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ORIGINAL RESEARCH

Risk factors for neurological complications and clinical outcomes in patients with left ventricular assist devices

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Abstract

Objectives: Patients with left ventricular assist devices (LVADs) frequently experience cerebrovascular complications. We investigated the complications, including intracranial hemorrhage (ICH) and ischemic stroke (IS), in patients with LVADs. **Methods**: A historical cohort study was performed at an emergency clinic including patients who underwent LVAD placement between February 16, 2015, and April 1, 2020. Of the 295 patients with LVADs, 71 (24.1%) were admitted to the emergency service between the study dates because of IS and ICH. Electronic medical files were reviewed, and patients were categorized as ICH or IS. **Results**: Of the included patients, 245 (83.0%) were male. The most common postoperative complications were pump thrombosis (26.8%, n = 79), blood culture positivity (19.3%, n = 57), and surgical bleeding (5.8%, n = 17). The most frequent LVAD indication was ischemic dilated cardiomyopathy (71.5%, n = 211). The mean age was 49.6 $\pm$ 16.7 and 51.3 $\pm$ 14.8 years for patients with and without neurological complications, respectively ($P = 0.415$). Neurological complications were seen in 65 (31.3%) patients with and in 6 (6.9%) patients without coronary ischemia ($P < 0.001$). Neurological complications were found in 39 (30.5%) patients with an implantable cardioverter defibrillator (ICD) and in 32 (19.2%) patients without an ICD ($P = 0.024$). Neurological complications were found in 19 (61.3%) patients with and in 52 (19.7%) patients without a history of stroke ($P < 0.001$). Logistic regression analysis revealed that age and Glasgow coma scale (GCS) were the only significant variables independently affecting mortality status. While a younger age was a protective factor, a one-unit increase in the GCS was associated with a 4.1-fold (95% CI: 1.308-13.071) increase in mortality. **Conclusions**: Coronary ischemia, ICD, cerebrovascular disease, and smoking significantly affected the presence of complications. Moreover, patients with combined IS and ICH had a lower chance of recovering. Interventional procedures should be performed as early as possible, especially in elderly patients with a low GCS.

Keywords

Left ventricular assist devices; Neurological complication; Stroke; Age. Glasgow coma scale

1. Introduction

The prevalence of heart failure is increasing, affecting up to 23 million people worldwide [1]. Despite advances in treatment, the mortality rates in these patients remain high [2]. Providing mechanical circulatory support with ventricular assist devices (VADs) is a life-saving treatment for patients with decompensated heart failure for whom optimal medical therapies are not sufficient for recovery [3]. A VAD is placed before a transplant to keep the patient alive until a suitable heart is found, to allow time to decide on the appropriateness of a transplant, as a permanent therapy, or to improve cardiac function [4]. In most patients with the above indications, a left ventricular assist device (LVAD) is attached, while a biventricular device (ventricular assist device connected to the right and the left sides) or an entire artificial heart is used in 15% of the cases [5].

Neurological complications associated with LVADs include both ischemic stroke (IS) and intracranial hemorrhage (ICH). The risk factors for the different stroke types vary. Hence, it is necessary to study the risk factors for neurological complications associated with LVADs, and this information can be used to guide accurate and individualized treatment strategies to mitigate these risk factors [6]. Analyzing the pre-implant history, the New York Health Association classification (NYHA) scores, LVAD device type, postoperative complications, and the treatment outcome within this patient group may lead to better regulation of the associated risk factors.

The majority of the previous studies on this topic were

TABLE 1. Characteristics of patients with or without neurological complications.

