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PREOPERATIVE EXTRACORPOREAL MECHANICAL CIRCULATORY SUPPORT FOR PATIENTS WITH ACUTE SEVERE MITRAL VALVE REGURGITATION DUE TO PAPILLARY MUSCLE NECROSIS

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Background. Acute mitral valve insufficiency has a high mortality rate (up to 100%). Mechanical circulatory support and emergency surgery can improve the survival of this patient cohort. **Objectives:** to analyze a 12-year single-center experience of treating acute post-infarction mitral valve insufficiency. **Materials and methods.** This retrospective study included 12 adult patients with ST elevated myocardial infarction (STEMI) and corresponding acute mitral valve insufficiency who underwent surgery between 2009 and 2017. We analyzed the in-hospital period of all patients and long-term follow-ups whenever possible. All patients underwent preoperative coronary angiography and echocardiography. All patients underwent cardiopulmonary bypass and cold-blood cardioplegia. If venoarterial extracorporeal membrane oxygenation (VA-ECMO) was required, the femoral approach was preferred. **Results.** Seven patients needed VA-ECMO support, six of them preoperatively; four received mechanical circulatory support outside the hospital. All patients underwent percutaneous coronary intervention (PCI) with successful revascularization of the culprit artery. All but one patient underwent surgery within the first 24 hours. One patient underwent repeat surgery once the mitral valve could be repaired, and the other patient did not require any coronary bypass. In-hospital mortality occurred in one patient in the VA-ECMO group. Patients receiving VA-ECMO had longer duration of inotropic support, ventilation time, and intensive care unit stay ($p < 0.01$). **Conclusions.** Acute mitral valve insufficiency due to STEMI remains a dramatic complication, but the perioperative use of VA-ECMO helps reduce 30-day mortality and improve outcomes in this group of patients.

Keywords: acute mitral regurgitation, ECMO, STEMI.

ПРЕДОПЕРАЦИОННАЯ МЕХАНИЧЕСКАЯ ПОДДЕРЖКА КРОВООБРАЩЕНИЯ У ПАЦИЕНТОВ С ОСТРОЙ МИТРАЛЬНОЙ РЕГУРГИТАЦИЕЙ ПОСЛЕ НЕКРОЗА ПАПИЛЛЯРНЫХ МЫШЦ

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Цель: проанализировать 12-летний опыт лечения острой постинфарктной недостаточности митрального клапана в одном центре. **Материалы и методы.** В ретроспективное исследование включены 12 взрослых пациентов с инфарктом миокарда с подъемом сегмента ST (STEMI) и соответствующей острой митральной регургитацией, которые были прооперированы с 2009-го по 2017 год. Мы проанализировали внутрибольничный период всех пациентов и отдаленный период. Все пациенты прошли предоперационную коронарную ангиографию и эхокардиографию. Все пациенты были оперированы в условиях искусственного кровообращения и холодовой кровяной кардиоплегии. При необходимости проведения веноартериальной экстракорпоральной мембранной оксигенации (ВА-ЭКМО) предпочтение отдавалось бедренному доступу. **Результаты.** Семь пациентов нуждались в ВА-ЭКМО-поддержке, шесть из них – до операции; четверо из них получали механическую циркуляторную поддержку вне нашего стационара и были транспортированы на ЭКМО. Всем пациентам было выполнено чрескожное коронарное вмешательство (ЧКВ) с успешной реваскуляризацией инфаркт-связанной артерии. Все пациенты, кроме одного, были прооперированы в

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течение первых 24 часов от отрыва папиллярной мышцы. В раннем послеоперационном периоде погиб один пациент. Пациенты, получавшие ВА-ЭКМО, имели большую продолжительность инотропной поддержки, времени вентиляции и пребывания в отделении интенсивной терапии ($p < 0,01$). **Выводы.** Острая недостаточность митрального клапана вследствие STEMI остается тяжелым осложнением, но периоперационное использование ВА-ЭКМО позволяет существенно снизить 30-дневную смертность и улучшить результаты лечения этой группы пациентов.

Ключевые слова: острая митральная регургитация, ЭКМО, инфаркт миокарда.

