrioventricular block or fascicular block

	Postoperative AVB or FB						
	Present (n=30)		Absent (n=44)				
Preoperative ECG finding	n	%	n	%	OR	95% CI	*p*
Left ventricular hypertrophy	18	60.0	17	38.6	2.38	0.92-6.15	0.071
Right ventricular hypertrophy	6	20.0	8	18.2	1.125	0.34-3.65	0.845
ST segment depression	7	23.3	4	9.1	3.04	0.80-11.52	0.091
Left anterior fascicular block	4	13.3	3	6.8	2.10	0.43-10.16	0.431
Left posterior fascicular block	2	6.7	1	2.3	3.07	0.26-35.49	0.562
Left septal fascicular block	9	30.0	9	20.5	1.667	0.57-4.86	0.347
Left bundle branch block	5	16.7	0	0	8.60	0.95-77.84	0.009*
Right bundle branch block	3	10.0	1	2.3	4.77	0.47-48.31	0.30

ECG: Echocardiogram; AVB: Atrioventricular block; FB: Fascicular block; OR: Odds ratio; CI: Confidence interval.

type 2 AV block in four, and idioventricular rhythm in three. Three (4.1%) patients who developed third degree AV block required permanent pacemaker implantation before discharge. Table 4 shows the univariate analysis to identify potential predictors of the postoperative need for a temporary pacemaker. Although there was a tendency for the male sex, interventricular septum >1.2, shorter aortic clamping, and CPB times in patients requiring temporary pacemaker, none of these variables were statistically significant, according to univariate analysis. As a result, no multivariate regression model was created.

Within the first 48 h after surgery, 30 (40.5%) patients experienced fascicular block or AV block. Although patients with preoperative left ventricle hypertrophy, ST segment depression, left septal fascicular block, left bundle branch block, and right bundle branch block were more likely to develop postoperative AV block or fascicular block, only the risk of having left bundle branch block was statistically significant.

DISCUSSION

The main finding of our study is that preoperative ECG findings are related to the risk of postoperative AV block or fascicular block in patients undergoing isolated aortic valve replacement for isolated aortic stenosis. In our study, the risk of postoperative AV block or fascicular block appeared to be two to four times higher in patients with preoperative ECG findings of left ventricular hypertrophy, left anterior fascicular block, left posterior fascicular block, left septal fascicular block, or right bundle branch block, but this result was not statistically significant. However, this risk was statistically significantly 8.60 times higher in patients with preoperative left bundle branch block, indicating that the slowdown in the conduction system in patients with preoperative left bundle branch block progressed to a more advanced block after surgery or that the symptoms of left bundle branch block persisted. Furthermore, patients who required a temporary pacemaker after surgery tended to be male and to have an enlarged interventricular septum, although these associations were not statistically significant. Age, obesity, advanced disease, and other previously suggested operative parameters were not significantly associated with an increased risk of requiring a temporary pacemaker following surgery.

Numerous studies have attempted to reveal the relationship between aortic stenosis, aortic valve replacement, and conduction system disorders. In an early report, Follath and Ginks[11] demonstrated that intraventricular conduction system defects are common (26%) following aortic valve surgery. Due to the close proximity between the aortic valve and the conduction system, it is believed that direct trauma caused during surgery is the cause of the problem. This trauma may be caused by suture damage, calcific material compression, or compression of the conduction tissue by the valve stent.[12] In fact, it has been demonstrated that continuous suturing increases the incidence of postoperative AV conduction system disorders compared to intermittent suturing.[13] Conduction defects may also be associated with total bypass time, cross-clamp time, and cardioplegia administration route.[14-16] These findings indicate that ischemic damage to the conduction system is predominant. These factors were not found to be associated with the outcome in our study. This outcome is due to advancements in surgical technique as well as myocardial preservation.

The most common finding in our study group's preoperative ECGs was that the criteria for left ventricular hypertrophy (Sokolow-Lyon criteria) were met in nearly one out of every two patients (47%). A drug study demonstrated the significance of these criteria in patients with aortic stenosis, and the left ventricular hypertrophy criteria in patients with aortic stenosis were shown to be associated with poor prognosis in asymptomatic patients.[8] In our study, 60% of patients with AV block or fascicular block in the postoperative period had preoperative left ventricular hypertrophy, and while this finding did not reach statistical significance, it increased the risk of AV block by 2.38 times (p=0.071).