		Complication					
		No		Yes			
		n	%	n	%	χ^2	*P*
Sex	Male	185	75.2	61	24.8	0.431	0.512
	Female	39	79.6	10	20.4		
History							
Diabetes mellitus		47	69.1	21	30.9	2.246	0.134
Coronary ischemia		143	68.8	65	31.3	19.908	**< 0.001**
Atrial fibrillation		15	62.5	9	37.5	2.579	0.108
Chronic renal failure		12	70.6	5	29.4	0.282	0.567
ICD		89	69.5	39	30.5	5.069	**0.024**
Hypertension		88	78.6	24	21.4	0.688	0.407
CVD		12	38.7	19	61.3	26.262	**< 0.001**
Smoking		97	69.8	42	30.2	5.437	**0.020**
CABG		36	76.6	11	23.4	0.013	0.908
Valve surgery		8	61.5	5	38.5	1.542	0.315
Aortic surgery		0	0.0	1	100.0	3.166	0.241
LVAD indications	Ischemic dilated CMP	156	73.9	55	26.1	3.659	0.161
	Idiopathic dilated CMP	58	84.1	11	15.9		
	Restrictive CMP	0	0.0	0	0.0		
	Others	10	66.7	5	33.3		
LVAD device type	HA5	3	60.0	2	40.0	19.018	< 0.001
	HM2	14	93.3	1	6.7		
	HM3	51	96.2	2	3.8		
	HW	156	70.3	66	29.7		
Preimplant_NYHA	1	7	100.0	0	0.0	49.479	< 0.001
	2	153	82.7	32	17.3		
	3	47	83.9	9	16.1		
	4	17	36.2	30	63.8		
Postoperative complications							
Atrial fibrillation		0	0.0	7	100.0	22.621	< 0.001
Pump thrombosis		40	50.6	39	49.4	37.788	< 0.001
Postoperative bleeding		11	64.7	6	35.3	1.224	0.255
GI bleeding		0	0.0	4	100.0	12.793	0.003
Re-operation		13	86.7	2	13.3	0.996	0.535
Pump infection		1	50.0	1	50.0	0.741	0.424
Drive-line infection		4	100.0	0	0.0	1.285	0.576
Positive blood culture		43	75.4	14	24.6	0.009	0.923
UTI		5	71.4	2	28.6	0.08	0.676

ICD: Internal cardiac defibrillator, CVD: Cerebrovascular disease, GI: Gastrointestinal, UTI: Urinary tract infection, CABG: Coronary artery bypass graft, LVAD: Left ventricular assist device, CMP: Cardiomyopathy, NYHA: New York Heart Association

carried out in surgery, neurology, or cardiology departments [3, 4, 7]. The present study was performed in an emergency department and designed to include the opinions of emergency specialists. The aim of this study was to investigate the complications, including ICH and IS, in patients with LVADs to provide a reference for the development of appropriate treatment strategies to reduce the risks of these complications.

2. Methods

2.1 Study design

A retrospective cross-sectional study was conducted. The study reporting followed the Strobe Guidelines [8]. The research protocol was approved by the local ethics committee of Ege University (Date: December 12, 2019, number: 19-12T/52).

2.2 Setting

This study was performed between May and October 2020 in the emergency clinic at Ege University Hospital as a retrospective investigation of the files of patients who underwent LVAD placement between February 16, 2015, and April 1, 2020. The research unit is a third-level reference health center in Izmir, a city on the Aegean border with 4.1 million inhabitants. Among other specialized services, the hospital has artificial heart implantation and heart transplantation facilities.

2.3 Participants

Patients with LVADs who were admitted to the emergency service between the study dates because of stroke or ICH were included in the study. Cases with whole or biventricular artificial hearts were excluded.

An archive search was conducted by an experienced data analyst from the hospital's IT department using the relevant International Statistical Classification of Diseases and Related Health Problems [9], producing a total of 295 patients. The electronic medical files of these patients were reviewed by the researchers, and 71 patients with stroke were identified. These cases were initially categorized as ischemic or hemorrhagic stroke. The patients in the hemorrhagic stroke group were further classified as subdural, intraparenchymal, or subarachnoid (Fig. 1). The term cerebrovascular disease (CVD) comprises medical conditions affecting cerebral blood vessels [10]. In this study, CVD was categorized as IS or ICH.