INTRODUCTION

Acute progression of coronary artery disease typically presents with ST-elevation myocardial infarction (STEMI), and depending on the localization of ischemia, may lead to papillary muscle necrosis with subsequent rupture, which is often accompanied by leaflet prolapse and mitral valve regurgitation (MR) [1, 2]. Chronic ischemic mitral valve disease is the second largest cause of MR, accounting for 20% of all cases, preceded only by degenerative mitral disease (60–70%) [3, 4]. However, acute ischemic MR is relatively rare, and patients often present with cardiogenic shock and have high mortality [5]. For instance, Kettner et al. reported that the preoperative mortality in these patients was as high as 88%, with a 30-day mortality of 100% if no mechanical circulatory support was established [6]. Primary diagnosis of the acute state involves echocardiographic evaluation of the mitral valve, left atrium, and left ventricle. Furthermore, hemodynamic stabilization of the patient is the primary goal to prevent pulmonary congestion and development of pulmonary edema [7, 8]. To avoid further clinical deterioration, early implementation of venoarterial extracorporeal membrane oxygenation (VA-ECMO) in patients with acute myocardial infarction complicated by cardiogenic shock has been proven beneficial [9]. After hemodynamic stabilization, surgical treatment of the mitral valve has shown similar results in patients who undergo mitral valve repair and replacement [10]. Furthermore, simultaneous mitral valve repair and myocardial revascularization are not associated with better outcomes than revascularization alone after two years of follow-up [11]. As stated previously, VA-ECMO is the preferred therapy for patients with cardiogenic shock. However, literature on preoperative management of patients with severe acute ischemic MR is relatively scarce [12, 13]. In this study, we present and evaluate our experience with patients presenting with severe acute MR due to myocardial ischemia.

MATERIALS AND METHODS

This retrospective study was performed at the cardiac surgery department of our institute (Hannover Medical School, Hannover, Germany). The ethics committee of our institute waived the need for patient consent for this study.

Patient population

All patients who presented to our center between July 2009 and February 2017 with acute severe MR due to myocardial ischemia and those aged >18 years at the time of presentation were included in this study ($n = 12$). All data were retrieved through a retrospective review of patient records. Hospital databases, patient charts, surgical reports, and imaging data were reviewed. Patient follow-up was performed by telephoning the patient and referring them to the cardiologist and/or general practitioner. Postoperative diagnostic examination results were obtained via mail or fax.

Diagnosis and assessment of MR severity

STEMI was confirmed using electrocardiography (ECG). Ongoing myocardial ischemia was confirmed by clinical chemistry. Elevated values of troponin T and MB fraction of creatinine kinase were considered upon diagnosis. Coronary angiography was performed at our center or the hospital of primary presentation. Transesophageal echocardiography was performed prior to surgery to determine the grade of mitral valve regurgitation, cardiac orifice dimensions, and left ventricular ejection fraction (LVEF). The LVEF was determined using the modified Simpson's method, and MR was graded from 1+ to 3+ (mild, moderate, or severe) according to the American Society of Echocardiography guidelines [14]. The patient characteristics are presented in Table 1.

ECMO implantation

In all patients, the development of cardiogenic shock was rapid; therefore, end-organ perfusion assessment was not performed because of emerging circulatory failure. The decision to use VA-ECMO was mainly based on the patient's clinical evaluation results. The signs of cardiogenic shock according to SHOCK and IABP-SHOCK II trials, high doses of inotropes and vasopressors (epinephrine >0.3 mcg/kg/min in a combination with norepinephrine >1 mcg/kg/min) and rapid worsening of the hemodynamics despite pharmacological support were the indications for ECMO implantation.

All patients with preoperatively implanted ECMO at the end of surgery were switched back from cardiopulmonary bypass to VA-ECMO, per protocol. In other patients who had no mechanical circulatory support preoperatively, the decision to use VA-ECMO was made

according to the hemodynamic situation at the end of the cardiopulmonary bypass, similar to the preoperative situation.