In patients with aortic valve disease, histological abnormalities of the conduction system are common, and various hypotheses have been advanced as to their causes, including mechanical (increased left ventricular pressure) and ischemic factors and age-related or primary degenerative disease of the conduction system.[17] Fascicular block, on the other hand, refers to partial blocks that occur in the intraventricular conduction system, which is distal to the AV node of the conduction system and is considered to be divided into two distinct branches: left bundle branch block and right bundle branch block. The diagnostic criteria for this system's blockages were documented in 1985, revised in 2009, and given their current form. In the years that followed, numerous studies on the clinical significance of conduction disorders in the fascicular conduction system were conducted.[10] Coronary artery disease is almost always associated with intraventricular conduction system disorders, according to these studies. Patients with myocardial asynchrony are more likely to develop left bundle branch block and left posterior fascicular block after myocardial infarction, as reported by Janion et al.[18] In a meta-analysis investigating the incidence and prognostic significance of postoperative conduction system disorders in patients undergoing coronary artery bypass grafting, Kumbhani et al.[19] reported that the incidence ranged from 3.4 to 55.8%, and contrary to the findings of previous studies, the association between these conduction disorders and a poor prognosis was unclear. Researchers attributed this result to technical advancements in cardiac surgery and the optimization of techniques for myocardial preservation.

In our study, it is believed that the left anterior fascicular block was observed with at the same frequency before and after the operation for two reasons. The main component of the fascicular conduction system is the left anterior fascicle, and its blockage results in permanent change. The second reason is that the perfusion of the left anterior fascicle is provided by the proximal septal marginal branches of the left anterior descending artery; therefore, it is not uncommon for a well-preserved heart free of coronary artery disease to be discovered as a new finding following surgery. The left posterior fascicle runs along the posterior surface of the septum and, unlike the left anterior fascicle, branches into the myocardium in a weaker and more extensive manner. Since it is supplied by both the right and left sides of the coronary circulation, it is resistant to ischemia. Consequently, it is the most uncommon type of fascicular block.[20] Our study confirmed that left and right bundle branch blocks are not uncommon in these patients during the preoperative period and that they occur in a certain percentage of patients following surgery.

In our study group, left septal fascicular block was the third most common preoperative finding (24% of patients). Due to the thickening of the interventricular septum in nearly all of the preoperative patients in our study group and the absence of initial Q waves indicating septal depolarization, which is an essential criterion for septal fascicular block,[21] we deemed it appropriate to include this finding as a risk factor in this patient group. Left septal fascicular block may be associated with a low risk for the development of AV block or fascicular block in the postoperative period (OR 1.667 [0.571-4.862]), but this risk is not statistically significant. However, left septal fascicular block was by far the most prevalent ECG finding in the first 48 h following surgery (32.4% of patients).

There are few studies linking intraventricular conduction system disorders to aortic valve disease and surgery. Similar to our study, El-Khally et al.[22] found that a newly developed left bundle branch block and left anterior fascicular block following surgery increased the risk of adverse events by eightfold. Left bundle branch block increased the risk of adverse events by the same rate in both our study and this study involving patients with isolated SAVR (8.0- *vs.* 8.6-fold). In our study, aortic regurgitation patients were excluded, a more isolated group was created, and intraventricular conduction system disorders were examined in greater diagnostic and time-based detail by dividing them into four distinct time points. In numerous studies, the only conduction system disorders recorded were left bundle branch block, left anterior hemiblock, and right bundle branch block. Left septal fascicular block was not included in these studies since globally accepted criteria have not been established or perhaps because large clinical studies or meta-analyses have not yet demonstrated the prognostic significance of this finding.[10]

Dawkins et al.[23] reported that 8.5% of 354 patients who underwent isolated SAVR required a permanent pacemaker. In their report, they provided a summary of the studies published in prior years, as well as the incidence of pacemaker need reported in these studies. Erdoğan et al.[24] investigated patients who required a permanent pacemaker and their risk factors within the next decade. Half of the patients in their study (21 of 49) with permanent pacemakers had undergone aortic valve replacement. The incidence of AV block was low in our study. In patients with AV block of the first and second degrees, the decreasing frequency of occurrence at subsequent time points indicates that these disorders are transient. Three (4.7%) patients developed AV block of the third degree postoperatively; these patients required permanent pacemaker implantation. The patient with Mobitz type 2 AV block was monitored with a temporary pacemaker until the day of discharge with normal ventricular rhythm and returned to normal sinus rhythm prior to discharge. Consequently, 4.1% of patients in this study required a permanent pacemaker during the early period.

This study has some limitations. The was retrospective in design, its patient population was small, and it was conducted over a two-year period. The absence of a control group also contributed to the lack of statistical significance in our study results. We believe that a prospective study employing continuous ECG monitoring in a larger patient group may yield more meaningful results to elucidate the significance of fascicular conduction system disorders in this patient population.

In conclusion, the presence of monofascicular, bifascicular, or bundle branch blocks on the preoperative ECG may predict the likelihood of developing AV block or fascicular conduction system disorders after SAVR. Predictive value of preoperative structural ECG abnormalities of the intraventricular conduction system should be elucidated in a prospective study employing continuous ECG monitoring in a larger patient population, as suggested by our findings.