2.4 Variables

According to the hospital's protocol, all patients underwent computer tomography, and a diagnosis of stroke was made based on a consensus between a neurologist and neuro-radiologist. Data on the patients' demographic features, LVAD indications, device type, pre-implant NYHA class, postoperative complications, cerebrovascular events (including Glasgow Coma Scale (GSC) and extended Glasgow Outcome Scale (GOSE)), modified Rankin Scale (mRS), CHA_2DS_2-VASc score, National Institutes of Health Stroke Scale (NIHSS), and outcomes (died/discharged) were recorded.

The Glasgow coma scale (GCS) is a practical method to objectively assess a patient's conscious level by measuring the responses to specific visual, verbal, and motor stimuli. The total evaluated score is between 3 and 15. A score between 3 and 8 indicates a significant neurological injury (deep coma or death), a score between 9 and 12 indicates a medium neurological injury, and a score between 13 and 15 indicates a mild neurological injury [11, 12].

The GOSE is a widely used scale to measure the outcome of patients with traumatic brain injury. The eight-point scale indicates the degree of recovery. A score of one indicates that the patient is dead, a score of five indicates lower-moderate disability, and a score of eight indicates upper-good recovery [13].

The mRS is a scale used as a clinical outcome measure for patients with stroke or other neurological disabilities. It assesses the overall independence or degree of disability of patients regarding performing daily activities. The final score of the scale is between zero and six, with zero indicating no symptoms, six indicating death, and an intermediate score, such as three, indicating moderate disability [14, 15].

The CHA_2DS_2-VASc score is a clinical prediction method to estimate the risk of stroke in patients with atrial fibrillation. Different from the $CHADS_2$ score, the CHA_2DS_2-VASc score includes additional stroke modifier risk factors; thus, it better stratifies low-risk patients. The final score is between zero and nine, with zero representing no risk and nine representing a 15.2% stroke risk [16].

The NIHHS is a diagnostic method used to quantify the severity of a patient's stroke. Its minimum score is zero, indicating no symptoms, and the maximum score is 42. Scores between 21 and 42 indicate a severe stroke [17].

The NYHA classification is a method used to categorize patients with heart failure based on the extent of symptoms/limitations during physical activity, and it takes into account varying degrees of shortness of breath or angina pain. The NYHA classification has four classes, where Class I represents no symptoms and Class IV represents severe limitations [18].

2.5 Bias

A list of patients who underwent LVAD placement during the study period in the department of cardiovascular surgery was matched with the names retrieved by the IT technician using the hospital's registry to assure bias in patient selection. Data recorded from the patient files were double-checked by two researchers, and the NIHHS score was confirmed by a neurologist.

2.6 Statistical analysis

Statistical analysis was performed using SPSS version 25 (IBM Inc., New York, USA). Descriptive statistics were applied to present demographic data. The suitability of variables to a normal distribution was assessed visually (histogram) and with analytical methods (Shapiro-Wilk tests). For the variables that did not conform to a normal distribution, descriptive analysis was performed using the median and interquartile range (using frequency tables for ordinal variables), and the normally distributed variables are presented as means and standard deviations. To compare independent groups, Chi-square and Mann-Whitney U tests were used for non-normally distributed, ordinal, and nominal data, while Student's t-test was used to compare normally distributed variables. Lastly, for the stroke cases, the association of the dependent variables with the patient outcome (death, discharge) was investigated by logistic

TABLE 2. Distribution of the variables according to complication type.