Cannulation was performed by a cardiac surgeon at the bedside in our department. After percutaneous placement of the guidewires in the common femoral artery (for both body and distal limb perfusion) and femoral vein, a single bolus of 5000 IU of unfractionated heparin was administered intravenously. The outflow cannula was implanted using Seldinger's technique into the femoral vein using a 55 cm long BIOLINE-coated HLS cannula (Maquet, Rastatt, Germany) with a size of 21, 23, or 25 F. Correct positioning of the outflow cannula just below the entrance of the inferior vena cava in the right atrium was proven using ultrasound. For the inflow cannula, a 15 cm long BIOLINE-coated HLS cannula (Maquet, Rastatt, Germany) with a size of 13, 15, or 17 F according to the patient size, was placed in the common femoral artery. A 7 F introducer sheath (Medicovation GmbH, Gladbeck, Germany) was used for distal limb perfusion. After successful cannulation, the cannulas were connected to our mobile ECMO system, CardioHelp pump with HLS Set Advanced 7.0 (Maquet, Rastatt, Germany) for those patients who required transportation from an external hospital, and to the PLS System with PLS Set Plus (Maquet, Rastatt, Germany) for others.

Surgical techniques

All patients were operated under combined general anesthesia via a median sternotomy using cardiopulmonary bypass and cold blood cardioplegia. In patients with preoperative ECMO implantation, a femoral venous cannula was also used for cardiopulmonary bypass with additional cannulation of the superior vena cava; in others, a standard bicaval cannulation was applied.

In all but one patient, only venous grafts were used for myocardial revascularization because of an emergency. Distal anastomoses were performed before valve repair or implantation. Mitral valve access was achieved via the Soondergaard interatrial groove in all cases. Traditionally, mitral valve replacement has been performed with preservation of the posterior leaflet using 12–15 pledgeted sutures. We used biological or mechanical valves according to the actual guidelines [15].

Statistical analysis

Summary statistics were presented as medians and ranges. Categorical variables were presented as counts and percentages. Group comparisons were performed using Student's t-test for continuous variables. For categorical analysis, the Wilcoxon–Mann–Whitney test for small sample sizes was used. Statistical significance was set at $p < 0.05$ all tests. SPSS version 26 (SPSS Inc., Chicago, IL, USA) was used to analyze the data.

RESULTS

The mean follow-up period for the entire patient cohort was 1166 (998–2037) days. Table 3 shows all patients individually, including postoperative and follow-up details.

Most patients had inferior or posterior infarction (75%) and all developed symptoms of MR within one week after STEMI. Six of seven patients from the VA-ECMO group received circulatory support preoperatively; at the time of evaluation by the cardiac surgeon, two had Shock Stage E, and four had Shock Stage D. The other patients who did not receive ECMO preoperatively had Shock Stage C (SCAI shock staging) [16]. Four patients were assessed in a regional hospital by our team, received mechanical support there, and were transported using running VA-ECMO to our institute. All but one patient underwent surgery within the first 24 hours after admission (93%) as a clear improvement of end-organ perfusion (i.e., increase in urine output and decrease in serum lactate) and a drop in pharmacological support. In one patient on VA-ECMO, redo surgery was performed 12 years after the previous myocardial revascularization. Intraoperative data are presented in Table 2.

As shown in the table, patients on VA-ECMO tended to have lower bypass and cross-clamp times, although this was not statistically significant. In one patient, the mitral valve could be reconstructed, and all other patients received either biological (five patients) or mechanical (six patients) valves. Two patients did not require

Table 1

Preoperative data of patients with acute mitral valve regurgitation due to STEMI

	Without ECMO	With ECMO	p
Age, yrs	60 (45.9–60.1)	60.1 (53–65.7)	0.17
EuroSCORE II, %	22.79 (21.79–30.11)	30.63 (25.19–33.12)	**0.04**
PCI preoperatively	100%	100%	–
EF, %	60 (50–60)	55 (40–60)	0.4
CK-MB, U/l	21 (13–32)	63 (41–586)	**0.03**
AST, U/l	30 (22–31)	1850 (112–8071)	**0.03**
LDH, U/l	392 (289–496)	2580 (717–9309)	**0.05**
CRP, mg/l	27.5 (8–123)	103 (67–369)	0.11