Ethics Committee Approval: This thesis study was performed with the permission and approval of the Medical Directory Department of Kartal Kosuyolu Training and Research Hospital. 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: Concept, design, data collection and interpretation, literature review and writing the article: E.A.; Concept, critical review of the article: H.S.

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Abdominal compartment syndrome following open and endovascular repair of ruptured abdominal aortic aneurysm

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ABSTRACT

Objectives: This study aimed to reveal the incidence, treatment, and outcomes of abdominal compartment syndrome (ACS) following open or endovascular repair of ruptured abdominal aortic aneurysm (rAAA).

Patients and methods: The retrospective study included 36 patients (27 males, 9 females; mean age: 68.9±7.2 years; range, 61 to 81 years) who presented with rAAA between May 2016 and July 2023. In all patients, data regarding demographic characteristics, type of repair (open repair or endovascular aneurysm repair [EVAR]), ACS onset, morbidity, and mortality were recorded. The diagnosis of ACS was made by clinical signs and abdominal pressure measurements.

Results: The overall mortality was 41.7% (n=15). Abdominal compartment syndrome developed in five (13.9%) patients, including two (25%) of eight patients who underwent EVAR and three (10.7%) of 28 patients who underwent open repair. In the open repair group, three (60%) of five patients who developed ACS and 12 (38.7%) of 31 patients without ACS died while one (50%) of two patients who developed ACS died in the EVAR group. No death was noted among patients without ACS in the EVAR group.

Conclusion: This study shows that ACS can develop following both EVAR and open rAAA repair. Decompression laparotomy and open abdominal treatment should not be delayed when indicated. Although intra-abdominal pressure remains high, appropriate therapy may significantly affect outcomes.

Keywords: Abdominal compartment syndrome, EVAR, intra-abdominal hypertension, ruptured abdominal aortic aneurysms.

Ruptured abdominal aortic aneurysm (rAAA) remains to be a major surgical problem due to high surgical mortality and morbidity and need for rapid diagnosis and surgical repair despite contemporary advances. In aortic pathologies, endovascular repair techniques have replaced surgery with technological advances and improved experience.[1,2] Although endovascular rAAA repair shows promising outcomes regarding survival in selected patients, it is controversial that the technique is associated with favorable outcomes in all patients.[3,4]

As was the case in elective endovascular interventions, novel complications have been defined with unclear treatment paradigms by improving experience in emergent endovascular repair. Intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) are known causes off multiorgan failure (MOF) and leading causes of postoperative mortality in rAAA patients undergoing open repair.[4-6] Abdominal compartment syndrome development was observed following both open and endovascular rAAA repair.[7-9] However, unlike open surgery, endovascular repair does not allow evacuation of retroperitoneal hematoma, which theoretically may lead to increased ACS incidence. Intra-abdominal hypertension and ACS resulting from elevated intra-abdominal pressure (IAP) have long been known in patients with acute aortic pathologies.[10] However, the diagnosis of IAH and ACS is underestimated in many clinics. Although treated sufficiently, the IAH overlooked following open and endovascular rAAA repair can transform into ACS with remarkable

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mortality rate due to irreversible pathophysiological changes causing MOF.[10]

The term IAP refers to pressure in the intra-abdominal cavity. Reference values are defined following intermittent measurements through the bladder. The measurement is performed during expiration at supine position with the abdominal muscles relaxed. It was reported to be 0-5 mmHg in healthy individuals.[11] The mean IAP was reported as 5-7 mmHg in critically ill patients.[12]

Intra-abdominal hypertension is a term used for IAP that continuously or recurrently exceeds 12 mmHg in pathological conditions.[11,12] Four grades have been defined based on pressure level (Table 1).[11] Abdominal perfusion pressure is a relative marker of abdominal blood flow, which is estimated using the following formula: abdominal perfusion pressure = mean arterial pressure-IAP.

Intra-abdominal hypertension is often associated with bleeding or splanchnic reperfusion-related massive fluid resuscitation, resulting in profound physiological derangement affecting each organ system in either a direct or indirect manner, and can also lead ACS.[12-15] Vena cava inferior is stressed by IAP elevation, which results in decreased venous return, leading to systemic vascular resistance through decrease in end-diastolic ventricular volume, stroke volume, and cardiac output. In addition, IAP elevation also affects kidneys, leading to decreased renal flow and urine output together with unfavorable effects on cardiac function. Simultaneously, the elevated IAP compresses the diaphragm and leads to increased intrathoracic pressure by elevating the airway pressure, pulmonary artery pressure, and central venous pressure and decreasing pulmonary compliance. Individual organ perfusion dysfunction occurs at a different level of IAP. For instance, renal blood flow and renal function will manifest as oliguria at an IAP level of 15 mm and anuria at 30 mmHg. If ACS is left untreated, MOF will develop. All pathophysiological changes are potentially reversible without severe organ dysfunction if IAH is diagnosed early and treated adequately.[7-10] The management often requires decompression laparotomy and aims at reducing IAP. Failure to relieve pressure is almost always fatal and surgical decompression provides significant improvement in mortality.[7]

Table 1
Stages of intra-abdominal hypertension

Grade	IAP (mmHg)
1	12-15
2	16-20
3	21-25
4	≥25

IAP: Intra-abdominal pressure.