	Complication Type							
	ICH		IS		Both			
	n	%	n	%	n	%	χ^2	*P*
Sex								
Male	11	18.0	27	44.3	23	37.7	3.956	0.102*
Female	4	40.0	5	50.0	1	10.0		
Diabetes mellitus	5	23.8	9	42.9	7	33.3	0.136	0.934
Coronary ischemia	14	21.5	31	47.7	20	30.8	3.024	0.212*
Atrial fibrillation	1	11.1	6	66.7	2	22.2	1.614	0.464*
Chronic renal failure	3	60.0	2	40.0	0	0.0	4.798	0.080*
ICD	4	10.3	20	51.3	15	38.5	6.136	**0.047**
Hypertension	4	16.7	12	50.0	8	33.3	0.539	0.764
CVD history	6	31.6	8	42.1	5	26.3	1.822	0.402
Smoking	7	16.7	20	47.6	15	35.7	1.228	0.541
CABG	4	36.4	4	36.4	3	27.3	1.800	0.443*
Valve surgery	0	0.0	4	80.0	1	20.0	2.115	0.281*
Aortic surgery	0	0.0	1	100.0	0	0.0	1.383	1.000*
LVAD indications								
Ischemic dilated CMP	12	21.8	24	43.6	19	34.5	0.827	0.986*
Idiopathic dilated CMP	2	18.2	6	54.5	3	27.3		
Restrictive CMP	0	0.0	0	0.0	0	0.0		
Others	1	20.0	2	40.0	2	40.0		
Preop_NYHA								
2	7	21.9	12	37.5	13	40.6	5.673	0.212*
3	3	33.3	2	22.2	4	44.4		
4	5	16.7	18	60.0	7	23.3		
Mortality	3	13.0	8	34.8	12	52.2	5.248	0.073

*ICD: Internal cardiac defibrillator, CVD: Cerebrovascular disease, GI: Gastrointestinal, UTI: Urinary tract infection, CABG: Coronary artery bypass graft, LVAD: Left ventricular assist device, CMP: Cardiomyopathy, NYHA: New York Heart Association, χ^2: Pearson Chi-square, *: Fisher's exact test.*

regression analysis. Throughout the analyses, results where the *P*-value was below 0.05 were considered statistically significant.

3. Results

A total of 295 patients were included in this study. Of the patients, 245 (83.0%) were male, and 71 (24.0%) had neurological complications. The most common postoperative complications were pump thrombosis (26.8%, n = 79), blood culture positivity (19.3%, n = 57), and surgical bleeding (5.8%, n = 17). The most frequent LVAD indication was ischemic dilated cardiomyopathy (CMP) (71.5%, n = 211), followed by idiopathic dilated CMP (23.4%, n = 69), and others (5.1%, n = 15).

The patient characteristics are presented in Table 1. The patients' ages varied between 7 and 74 years, with a mean of 49.6 ± 16.7 and 51.3 ± 14.8 years for patients with and without neurological complications, respectively (t = 0.817, *P* = 0.415).

According to the patient records, neurological complications were seen in 65 (31.3%) of the patients with coronary ischemia and in 6 (6.9%) of those without coronary ischemia (Chi-square = 19.908, $P < 0.001$). Among the patients with an implantable cardioverter defibrillator (ICD), 39 (30.5%) had neurological complications (51.3% of which were IS), whereas 32 (19.2%) of those without an ICD had neurological complications (Chi-square = 5.069, *P* = 0.024). In addition, 19 (61.3%) of the patients with a history of stroke and 52 (19.7%) of those without a history of stroke had neurological complications (Chi-square = 26.262, $P < 0.001$). Smoking was another patient history factor related to neurological complications, as 42 (30.2%) of the smokers had neurological complications (Chi-square = 5.437, *P* = 0.020) (Table 1).

The most widely used (75.3%, n = 222) device was the HeartWare (HW) device (Medtronic, Meerbusch, Germany). The complication rate among those with the HW device was

TABLE 3. Comparison of the studied variables between the outcome groups.