Table 2

Intraoperative data of operated patients

	Without ECMO	With ECMO	p
Mitral surgery	3 biological, 1 mechanical, 1 reconstruction	4 biological 3 mechanical	
CPB, min (median)	125 (113–143.5)	132 (117–146)	0.46
X-Clamp, min (median)	81 (65.75–70.5)	67.5 (62–70.5)	0.3
Grafts, (mean)	1 (0–2)	1.875 (0–3)	
Re-Operation	–	1 (14%)	
ECMO preoperatively	–	6 (86%)	
IABP	1 (14%)	–	

coronary artery grafting because of previous complete endovascular revascularization.

However, the in-hospital mortality rate is low. Only one patient (8.3%) died on postoperative day 13 due to several severe ischemic complications: on VA-ECMO, she developed limb ischemia and had to be operated on to relieve the compartment syndrome; however, after VA-ECMO removal on day 5, she developed mesenteric ischemia, which caused her death.

The mean duration of mechanical circulatory support was 5 (3–9) days. Inotropic support was needed for 2.5 (1–4) and 8 (4–13) days after surgery in the non-ECMO and VA-ECMO groups, respectively ($p < 0.01$). Similarly, patients in the ECMO group required a longer mechanical ventilation time: 5 (1–8) versus 8 (4–13) days.

Table 3

Follow-up summary

Pt	Age	Sex	MI site	Surgery	ECMO	Postoperative course	Follow up
1	60	M	Lateral	Mechanical MVR, CABG to 1, Closure of LAA	No	Extubated on POD 2, inotropic support till POD 4. Discharged on POD 8	Died late in follow up
2	45	M	Posterior	Mechanical MVR, CABG to LAD, OM-1 and RPD	Yes, 1 day before and 5 days after surgery	Extubated on POD 4, inotropic support till POD 6. Postoperative implantation of ICD. Discharged on POD 27	Lost
3	64	M	Posterior	Mechanical MVR, CABG to OM-1 and RCA, Closure of LAA.	No	IABP till POD 3. Extubated on POD 3, inotropic support till POD 4. Discharged on POD 21	Alive, uneventful
4	69	M	Lateral	Redo after CABG 12 years ago, Biological MVR	Yes, 2 days before and 4 days after surgery	Inotropic support till POD 7, new dialysis postoperatively. Transferred on dialysis and intubated for weaning on POD 8	Alive, right limb amputation due to atherosclerosis 3 months after surgery
5	48	M	Posterior	Biological MVR, CABG to PLA and RPLD	Yes, 1 day before and 4 days after surgery	Tracheostomy on POD 4. Inotropic support till POD 13. Dialysis till POD 20. Transferred intubated for weaning on POD 28	Lost
6	44	M	Posterior	Mechanical MVR, closure of LAA and PFO	No	Tracheostomy on POD 7, inotropic support till POD 3. Transferred for weaning on POD 15	Lost
7	52	M	Posterior	Biological MVR, CABG to LAD, OM, RPD	Yes, 1 day before and 5 days after surgery	Tracheostomy on POD 9. Limb ischemia with surgery. Transferred for weaning with mild inotropic support on POD 11	Alive, uneventful
8	66	F	Posterior	Biological MVR, CABG to 2	Yes, 5 days after surgery	Tracheostomy on POD 7. Transferred for weaning with mild inotropic support on POD 8	Lost
9	65	F	Posterior	Mechanical MVR, CABG to 1	Yes, 1 day before and 9 days after surgery	Limb and mesenterial ischemia, new dialysis postoperatively. Tracheal injury during emergency intubation	Died on POD 13 due to multiple ischemic events
10	60	M	Lateral	Biological MVR, CABG to 3	Yes, 1 day before and 3 days after surgery	Tracheostomy on POD 6. Multiple small ischemic lesions in the brain. Transferred for weaning on POD 8	Lost
11	62	F	Posterior	MV-Repair, CABG to 1	No	Extubated on POD 1. Inotropic support till POD 1. Discharged on POD 8	Alive, has developed lung cancer
12	53	M	Posterior	Mechanical MVR, CABG to 1	Yes, 1 day before and 5 days after surgery	Extubated on POD 4, inotropic support till POD 6	Lost

