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Case Report
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Patent Foramen Ovale Percutaneous Closure for Refractory Hypoxemia after Heartmate III Left Ventricular Device Implantation

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Abstract

Patients undergoing LVAD placement should be screened and treated for PFO during initial LVAD implantation to avoid right-to-left atrial shunt and related severe post-procedure complications. However, diagnosis before Cardiopulmonary Bypass (CPB) can be challenging. A provocative procedure, such as a Valsalva Maneuver (VM), that temporarily inverts the pressure gradient between both atria, allowing a right-to-left shunt with passage of contrast material or color flow through the PFO, is necessary for diagnostic purposes. In patients with increased Left Atrial Pressure (LAP), i.e., those with Left Ventricle Failure (LVF), methods based in VM may be falsely negative as pressure gradient may hardly be reversed. This was probably the case of our patient, whose pulmonary capillary wedge pressure was 25 mmHg. Transesophageal Echocardiography (TEE) is less accurate for PFO detection in the setting of the population undergoing LVAD placement. Diagnosis of PFO in patients with LVF may be only made reliably by TEE after LVAD activation. We present the case of a 73-year-old man in which HeartMate III LVAD implantation, *via* left lateral thoracotomy, was decided as destination therapy. The intraoperative TEE performed prior to CPB showed no evidence of PFO. Bubble test with agitated dextrose after release of Valsalva maneuver was negative. First attempt to disconnect from CPB was unsuccessful due to refractory severe hypoxemia and progressive hemodynamic instability. TEE revealed a severe atrial right-to-left shunt previously absent. The patient was treated for an emergent PFO percutaneous closure, with resolution of hypoxemia.

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Introduction

Patent Foramen Ovale (PFO) is common and found in approximately 25% of post-mortem examinations, but in most cases without any clinical significance [1]. However, right-to-left atrial shunt can occur, leading to severe hypoxemia and systemic thromboembolism, when right atrial pressure exceeds left atrial pressure. These specific abnormal hemodynamical conditions are found under the mechanical circulatory support of Left Ventricular Assist Devices (LVAD) [2]. Identification and immediate closure of PFO in patients undergoing LVAD placement is of paramount importance to avoid severe post-procedure complications such as hypoxemia, hemodynamical instability or failure to separate from cardiopulmonary bypass [3]. Transesophageal Echocardiography (TEE) is considered to be the "gold standard" for PFO detection, but its diagnostic accuracy is suboptimal in the context of congestive heart failure.

Case Presentation

A 73-year-old man presented with an extensive acute anterolateral myocardial infarction and a cardiogenic shock refractory to optimal medical therapy and mechanical support with intra-aortic balloon counterpulsation. Transthoracic echocardiography showed severe left ventricular systolic dysfunction with an ejection fraction of 25% and no right ventricular dysfunction. Mean pulmonary arterial pressure was 35 mmHg and pulmonary capillary wedge pressure was greater than 20 mmHg, diagnosing for secondary mild-to-moderate pulmonary hypertension. The patient was scheduled for HeartMate III Left Ventricular Assist Device (LVAD) implantation, *via* left lateral thoracotomy, as destination therapy.

The intraoperative Transesophageal Echocardiography (TEE) performed (Figure 1) by the

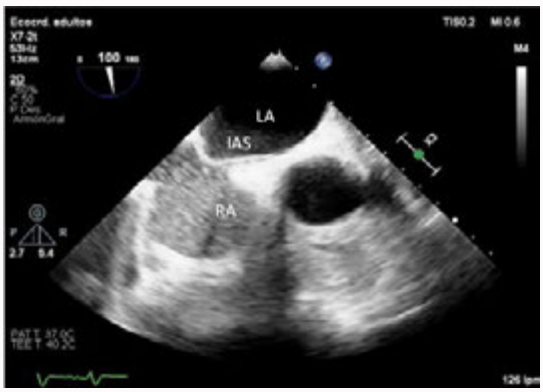

Figure 1: Intraoperative TEE performed prior to CPB showing no evidence of PFO.
IAS: Interatrial Septum; LA: Left Atrium; RA: Right Atrium

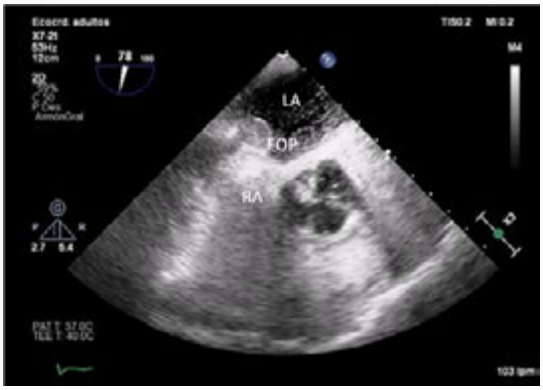

Figure 2: Intraoperative TEE after HeartMate III left ventricular device initiation revealing a severe atrial right-to-left shunt previously absent.
PFO: Patent Foramen Ovale; LA: Left Atrium; RA: Right Atrium

