Ventricular Septal Rupture

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Contributor: Karolina Żbikowska, Krzysztof Wróbel

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Keywords: ventricular septal rupture ; post-infarction ventricular septal defect ; delayed surgery ; mechanical circulatory support ; myocardial infarction ; cardiogenic shock

1. Introduction

Ventricular septal rupture is a serious mechanical complication of myocardial infarction (MI) with an unfavorable prognosis. Observational studies have shown that delayed surgical treatment (especially longer than 7 days) is associated with better outcomes than urgent surgery [1]. However, it is not clear whether better survival is associated with better preoperative status, allowing patients to survive prolonged waiting time for surgery of more than 7 days, or postponing surgery itself. Many patients in cardiogenic shock in the course of VSR are unable to survive until delayed surgical intervention. Mechanical circulatory support may enable hemodynamic stabilization of the patient in shock and postpone the procedure, although this therapy can be associated with serious complications. The optimal duration of safe circulatory support in these cases as well as the type of MCS device used remain unknown. Researchers analyze the recent studies of preoperative use of mechanical circulatory support, especially venoarterial extracorporeal membrane oxygenation, Impella, and Tandem Heart as a bridge to a delayed cardiac surgery.

2. Epidemiology

VSR is a serious, life-threatening complication typical of transmural MI, the incidence of which decreased due to early percutaneous revascularization strategies from 2% to about 0.25% of cases [2][3][4][5]. Mortality in the natural course of the disease as well as in a pharmacological treatment is similar and amounts approximately to 87–96% [6][7]. The presence of a cardiogenic shock and hemodynamical instability substantially worsen the prognosis [8].

3. Pathophysiology

VSR develops in the course of MI with an occlusion of the left anterior descending artery supplying the anterior two-thirds of the interventricular septum or the right coronary artery (less frequently the circumflex artery), providing blood to one-third of the posterior part. Acute VSD is usually related to sudden, severe ischemia in the course of total occlusion of the artery, which causes advanced, extensive necrosis [9]. It is emphasized that the time of VSD formation in the reperfusion era was reduced to 1 day from 3–5 days in the pre-thrombolytic period [9]. Inferior infarct usually causes the defect with complex structure [10]. It is formed as a result of dissection, commonly of the posterior and inferior parts of the interventricular septum, caused by the formation of a hematoma in the infarcted tissue after acute coronary syndrome [3][10]. Anterior infarcts are often a simple defect between the chambers at the same height, most often involving the apical segments [11]. However, in clinical practice, complex VSR at the medial anterior part of the interventricular septum may be diagnosed, which occurs as a result of occlusion of the left descending artery leading to extended anterior wall infarction. VSD can also appear later in the post-infarction period as a consequence of a thin muscle tissue rupture inside a septal aneurysm [12][13]. The ventricular septal defect can increase in size within several weeks due to changes in the tissues affected by the infarction [6]. The grade of an interventricular shunt depends on the dimension of the defect and the ratio of pulmonary to systemic vascular resistance as well as the post MI right and left ventricular function [3][11]. Reducing cardiac output increases systemic resistance and thus afterload, which increases ventricular overload and can lead to an enlargement of the shunt [3].

4. Surgical Treatment

Surgical intervention remains the treatment of choice, with a mortality rate ranging from 20 to 88%, depending on initial hemodynamic status [11][14][15]. There is no agreement concerning optimal time of cardiac surgery [15]. The 2013 American guidelines recommend an urgent operation [16]. Observational study has shown that delayed surgery is associated with significantly better results [7][11][17]. Arnaoutakis et al. analyzed the results of treatment of over 2800 patients and found that surgery performed within 7 days after myocardial infarction was associated with 54.1% mortality, whereas surgery performed after 7 days was associated with the mortality rate at 18.4% within the first 30 days [1]. However, delay of the operation may lead to further enlargement of the interventricular shunt or, especially in the case of hemodynamical instability, to preoperative death [15]. Mechanical circulatory support as a bridge to cardiac surgery may be an encouraging solution [17]; nevertheless, recent European guidelines emphasize that the use of mechanical circulatory devices in patients with heart failure or cardiogenic shock, due to possible complications, requires further research [18]. There are two main techniques for the surgical treatment of VSR: Daggett's method, consisting of direct reconstruction of the septum, most often with the use of Dacron patches after previous infartectomy [19], and David's procedure, associated with exclusion of tissues with complications from myocardial infarction by sewing a patch from the left ventricle [20].