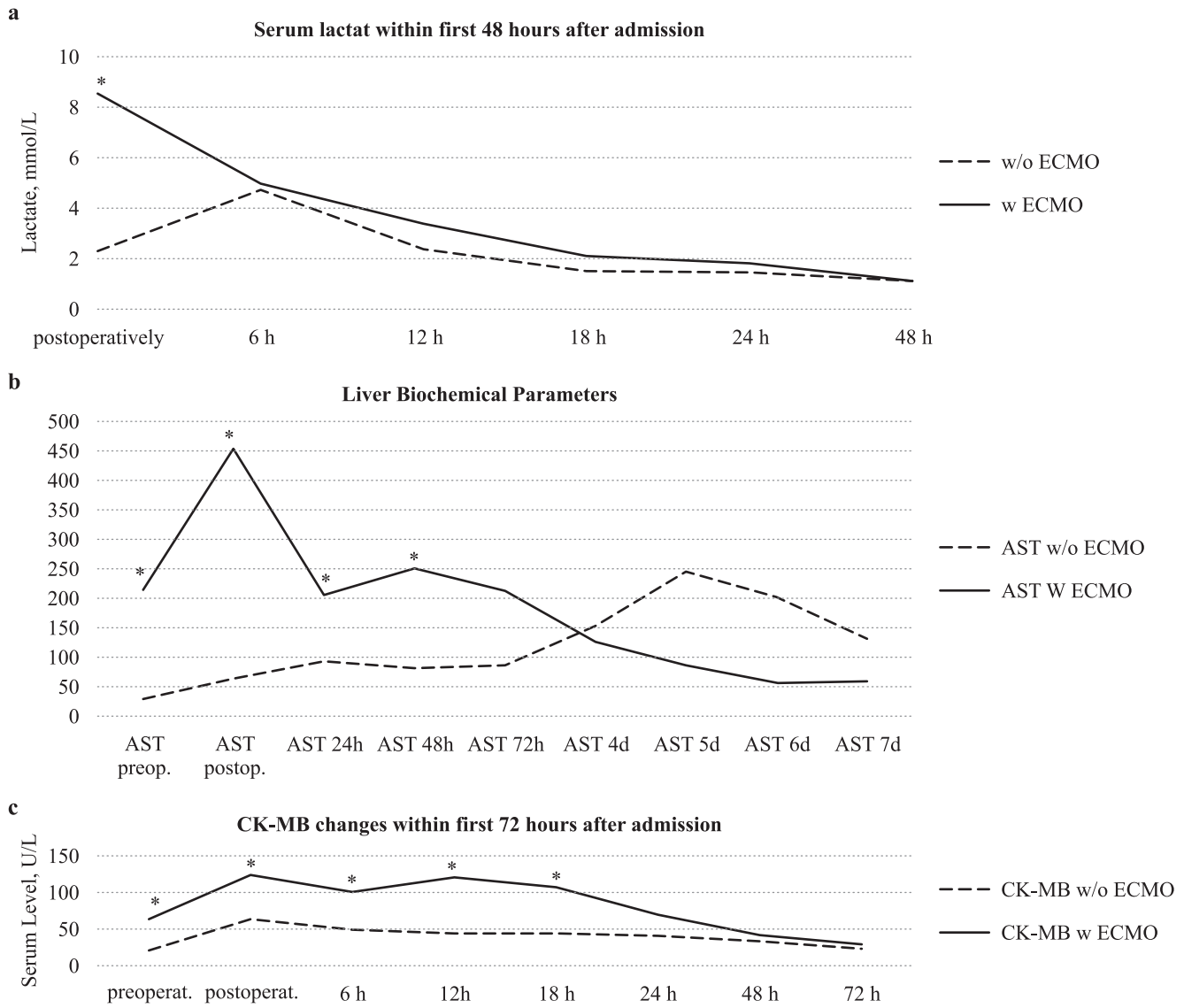

Fig. Changes in selected biochemical markers after the surgery: a – serum lactate; b – liver markers; c – CK-MB. The levels of serum lactate and liver markers suggest that patient with ECMO had more severe circulatory disturbance preoperatively, while higher CK-MB levels in the ECMO group could be explained by greater infarction area. * – $p < 0.05$

