



Review Article

Pathophysiology of Perioperative Low Cardiac Output Syndrome in Cardiac Surgery: What do we know?

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Abstract

The most important challenge in perioperative of cardiac surgery is to maintain optimal cardiac output, tissue oxygenation, and the ratio of myocardial oxygen supply and demand. Ideally, the cardiac index must be greater than 2.2 L/min/m² with a normal mixed venous oxygen saturation [1]. Perioperative Low Cardiac Output Syndrome (LCOS) is defined as the pre, intra or postoperative decrease of cardiac index less than 2.2 L/min/m² requiring inotropic agents and /or mechanical circulatory to maintain the systolic blood pressure higher than 90 mm Hg and the cardiac index greater than 2.2 L/min/m² after optimizing and correcting preload, afterload, electrolyte and blood gas abnormalities [2]. This review aims to expose the basic pathophysiological mechanisms of LCOS.

Keywords: Cardiac Surgery; Low Cardiac Output; Pathophysiology

List of Abbreviations: LCOS: Low Cardiac Output Syndrome; HR: Heart Rate; SV: Stroke Volume; LVEDV: Left Ventricular End-Diastolic Volume; LVESV: Left Ventricular End-Systolic Volume; LVSD: Left Ventricular Systolic Dysfunction; RVSD: Right Ventricular Systolic Dysfunction; LVDD: Left Ventricular Diastolic Dysfunction; LV: Left Ventricular; CPB: Cardio-Pulmonary Bypass

Background

Cardiac Output (CO) is the volume of blood that is pumped by the heart to the systemic circulation per minute. It's determined by the Stroke Volume (SV) and the Heart Rate (HR) according to the following formula: $CO = SV \times HR$. The Stroke Volume (SV) is determined by the left ventricular end-diastolic volume (LVEDV) and the Left Ventricular End-Systolic Volume (LVESV) according to the following formula: $SV = LVEDV - LVESV$. Preload, afterload, and contractility are the three major determinants of

stroke volume [1,2-6]. Preload refers to the ventricular parietal tension at the end of the ventricular diastole and is considered to reflect the ventricular volume at the end of the ventricular diastole also call Left Ventricular End-Diastolic Volume (LVEDV) [1]. The preload represents the volume present in the ventricle before each contraction. Afterload is the sum of all forces due to vasoconstriction or other resistance opposing ventricular emptying and against which the ventricle is ejecting. Contractility is the force generated by the myocardium during systole independent of preload and afterload and refers to the strength and efficiency of the contraction. It is expressed as the ejection fraction [1,3-6]. There are 3 Common underlying mechanisms behind perioperative LCOS (Figure 1): **1-Left Ventricular Systolic Dysfunction (LVSD)**, **2-Right Ventricular Systolic Dysfunction (RVSD)**, and **3-Left Ventricular Diastolic Dysfunction (LVDD)** also called heart failure with preserved ejection fraction [7,8]. LVSD and RVSD are the result of the decreasing of the myocardial contractility due to the decreased ventricular ejection fraction and are worsened by any condition that disturb ventricular preload and afterload [1,3,7,8]. LVDD is due to filling anomaly of left ventricle related

to impairment of protodiastolic relaxation and meso-telediastolic compliance (elasticity and distensibility) [9-13].