In the literature, there is limited data regarding ACS development following open or endovascular rAAA repair and its effects on morbidity and mortality. Hence, this study aimed to reveal the incidence, treatment, and outcomes of ACS following open or endovascular repair of rAAA.

PATIENTS AND METHODS

This retrospective study examined 36 patients (27 males, 9 females; mean age: 68.9±7.2 years; range, 61 to 81 years) who underwent surgery with a diagnosis of rAAA in the Izmir Bakırçay University Faculty of Medicine between May 2016 and July 2023. Data regarding demographic characteristics, type of repair (open repair or endovascular aneurysm repair [EVAR]), and comorbid conditions were extracted from patient files. The clinical suspicion and close monitorization of IAP are keys for diagnosis of IAH/ACS. The diagnosis of ACS was made a series of clinical finding including increased airway pressure, impairment in respiratory parameters, oliguria, cerebral dysfunction, intestinal dysfunction, and abdominal wall tension, together with the measurement of IAP. A urine catheter was inserted into the bladder to monitor IAP. A sterile, disposable, noninvasive pressure monitorization kit (UnoMeter Abdo-Pressure; Convatec, London, UK) was attached to the catheter. Intra-abdominal pressure measurements were performed using a specific probe, and mean values were recorded. The outcome and discharge data were also recorded.

Statistical analysis

Statistical analyses were performed using IBM SPSS version 19.0 (IBM Corp., Armonk, NY, USA). Comparisons were made by the unpaired t-test. Categorical data was compared with Fisher exact test or the Mann-Whitney U test. A *p*-value <0.05 was considered statistically significant.

Table 2
Patient characteristics and patient outcomes

	EVAR (n=8)				Open (n=28)				
	n	%	Mean	Median	n	%	Mean	Median	*p*
Patient characteristics									
Age (year)			72.9				67.9		0.4
Sex									NS
Male	7	88			20	71			
Coronary artery disease	3	38			11	39			NS
COPD	3	38			9	32			NS
Diabetes mellitus	1	13			7	25			NS
Hypertension	4	50			16	57			NS
Chronic renal failure	0	0			2	7			NS
Outcome									
Abdominal compartment syndrome	2	25			3	11			NS
Myocardial infarction	0	0			2	7			NS
Pneumonia	1	13			7	25			NS
Renal failure	4	50			17	60			NS
Dialysis	1	13			5	18			0.09
Sepsis	1	13			4	14			NS
Ischemic colon	0	0			2	7			0.079
Multisystem organ failure	1	13			4	14			0.145
Death	2	25			13	47			0.146
Abdominal compartment syndrome/death	1	13			2	7			NS
Hospital length of stay (days)				8				15	0.215
Intensive care unit length of stay (days)				4				8	0.052

EVAR: Endovascular aneurysm repair; COPD: Chronic obstructive pulmonary disease; NS: Not significant.

RESULTS

The overall mortality was 41.7% (n=15). Abdominal compartment syndrome developed in five (13.9%) patients. Ruptured abdominal aortic aneurysm repair was performed using an endograft in eight (22.2%) patients, while open repair was performed in 28 (77.8%) patients. Patient characteristics were comparable in endovascular repair and open repair groups (Table 2). There was a tendency towards lower mortalite, shorter length of hospital stay and ICU stay in endovascular repair group when compared; however, the difference did not reach statistical significance.

Abdominal compartment syndrome developed in five (13.9%) patients, including two (25%) of eight patients who underwent endovascular repair and three (10.7%) of 28 patients who underwent open repair. No difference was observed in patient characteristics between patients with or without ACS in the endovascular repair and open repair groups. In the open repair group, three (60%) of five patients who developed ACS and 12 (38.7%) of 31 patients without ACS died, while one (50%) of two patients who developed ACS died in the endovascular repair group. No death was noted among six patients without ACS in the endovascular repair group (Table 2).