	Outcome					
	Discharged		Exitus			
	n	%	n	%	χ^2/Z	*P*
Sex						
Male	40	65.6	21	34.4	0.816	0.482*
Female	8	80.0	2	20.0		
Diabetes mellitus	15	71.4	6	28.6	0.199	0.656
Coronary ischemia	42	64.6	23	35.4	3.140	0.167*
Atrial fibrillation	7	77.8	2	22.2	0.487	0.708*
Chronic renal failure	2	40.0	3	60.0	1.872	0.320*
ICD	25	64.1	14	35.9	0.485	0.486
Hypertension	13	54.2	11	45.8	2.990	0.084
CVD history	12	63.2	7	36.8	0.284	0.628
Smoking	29	69.0	13	31.0	0.098	0.755
CABG	7	63.6	4	36.4	0.094	0.739
Valve surgery	1	20.0	4	80.0	5.566	**0.035***
Aortic surgery	0	0.0	1	100.0	2.117	0.324*
LVAD indications						
Ischemic dilated CMP	38	69.1	17	30.9	1.926	0.426*
Idiopathic dilated CMP	8	72.7	3	27.3		
Restrictive CMP	0	0.0	0	0.0		
Others	2	40.0	3	60.0		
Preop_NYHA						
2	21	65.6	11	34.4	0.139	0.933
3	6	66.7	3	33.3		
4	21	70.0	9	30.0		
Complication type						
ICH	12	80.0	3	20.0	5.248	0.073
IS	24	75.0	8	25.0		
ICH + IS	12	50.0	12	50.0		
Pump thrombosis	30	76.9	9	23.1	3.430	0.064
Surgical bleeding	3	50.0	3	50.0	0.928	0.381*
GI bleeding	2	50.0	2	50.0	0.600	0.591*
Re-operation	1	50.0	1	50.0	0.291	0.546*
Pump infection	0	0.0	1	100.0	2.117	0.324*
Positive blood culture	4	28.6	10	71.4	12.132	**0.001***
UTI	0	0.0	2	100.0	4.295	0.102*
Age (median, min-max)	52.50	7-10	59.00	10-74	1.862	0.063#
GCS (median, min-max)	15.00	5-15	8.00	3-15	5.911	< **0.001**#
CHA_2DS_2-VAS_c score	3.00	1-8	2.00	1-7	0.403	0.687#

Numeric variables are presented as the median (min-max), #: Mann-Whitney U test. ICD: Internal cardiac defibrillator, GI: Gastrointestinal, UTI: Urinary tract infection, CABG: Coronary artery bypass graft, LVAD: Left ventricular assist device, CMP: Cardiomyopathy, NYHA: New York Heart Association, χ^2: Pearson Chi-square, Z: Mann-Whitney U test.

significantly different from those with other devices ($P < 0.001$). Moreover, significant differences in atrial fibrillation, pump thrombosis, and gastrointestinal bleeding were observed between patients with and without postoperative complications

TABLE 4. Comparison of the numerical variables between the neurological complication groups.

	ICH			IS			ICH + IS				
	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	K-W χ^2	*P*
GCS	15	5	15	15	3	15	14	3	15	4.647	0.098
GOSE	7	0	8	7	0	8	3	0	8	9.587	**0.008**
mRS	1	0	6	1	0	6	4	0	6	7.058	**0.029**
CHA_2DS_2-VAS_c score	3	1	7	3	1	8	3	1	6	0.903	0.637

ICH: Intracranial hemorrhage, IS: Ischemic stroke, GCS: Glasgow coma scale, GOSE: Glasgow outcome score extended, mRS: modified Rankin score.