anesthesiologist prior to Cardiopulmonary Bypass (CPB) showed no evidence of PFO. Bubble test with agitated dextrose injected *via* central line after release of Valsalva maneuver was negative. The implant procedure was completed without incidents and followed by LVAD support initiation. First attempt to disconnect from CPB was unsuccessful due to persistent right ventricular dysfunction, severe hypoxemia (PaO_2 was 60 mmHg despite being on a FiO_2 of 1) and progressive hemodynamical instability. Vasopressor and inotrope therapy was intensified, inhaled pulmonary vasodilators were started. TEE revealed a severe atrial right-to-left shunt previously absent (Figure 2). The patient was transferred to the Interventionist Cardiology Unit to undergo an emergent PFO percutaneous closure with an Amplatzer device (Figure 3). After the procedure, $PaFi/FiO_2$ improved from 60 to 106 but FiO_2 requirements remained high. At arrival to Intensive Care Unit (ICU) SpO_2 was 85% despite being on a FiO_2 of 1. A lung Ultrasound (US) exam showed absence of lung sliding in the left hemithorax. A large left-sided pneumothorax was diagnosed, and a chest drain tube was inserted. Immediately afterwards, the patient's FiO_2 requirements improved and was subsequently extubated within 72 h.

Discussion

TEE combined with color flow doppler and bubble studies with standard provocative maneuvers is considered by many authors to be the gold standard for diagnosing PFO. Its diagnostic accuracy in general population is 89%.

TEE detection of a PFO is a dynamic process. Passage of contrast material or color flow through the interatrial septum defect should be demonstrated to establish the diagnosis. Under normal hemodynamical conditions left atrial pressure is higher than right atrial pressure, and left-to-right flow does not occur unless PFO is both anatomically and functionally open. A provocative procedure, such as a Valsalva maneuver, that temporarily inverts the pressure gradient between both atria, allowing a right-to-left shunt if PFO is present, needs to be performed for diagnostic purposes. Valsalva maneuvers produce an increase in intrathoracic pressure leading to a reduction of blood flow into the thorax. Upon sudden release of this maneuver, the intrathoracic pressure decreases allowing blood to rapidly enter the thoracic cavity and fill the right atria. This results in a right atrium pressure temporary above the left atria pressure.

In patients with increased left atrial pressure, i.e., those with congestive heart failure, methods based in Valsalva maneuvers may be falsely negative. Pressure gradient may hardly be reversed with any provocative procedure in this population. An increased left atrial pressure can mask the presence of a PFO by pressing the septum primum against the septum secundum and closing the foramen ovale, even at increased right atrial pressures. This was probably the case of our patient, who presented a pulmonary capillary wedge pressure about 25 mmHg.

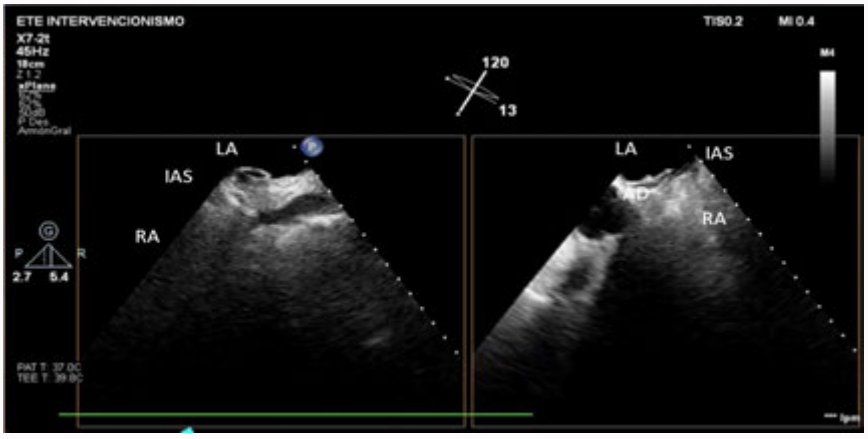

Figure 3: Successful PFO percutaneous closure with an Amplatzer® device, with no transfer of contrast material from the right atrium into the left atrium.
AD: Amplatzer® Device; IAS: Interatrial Septum; LA: Left Atrium; RA: Right Atrium

LVADs unload the left ventricle by decreasing left atrial pressure. This can create a pressure gradient across a pre-existent intra-atrial septal defect, allowing blood to shunt right-to-left permanently, with subsequent hypoxemia. Incidence and magnitude of related complications is unpredictable, and delayed onset hypoxemia due to physiological Valsalva maneuvers have been described in the literature. All patients undergoing LVAD placement should be screened for the presence of PFO, and any PFO detected should be closed during initial LVAD implantation. A misdiagnosed PFO before LVAD placement can be fatal. However, because of the characteristics of the population undergoing LVAD placement, TEE is less accurate in this setting and detection of PFO prior to CPB can be challenging. Diagnosis of PFO in congestive heart failure patients may be only made reliably by TEE after LVAD activation.

A new technique consisting of partially occluding the pulmonary artery intraoperatively has been described. This would safely increase right atrial pressure and decrease left atrial pressure, inverting intensively the pressure gradient. Nevertheless, more studies are needed to demonstrate whether or not the use of this technique will improve the diagnostic accuracy of subclinical PFO detection through intraoperative TEE prior to initiating CPB for LVAD placement.

Conclusion and Learning Points

- Identification and immediate closure of PFO in patients undergoing LVAD placement is of paramount importance.
- Diagnosis of PFO in population with increased left atria pressure is less accurate.
- Previously undetectable PFO can be revealed after initiation of LVAD support.
- PFO related complications will increase as LVADs become more frequent.

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