DISCUSSION

The overall mortality rate of 41.7% in our study on patients who underwent rAAA repair was consistent with those reported in the literature.[4,7,10,16,17] Endovascular therapy in aortic aneurysms is preferred due to better early outcomes compared to open surgery. In rAAA, mortality and morbidity were found as 24 and 44% after endovascular repair, respectively.[18] In agreement with the literature, albeit not significant, there was a tendency towards lower mortality in patients treated with endovascular graft when compared to those who underwent open surgery in our study.[16-20]

Abdominal compartment syndrome may develop both in patients treated with endograft repair and open repair. In our study, ACS was observed in both groups. The incidence of ACS is unclear; however, it was reported to develop in 10% of patients.[21] In a systematic review, it was reported that ACS developed in 5.5% of patients treated with endovascular repair. In a recent meta-analysis, it was estimated as 8%; however, authors proposed that actual incidence may be >20% with awareness and close monitoring.[4] In our series, ACS rate was 25% in patients treated with

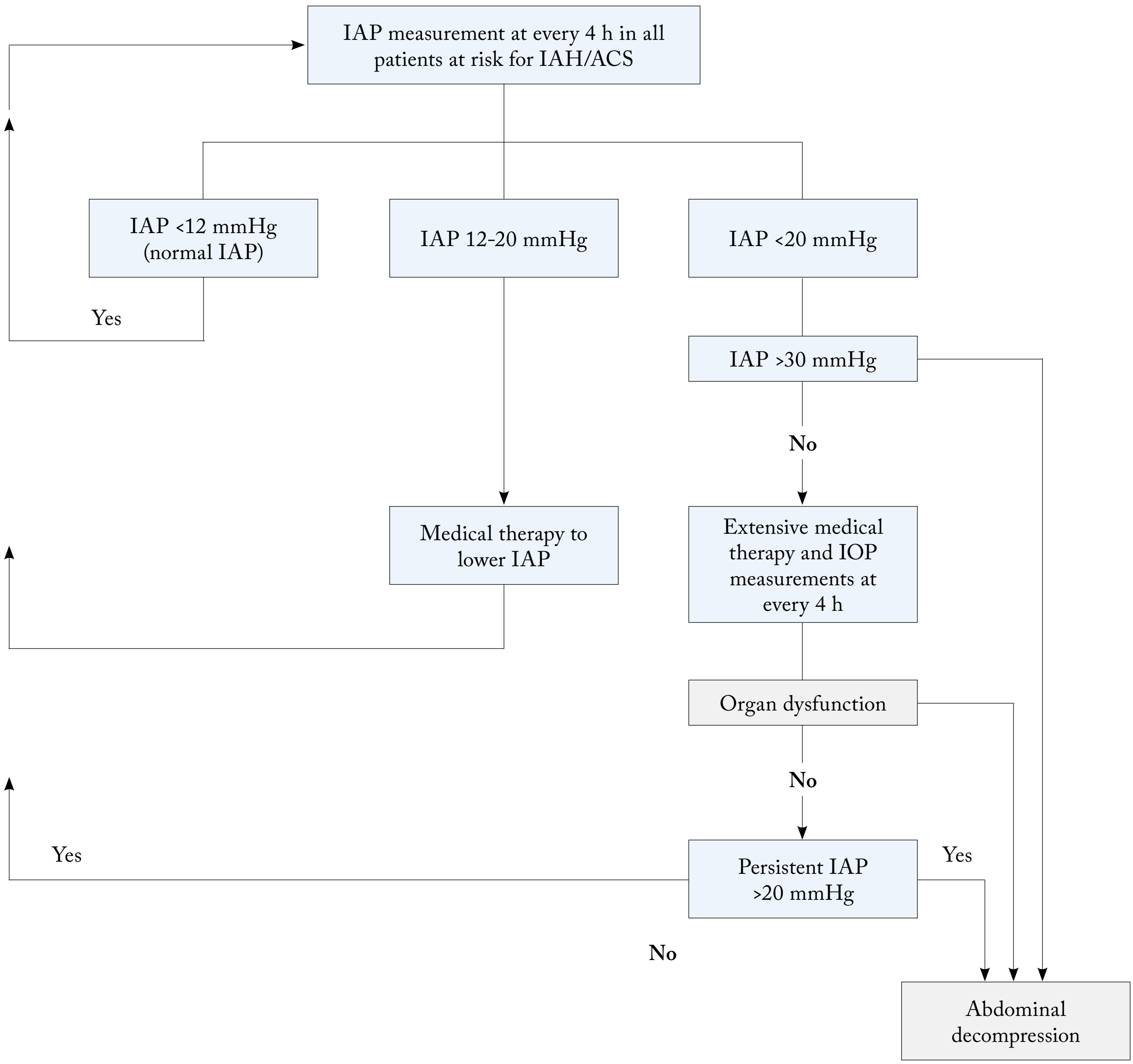

Figure 1. Algorithm for IAP monitorization and postoperative follow-up after repair of ruptured abdominal aortic aneurysm.[28]
IAP: Intraabdominal pressure; IAH: Intraabdominal hypertension; ACS: Abdominal compartment syndrome.

endovascular repair, whereas it was 10.7% in patients treated with open repair.