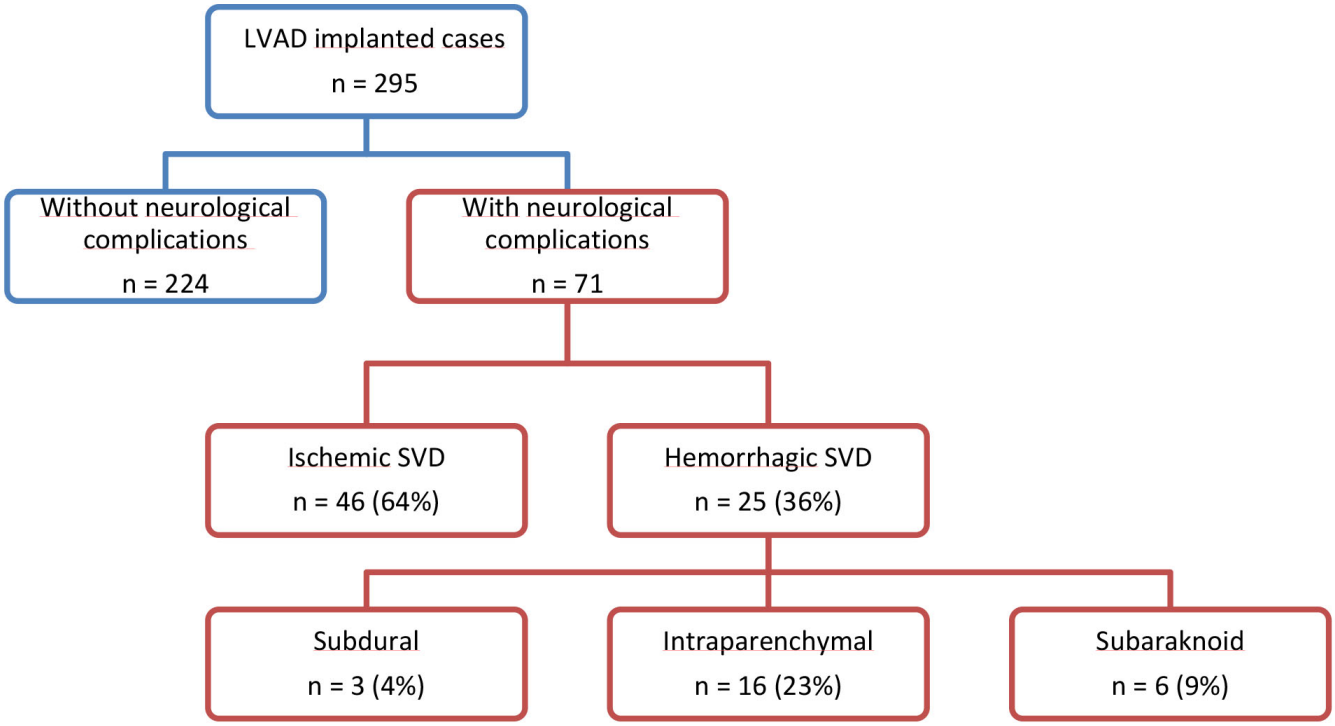

FIGURE 1. Patient flow diagram.

TABLE 5. Predictive features of the logistic regression model.

	Predicted		
Outcome	**Alive**	**Dead**	**% correct**
Alive	45	3	93.8
Dead	6	17	73.9
			87.3

(Table 1).

Among the patients with neurological complications, 32 (45.1%) had only IS, 15 (21.1%) had only ICH, and 24 (33.8%) had both IS and ICH. Except for the presence of an ICD, there were no significant associations between the studied variables and the type of neurological complication ($P > 0.05$) (Table 2). However, compared to the rate for discharged patients (25.0%, n = 12), patients who died in the hospital were more than twice as likely (52.2% n = 12) to have both ICH and CVD, although this difference was not significant (Table 2).

Moreover, an analysis was carried out to determine the relationship between the characteristics of patients with stroke and mortality rates. Mortality rates were significantly higher among patients with a history of valvular surgery and positive blood cultures Table 3. Additionally, the median GCS values were lower in patients with a positive blood culture (median 14, range: 3-15) than those in patients with a negative culture (median 15, range: 3-15) result (Mann-Whitney U Z = 3.209, $P = 0.001$).

Based on the median GCS values given in Table 4, all three groups had a mild neurologic injury. However, based on the GOSE and mRS, the condition of the combined ICH + CVD group was worse than those of the ICH and CVD alone groups.

The logistic regression model had a Nagelkerke R^2 of 70.2% and relatively high sensitivity and specificity values (Table 5).