5. The Role of Mechanical Circulatory Support

The type of impact on the cardiovascular system depends on the device used.

- An intra-aortic balloon pump is an easily accessible percutaneous implantable device that reduces the afterload (LV unloading only) and improves flow in coronary vessels. IABP could potentially help to unburden the left ventricle and reduce the left–right shunt, although with a poor effect, especially in unstable patients [21][22]. However, it is used in combination with other types of mechanical circulatory supports.

- LV-based Impella (LV to Ao; LV support and unloading) is a hemodynamically effective microaxial device that pumps blood from the left ventricle to the ascending aorta, generating flow over 5 L/min, which leads to significant direct unloading of the LV and increased cardiac output [23]. Reducing left–right shunt Impella decreases the right ventricle overload and pulmonary congestion, simultaneously posing a risk of shunt inversion and hypoxia of the central nervous system and myocardium; therefore, intensive monitoring is recommended [24]. The presence of VSR is considered a contraindication to implantation of this type of support due to the risk of aspiration of necrotic tissues, thus, some researchers suggest using Impella with posterior VSR to reduce the possibility of embolization [24].

- Venoarterial ECMO (RA to femoral artery (FemA)—biventricular support with RV unloading)—supports systemic circulation (biventricular support), increases the level of arterial blood oxygen saturation, and ensures proper tissue oxygenation, which is essential in the setting of large left to right shunts, especially in a non-opening aortic valve [22][25]. This MCS unloads the right ventricle; however, at the same time, ECMO raises the left ventricular end-diastolic pressure and the total blood flow, which may contribute to overload LV and enlargement of the rupture [25][26]. ECMO with LV unloading is the simultaneous use of IABP or LV-located Impella with ECMO (i.e., Ecpella) [23][27]. Ecpella unloads LV, prevents the VSD enlargement, reduces afterload, and drains the right atrium, supporting the right ventricle. An interesting option is the applicability of left atrial venoarterial membrane oxygenation (LAVA ECMO biatrial) with transeptal located cannula, which at the same time drains the left and right atria [23]. Another effective method for indirect unloading of the left ventricle is the use of the pulmonary artery draining cannula.

- Tandem Heart (LA to FemA; LV support and unloading) is a percutaneous system with a continuous-flow centrifugal pump that generates a flow of about 5 L/min, which indirectly decompresses the left ventricle [28]. Placing the inflow cannula through the femoral vein in the left atrium requires a transseptal puncture, which may be a certain limitation in the use of this system [28]. Tandem Heart reduces LV end-diastolic pressure, although, similar to ECMO, it increases afterload due to return of blood through the outflow cannula to the femoral artery [28]. In the setting of VSR, there is a risk of shunt inversion due to intensive LV unloading as well as affecting the opening of the aortic valve [24].

- Left ventricular assist device (LVAD) (LV to aorta) is also a support in some centers for patients with post-infarction VSD. However, LVAD is used less frequently for short-term pre-operative stabilization of the patient. Post-infarction fragility of tissues may impede adequate implantation of the support and aspiration of necrotic tissues, which in some cases may lead to improper function of the pump [24]. With the more favorable location of the post-infarction area and the possibility of using LVAD, there is a risk of reversing the leak, which can be solved by using BiVAD [24].

The most common complications associated with the use of MCDs include lower limb ischemia, bleeding, and hemolysis [29]. The relatively safe type of device among the listed ones is the IABP [30]. Low cardiac output may be a significant complication of MCD in patients with VSD, especially in the case of insufficient left ventricular unloading.

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