Following open repair, it has been suggested that the ACS-related mortality rate is generally over 50%, reaching up to 100%.[22,23] In our study, ACS-related mortality was 60%. In previous studies, mortality rate up to 57% was reported in patients who developed ACS following endovascular repair.[24] In agreement with the literature, mortality rate was found as 50% in patients who developed ACS following endovascular repair.

The mechanism underlying ACS development following endovascular or open repair of rAAA is not limited to a single mechanism and may be multifactorial in certain patients. There are several factors that may be involved in ACS development. For instance, patients who underwent endovascular repair may need substantial fluid after surgery due to effects of shock, while mass effect may be present due to retroperitoneal hematoma, or coagulopathy may exist. Similarly, patients who underwent open repair may require transfusion of blood and blood products due to coagulopathy or surgical bleeding in addition to retroperitoneal mass effect and intestinal edema caused by resuscitation. Blood transfusion need at an early phase after endovascular repair may be suggestive of ongoing bleeding related to surgical type 2 endoleak. This may warrant opening the aneurysmal sac. Early onset of ACS following open repair may result from ongoing hemorrhage due to coagulopathy or surgical bleeding. All efforts should be made to correct coagulopathy and achieve normothermia before decompression laparotomy.[7]

Abdominal compartment syndrome can lead to progressive organ dysfunction and even death if not diagnosed early and treated appropriately.[1,4,7,10,25] Thus, early diagnosis and treatment are of importance. It is widely accepted that treatment should include IAP reduction and abdominal decompression in patients with persistent IAP elevation above 20-25 mmHg.[10,26-28] In our series, IAP measurements were performed periodically, and laparotomy was performed for abdominal decompression when IAP was >20 mmHg (Figure 1).

Intra-abdominal hypertension and ACS are severe complications with high incidence following rAAA repair. Abdominal decompression is deemed a life-saving intervention in patients who develop ACS. In the case of ACS, a successful outcome depends on the early recognition of ACS, medical therapy directing to lower IAP, and decompression laparotomy at an early phase.[28]

This study has some limitations. First, significant changes may have occurred in diagnostic and therapeutic procedures due to differences in healthcare providers and approaches over the lengthy duration of the study. Second, this is a retrospective, nonrandomized study with a relatively limited number of patients. In addition, there was no prespecified standard for IAP measurement or ACS indication.

In conclusion, intra-abdominal hypertension and ACS are commonly seen in patients treated for rAAA and are associated with a high risk for morbidity and mortality. However, IAH/ACS are overlooked by many clinicians; in addition, the diagnosis is generally delayed, and treatment often fails. All healthcare providers involved in the treatment of rAAA via open surgery or endovascular repair should understand the pathophysiology, risk factors, and presentation. This study shows that ACS can develop following both endovascular repair and open rAAA repair. Early decompression laparotomy should be performed in patients with ACS at an early phase after endovascular repair and signs suggestive of ongoing bleeding. Nonsurgical and surgical treatment, as well as a timely diagnosis, are of importance. Decompression laparotomy and open abdominal treatment should not be delayed when indicated. Although IAP remains high, appropriate therapy may significantly affect outcomes.

Ethics Committee Approval: The study protocol was approved by the Izmir Bakırçay University Non-Invasive Ethics Committee (date: 13.09.2023, no: 1192/1172). 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, design, data collection, literature review, crtitical review, wrting the article: İ.K.; Control, literature review, references and fundings, data collection, materials: A.D.

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Cardiovascular Surgery and Interventions

Case Report Open Access

Median arcuate ligament syndrome: What is the best treatment?

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ABSTRACT

Median arcuate ligament syndrome is a rare condition that is usually recognized late. Chronic postprandial abdominal pain, weight loss, loss of appetite, nausea, and diarrhea are usual symptoms due to the median arcuate ligament's mechanical compression on the celiac trunk and celiac plexus. The gold standard in treatment is to eliminate the mechanical compression of the median arcuate ligament on the celiac trunk and celiac plexus. In this article, we present a 49-year-old female patient who previously underwent endovascular intervention but whose complaints were not relieved and who underwent surgical treatment.

Keywords: Abdominal pain, celiac plexus, compression, median arcuate ligament release, surgery.

Median arcuate ligament syndrome (MALS) or celiac artery compression syndrome is a condition characterized by abdominal pain, weight loss, and loss of appetite as a result of mechanical compression of the median arcuate ligament on the celiac trunk and celiac plexus. It occurs in an estimated 2/100,000 patients.[1] It is more common in women than men.[1,2] It has also been reported in the pediatric patient group.[1,2]

Clinical findings were chronic postprandial abdominal pain in 80% of cases, weight loss in 48%, murmur on auscultation in 35%, nausea in 9.7%, and diarrhea in 7.5%.[2,3] Diagnosis is made by color Doppler ultrasound or computed tomography angiography. Inflammatory bowel diseases and anxiety disorder should be considered in the differential diagnosis. The gold standard in treatment is to eliminate the mechanical compression of the median arcuate ligament on the celiac trunk and celiac plexus. Therefore, surgical treatment seems to be the best option for patients diagnosed with MALS. In this article, a patient who underwent endovascular intervention but whose complaints were not relieved and who underwent surgical treatment was reported.