New dialysis was required in four patients, all in the VA-ECMO group. One patient developed brain damage in the form of multiple small lesions. Eight patients (6 from the ECMO group) were transferred for weaning to other centers, either intubated or after dilative tracheostomy. Figure shows the differences in the biochemical markers between patients with and without mechanical support. Patients on VA-ECMO preoperatively had significantly higher levels of cardiospecific enzymes and markers of hepatic congestion, showing more severe disturbances in central hemodynamics and clarifying the implications of VA-ECMO. However, these patients do not show a secondary lactate peak representing reperfusion of the ischemic tissue after the operation because of sufficient preoperative circulatory support.

As seen in Table 3, only three patients, two without ECMO and one with VA-ECMO, were directly discharged. Others required longer weaning from ventilation and were transferred to other centers after tracheostomy. During the late follow-up period, six patients were lost due to multiple causes (e.g., foreign patients). One patient with known severe atherosclerosis required limb amputation at the knee level shortly after the initial surgery and another died several years later (detailed information was not available). Others were reported to be alive with low NYHA grades and acceptable life quality, according to brief telephone communication.

DISCUSSION

The incidence of acute mechanical complications (MR, wall rupture) due to myocardial infarction is extremely rare and remains at 0.27% for STEMI and 0.06% for NSTEMI. Interestingly, there have been no significant changes in the incidence during the last 20 years, according to Elbadawi et al. [17]. In one of the latest published case reports, a 69-year-old woman with pa-

pillary muscle rupture after STEMI presented to the hospital with signs of cardiogenic shock; however, the only mechanical support she received was an intraaortic ballon pump [18]. Transfer to cardiac surgery or ECMO implantation were not initiated, leading to death. To demonstrate the maximal mechanical support and correct timing of surgery, we report our case series.

In our study, nine of the 12 patients had posterior myocardial infarction leading to rupture of the posteromedial papillary muscle, and all of them were percutaneously revascularized several days before developing heart failure. Six of the 12 patients required preoperative mechanical circulatory transport to survive until they could undergo cardiac surgery and one another received VA-ECMO at the time of admission to our center. The patients were divided into two clearly incomparable groups was done to emphasize the obligatory differences in perioperative management and follow-up depending on preoperative hemodynamic deterioration.

The clinical evaluation of patients showed that the EUROSCORE II suggested very high mortality rates in both groups, with a clear prevalence in patients needing mechanical support – 21.79% (19.89–26.86) versus 32.68% (21.79–52.43). The latter also showed significantly higher levels of hepatic and myocardial damage markers, which were recognized as indications for VA-ECMO implantation, along with a high need for inotropic support and clinical signs of cardiogenic shock. Mechanical circulatory support was used in all cases of SCAI Schock Stage D and higher to prevent prolonged end-organ hypoperfusion and avoid possible complications of high-dose combined inotropes and vasopressors. There is a possibility of early implications of mechanical circulatory support.

The postoperative course of lactate, myocardial, and liver markers showed that preoperative mechanical support allowed the restoration of an acceptable level of end-organ perfusion and discontinuation of the development of cardiogenic shock within several hours. In these cases, despite higher possibilities determined using EUROSCORE II (32.68%) and previously reported (up to 100%) [6, 13] mortality, 91.7% (11 of 12 patients) showed early overall survival. At the same time, the VA-ECMO implantation rate amounted to 58.3% (7 of 12 cases), which is significantly higher, than previously reported. We suggest that the early establishment of mechanical circulatory support in terms of VA-ECMO and time to hemodynamic stabilization is crucial in such patients.

CONCLUSION

Our preoperative ECMO implantation strategy could significantly improve the results in the high-risk group of patients with acute severe mitral valve regurgitation due to papillary muscle necrosis. The postoperative mortality in the ECMO group (8.3%) was significantly reduced in comparison to previous studies, based on the use of EUROSCORE II.

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The authors declare no conflict of interest.

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