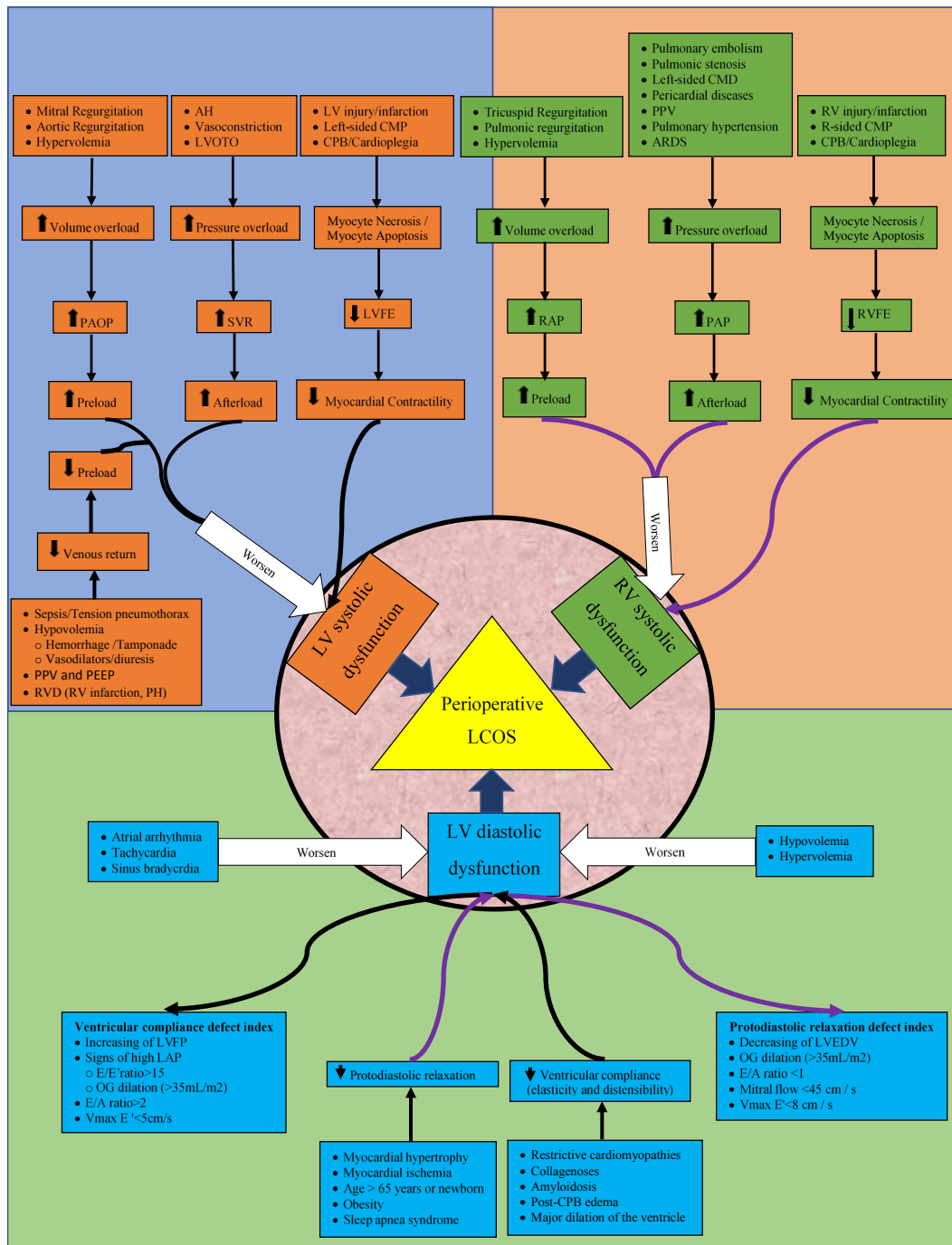


Figure 1: Schematic presentation of the pathophysiology of perioperative LCOS. CMP: Cardiomyopathy; TR, Tricuspid regurgitation; PR: Pulmonic regurgitation; PPV: Positive pressure ventilation; ARDS: acute respiratory distress syndrome; CI: cardiac index; E: early flow velocity at the level of the mitral valve; E': early velocity of the mitral annulus (myocardial Doppler imaging); EF: ejection fraction; HR: heart rate; LVDD: left ventricular diastolic dysfunction; LV: leftventricle; LVSD: leftventricular systolic dysfunction; PAP: pulmonary artery pressure; PAOP: pulmonary artery occlusion pressure; RAP: right atrial pressure; RV: rightventricle; RVSD:

right ventricular systolic dysfunction; SVR: systemic vascular resistance; SvO₂: mixed venous oxygen saturation; CPB: Cardio-pulmonary Bypass; LVEDV: Left Ventricular End-Diastolic Volume; LVFP: Left Ventricular Filling Pressures; LAP: Left Atrial Pressure; PO: Postoperative; PEEP: Positive End-Expiratory Pressure; PPV: Positive-Pressure Ventilation; RVD: Right Ventricular Dysfunction; PH, Pulmonary Hypertension; AH, Arterial Hypertension; LVOTO: LV outflow tract obstruction; LCOS: Low Cardiac Output Syndrome.

Left Ventricular Systolic Dysfunction

Left Ventricular (LV) systolic dysfunction is commonly a result of myocyte necrosis or myocyte apoptosis with a loss of functional myocytes or a decrease in their function due to any impaired coronary circulation condition such as LV injury, LV infarction, Left-sided Cardiomyopathy, Cardio-pulmonary Bypass and Cardioplegia which decreases the LV Ejection Fraction and therefore decreases the myocardial contractility. This LV systolic dysfunction due to a decreased LV ejection fraction and a decreased LV myocardial contractility will lead to LCOS which causes the tissue hypoperfusion, the reduced oxygen delivery (DO₂) and tissue hypoxia. Resulting physical signs of LCOS include a systolic blood pressure <90 mmHg, cold and clammy skin, confusion, and elevated lactate level. Any condition that increases preload and afterload or decreases preload leads to the worsening of the LV systolic dysfunction and therefore the LCOS [7,8].

Right Ventricular (RV) Systolic Dysfunction

Right Ventricular (RV) systolic dysfunction is a result of myocyte necrosis or myocyte due to any impaired coronary circulation condition such as RV injury, RV infarction, Right-sided Cardiomyopathy, Cardio-pulmonary Bypass (CPB) and Cardioplegia which decreases the RV Ejection Fraction and therefore decreases the right myocardial contractility. This RV systolic dysfunction is worsened by any condition that increases RV preload and afterload [7,8].

Left Ventricular Diastolic Dysfunction

LV diastolic dysfunction is the inability of the left ventricle to accept an adequate preload because of both the loss of left ventricular protodiastolic relaxation and left ventricular compliance (elasticity and distensibility). Any condition which decreases left ventricular protodiastolic relaxation such as myocardial hypertrophy, myocardial ischemia, Age > 65 years or newborn, obesity, sleep apnea syndrome leads to left ventricular protodiastolic relaxation defect index and any causes of decreased left ventricular compliance such as restrictive cardiomyopathies, collagenoses, amyloidosis, post-CPB edema, major dilation of the left ventricle leads to left ventricular compliance defect index. Arrhythmia, hypovolemia and/or hypervolemia lead to the worsening of the LV diastolic dysfunction and therefore the LCOS [7,8].

Conclusions

In summary, perioperative Low Cardiac Output Syndrome is a multifactorial process due to any condition that provides left ventricular systolic dysfunction (LVSD), right ventricular systolic dysfunction (RVSD), and /or Left ventricular diastolic dysfunction (LVDD). The perioperative management of patients with Low Cardiac Output Syndrome is based on a good understanding of the pathophysiology of this syndrome.

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