The logistic regression analysis revealed that age and GCS were the only significant variables that independently affected the mortality status after adjusting for possible confounders. While a younger age was a protective factor against mortality, a one-unit decrease in the GCS was associated with a 4.1-fold

TABLE 6. Logistic regression computer output.

					95% CI for EXP (B)	
	B	Wald	*P*	Exp(B)	Lower	Upper
Age	0.174	5.325	**0.021**	1.190	1.027	1.380
Sex (female vs. male)	-0.819	0.253	0.615	0.441	0.018	10.735
GCS	-1.419	5.843	**0.016**	0.242	0.077	0.764
Positive blood culture (yes vs. no)	0.380	0.119	0.730	1.462	0.169	12.643
Postoperative pump thrombosis (yes vs. no)	-1.301	1.998	0.157	0.272	0.045	1.654
Smoking (yes vs. no)	-0.524	0.283	0.594	0.592	0.086	4.073
CHA_2DS_2-VAS_c score	-0.740	3.337	0.068	0.477	0.216	1.055
Atrial fibrillation (yes vs. no)	0.268	0.038	0.846	1.307	0.087	19.585
Type of neurological complication		0.765	0.682			
CVD vs. ICH	0.874	0.459	0.498	2.397	0.191	30.079
ICH + CVD vs. ICH	1.060	0.748	0.387	2.887	0.261	31.910
Constant	11.309	4.685	0.030	81592.85		

**Dependent variable: Mortality status (no/yes). ICH: Intracranial hemorrhage, IS: Ischemic stroke, GCS: Glasgow coma scale.*

increase in mortality (Table 6).

4. Discussion

4.1 Key findings

Our findings revealed that male patients were more likely to require LVAD implantation, as more than 80% of all patients were male. The majority of the LVAD-implanted patients were classified as NYHA Class II, having mild physical activity restrictions (e.g., shortness of breath when walking) [19]. Of the patients with coronary ischemia, 31.3% had neurological complications, which was a significantly higher rate than for those without coronary ischemia. Moreover, an ICD, a small battery-powered device to monitor heart rhythm and detect and regulate irregular heartbeats [20], was used in 54.9% of the patients with stroke. Hence, patients using an ICD had a higher risk of having a stroke. Moreover, patients with a history of stroke or smoking were more prone to have neurological complications. Pump thrombosis was the most frequently observed postoperative complication among patients with stroke.

On the other hand, in patients without stroke, the most dominant complication was positive blood culture, followed closely by pump thrombosis. Furthermore, atrial fibrillation and gastrointestinal bleeding were only observed in patients with neurological complications. Finally, logistic regression analysis revealed that age and GCS were the only significant variables that independently affected mortality status, with a relatively high predictive accuracy.

4.2 Interpretation

Over the past several years, critical improvements in medical services have resulted in accelerating the diagnosis and improving the management of patients with an LVAD who have neurological symptoms. Besides medical therapy, neurosurgical interventions, such as thrombectomy, are becoming more available in established medical centers [6]. Despite these advancements, there remains a need to identify the risk factors associated with neurological complications and provide accurate, individualized treatment strategies to mitigate adverse outcomes [6, 21]. This study was carried out to further clarify these risk factors by analyzing stroke cases among patients implanted with an LVAD in a single research center.

The majority of patients with stroke were male (83.0%), and the most frequently observed stroke type was an IS. Among the patients with an ICD, 30.5% had neurological complications after LVAD placement, 51.3% of which were IS. On the other hand, an ICD is often used concomitant to LVAD placement, and some studies have shown that these patients had a reduced risk of mortality [7, 22]. However, based on our data, it was not possible to draw any conclusions about the effect of concomitant ICD use on mortality. We found that age and GCS were the only significant predictors of mortality.