CASE REPORT

A 49-year-old female patient had complaints of abdominal pain, fear of eating (cibophobia), weight loss, abdominal distention, belching, constipation, loss of appetite, and nausea that had persisted for five years and had increased since the last six months. In her gastroenterological examination, no pathology could be found to explain these symptoms. Later diagnosed with MALS on computed tomography angiography by interventional radiology. With the conventional mesenteric angiography technique, 80 to 90% stenosis was detected in the celiac artery, and the stenosis was resolved by placing a 6×27 mm stent (Figure 1a, b). The patient's abdominal pain complaints disappeared temporarily but started again after one week. In the control angiography performed by the interventional radiologist, the stent was found to be broken (Figure 2a, b), and surgical intervention was recommended to the patient. Open surgical intervention was scheduled after the completion of preoperative evaluations. A median laparotomy was performed above and below the umbilicus, following preparations under sterile conditions under general anesthesia. The celiac trunk, main hepatic artery, splenic artery, left gastric artery, and infrarenal aorta were released by encircling with a vessel tape. The stent was palpated proximal to the celiac trunk. There was no pulse distal to the stent. The ligament on the celiac

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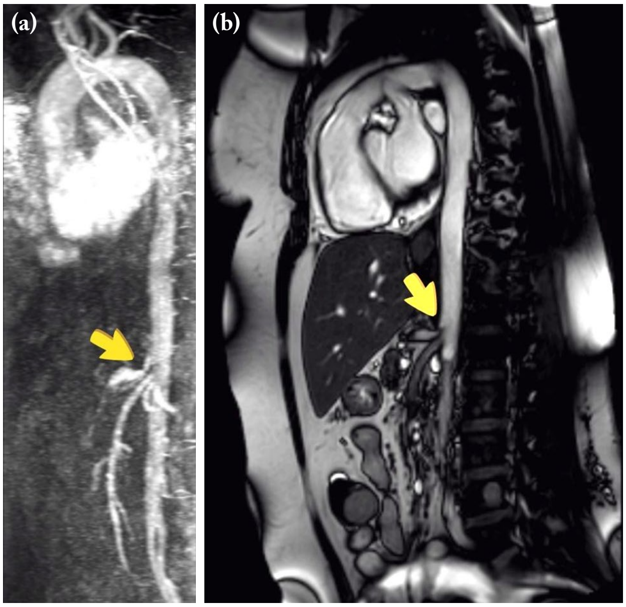

Figure 1. (a) Severe stenosis and poststenotic dilatation of the celiac artery in computed tomography angiography (yellow arrow); **(b)** severe stenosis and poststenotic dilatation of the celiac artery on magnetic resonance imaging (yellow arrow).

trunk and plexus was released with electrocautery. Intravenous 5,000 IU unfractionated heparin was administered. After an appropriate activated clotting time (ACT) was reached (ACT>150), bypass grafting was performed between the infrarenal aorta (Figure 3a) and the main hepatic artery (Figure 3b) using an 8 mm Dacron graft by tunneling from the intestinal mesos behind the stomach and in front of the duodenum/pancreas. The postoperative period was uneventful. The patient was discharged on the sixth postoperative day.

DISCUSSION

The existence of this disease is still controversial, and its diagnosis depends on the elimination of other possible causes of abdominal pain. The symptoms of MALS may not cause chronic mesenteric ischemia, and the pathophysiology of this disease is still not fully understood. However, a prospective cohort study using ischemia function testing demonstrated long-term benefit in approximately 80% of treated cases.[4] Patients treated nonoperatively appear to have worse outcomes.[2]

The main etiology of this disease is anatomical, as the median arcuate ligament mechanically compresses the celiac trunk and celiac plexus. In other words, since the main cause is anatomical, the treatment of the disease is to eliminate this pressure.[2] The stent is broken or kinked due to mechanical compression. In this case, an endovascular intervention was performed one month ago, a stent was placed, but the patient's complaints started again, as stent fracture occurred one week later. Open surgery, minimally invasive procedures, or laparoscopic methods are applied.[3,5]