A number of previous studies have associated diabetes mellitus, smoking, hypertension, and myocardial infarction, with an increased stroke risk [7, 23–25]. In general, our results were in agreement with the findings in the literature. Diabetes mellitus was observed in 29.6% of our patients with stroke, and other studies have reported a rate between 30% and 40% [3, 15]. Smoking history was observed in around 60% of our patients with stroke, which agreed with the rate reported by Harvey *et al.* [3], yet in other studies, it was reported to be between 30% and 40% [21, 22]. Hypertension was observed in one-third of our patients, whereas this rate was reported to be around 40% [21] in one study and above 50% in others [4, 7]. Lastly, among our patients with stroke, 36.6% had an MI, whereas rates between 28.2% and 46% have been reported in the literature [3, 7].

Almost all our patients (66 of 71) used an HW-type LVAD device, mainly for logistical and availability reasons. Hence, a comparison based on different instruments was not possible. A follow-up of the LVAD-implanted cases revealed that pump thrombosis was the most widely observed postoperative complication. It was seen in more than half of the cases with an

LVAD. In contrast, a similar study found this complication in 17%-36% of patients with stroke [7].

Pump thrombosis is a significant complication in patients implanted with a HeartWare LVAD, and its major risk factors are elevated blood pressure, sub-optimal anticoagulation, and anti-platelet therapies. Therefore, patient management guidelines need to be carefully revised with the aim of reducing pump thrombosis events [26]. A positive blood culture was the second most common complication observed in our study. Sepsis is a common complication of LVAD implantation, and it has been reported to increase the risk of mortality [3, 27]. However, based on our findings, after adjusting for the other study variables, a positive blood culture was not an independent risk factor for mortality. We think the significant relationships between blood culture positivity, GCS, and mortality are related to this finding. Therefore, we still recommend the urgent evaluation and management of patients with neurologic complications who have evidence of infection, especially sepsis.

The median GOSE in the ICH and IS groups was the same as the overall median, indicating an upper-moderate recovery [28]. When both IS and ICH were observed, the median GOSE was three, indicating a lower-severe disability. Moreover, the median mRS in cases with an IS or ICH event was one, indicating no significant disability [19], whereas the median mRS was four in cases with both IS and ICH, indicating moderate-severe disability. CHA_2DS_2-VAS_c was used to assess the annual stroke risk of the patients. The median for all groups was three, representing a yearly stroke risk of 3.2% [29]. Lastly, in our study the median NIHHS score in SVD was detected two and indicating a minor stroke severity.

In this study, the clinical outcomes of patients with neurological complications were evaluated using two different scales, the GOSE and mRS. The scores obtained with both scales indicated similar results. Especially for patients who had both IS and ICH, these scales revealed a similar degree of disability. The GOSE and mRS scores of our cases indicate that these patients required full assistance in their bodily needs, including walking. Therefore, if both IS and ICH are observed in patients with stroke, they are more likely to be dependent on others for care.

4.3 Limitations

The results of this study should be interpreted in light of some limitations. The primary limitation of our study is that it was retrospective and conducted in a single-center emergency service. Moreover, most of the patients with stroke used the same type of device (HW). Thus, while this resulted in a relatively homogenous patient group, it prevented a comparison of complications between different types of devices. In addition, although most of the studies in this field were carried out in surgery, neurology, and cardiology departments, this study was conducted in an emergency department; thus, it was aimed to assist in developing treatment approaches from this particular perspective.

4.4 Conclusions

Although medical services have experienced improvements regarding diagnosis, management, and equipment availability, it is still necessary to broaden the knowledge of the risk factors for neurological complications and their correlations to minimize adverse outcomes. Analyzing the available data will help to not only define the predictive factors but also develop individualized treatment methods and guide clinicians. Coronary ischemia, ICD, CVD, and smoking were among the factors found to significantly affect the occurrence of complications. Additionally, as indicated by the mRS, patients with both IS and ICH were more likely to require assistance with tasks of daily living and walking. We conclude that interventional procedures, such as mechanical thrombectomy, should be performed as early as possible without delay, especially in elderly patients with a low GCS.

DATA AVAILABILITY

Study data are available from the corresponding author upon request.

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CONFLICT OF INTEREST

The authors have no conflict of interest in this article.

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