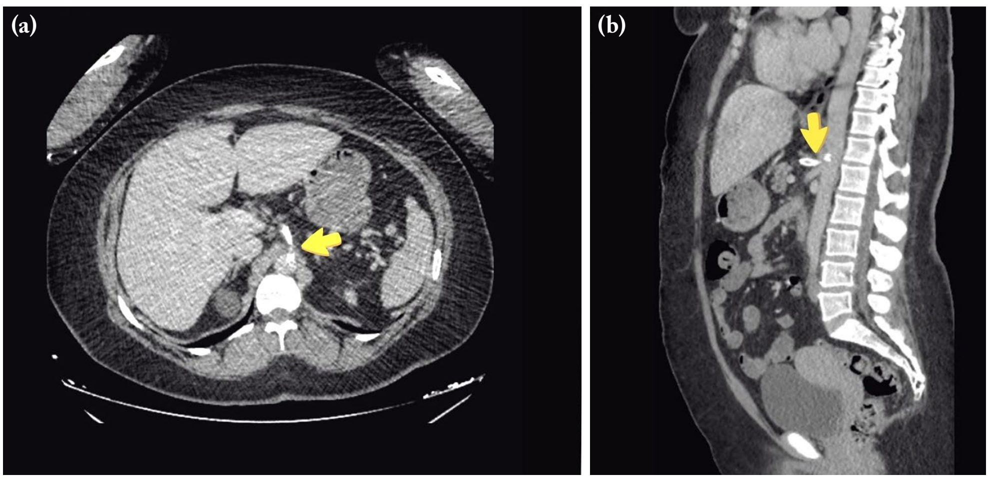

Figure 2. (a) One week after endovascular stent placement, computed tomography angiography (transverse section) shows that the stent is broken and thrombosed (yellow arrow); **(b)** computed tomography angiography (coronal section) shows that the stent is broken and thrombosed (yellow arrow).

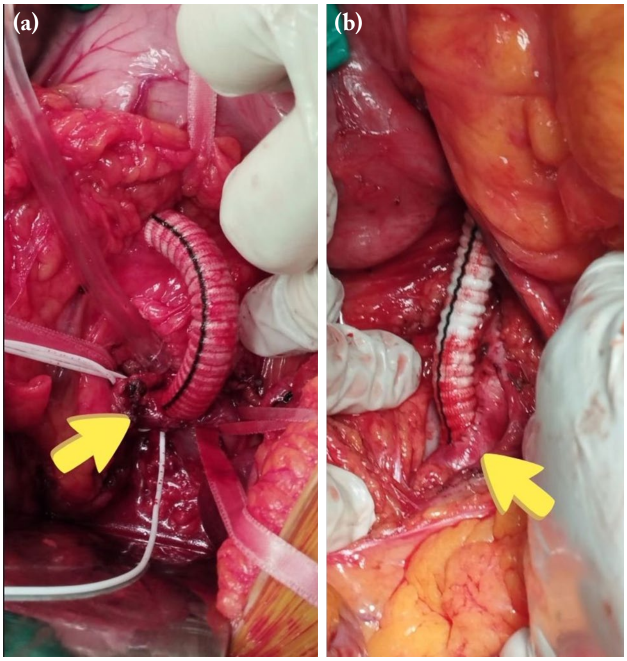

Figure 3. **(a)** Intraoperative view of the anastomosis between the infrarenal abdominal aorta and the Dacron graft (yellow arrow); **(b)** intraoperative view of the anastomosis between the hepatic artery and the Dacron graft (yellow arrow).

Whatever the method is, it should aim to eliminate compression.

Postprandial intestinal angina, cibophobia, weight loss, nausea, and vomiting are prominent complaints in MALS.[2] In our case, epigastric pain/rumbling, cibophobia, abdominal bloating, belching, constipation, loss of appetite, and nausea were present in accordance with the literature.

Bypass grafting seems to be the most appropriate surgical treatment in some cases. Revascularization is performed by providing antegrade arterial inflow from the thoracic or supraceliac aorta or retrograde arterial inflow from the infrarenal aorta.[2] For anatomical convenience, we performed bypass grafting between the infrarenal aorta and the main hepatic artery in our case.

In MALS, cutting the median arcuate ligament or releasing the fibrotic celiac ganglion by incision relieves pressure to a large extent and provides symptomatic relief.[3,5] The most suitable lesion for an endovascular procedure is a short-segment (<10 cm) lesion close to the celiac artery or superior mesenteric artery ostium.[2] In recent years, minimally invasive or laparoscopic methods have also been applied in appropriately selected patients.[3,5] Long-term follow-up data (over five years) after surgical management are lacking. In our case, stenting was previously performed, the stent was fractured and occluded within a week, symptoms relapsed, and the final treatment was open surgery. Ganglionectomy can also be performed if there is a neuropathic component. The celiac plexus was also released during the surgery. After the surgical treatment, the patient's complaints disappeared. It was observed that the patient's complaints completely resolved in the postoperative third month.

In conclusion, decompression of the median arcuate ligament's constriction of the celiac artery and plexus provides symptomatic relief in MALS. Bypass grafting seems to be the most appropriate treatment for the surgical treatment of some cases.

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: All authors contributed equally to the article.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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