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Indications, technical aspects, patient management, potential risks and benefits

Extracorporeal membrane oxygenation in neonates and children

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text

Introduction

Extracorporeal membrane oxygenation (ECMO) is a modified form of cardiopulmonary bypass (CPB) used to provide adequate organ oxygenation in patients with cardiac and/or respiratory failure. The scope of this article is to give a general practitioner and specialists not involved in ECMO management a brief overview of different indications, surgical implantation and patient management, and potential risks and benefits of ECMO therapy for children. ECMO therapy is an overwhelming event for the whole family, and we also highlight the role of psychosocial counselling and support for the parents.

Key words: ECMO; neonates; children; cannulation, management

The ECMO circuit

We use a Thoratec Centrimag® or PediVas® (Levitronix, Zurich, Switzerland) console with a back-up unit, a heater unit and a Sechrist Air-Oxygen-Mixer (Sechrist Industries, Anaheim, USA) (fig. 1). For neonates and infants weighing up to 15 kg the whole circuit contains approximately 250 ml priming solution with flow ranges up to 1.71/min; for children above 15 kg the volume of priming solution is about 750 ml and flow rates up to 7.0 l/min can be achieved.

Implantation techniques and cannulation sites

Weight limits for different cannulation sites and various cannulation algorithms have been published [5, 6]. Cannulation for neonates, infants and small children focuses on either neck vessels or large central vessels via median sternotomy. Cannulation of the femoral vessels in small children is not possible because the small size of the vessels does not allow implantation of cannulae large enough to achieve full ECMO flow.
Neck cannulation has the advantage of allowing an expeditious procedure in an emergency situation, even during mechanical cardiopulmonary resuscitation without interrupting chest compression. A transverse skin incision is made over the lower third of the sternocleidomastoid on the right side. The internal jugular vein, the common carotid artery and the vagal nerve are identified. Oval purse-string sutures are placed in the vein (VV-ECMO) and artery (VA-ECMO). Selected cannulas, according to the weight of the patient and desired achievable flow rate, are inserted through a vertical incision within the purse-string suture, tightened over tourniquets and connected to the ECMO circuit. A heparin bolus of 50–100 IU/kg is administered independently of the cannulation site prior to inserting the cannulas. Subsequently, continuous heparin infusion is titrated using a goal activated clotting time in the range of 160–180 seconds. The platelet count is maintained at or above 100,000/mm³. One perioperative injection of prophylactic antibiotic (cefazolin) is administered at each ECMO implantation.

The role of echocardiography for paediatric patients supported with ECMO

Echocardiography should be used preoperatively for patient selection, perioperatively for cannula placement and filling of the left ventricle and postoperatively for surveillance, optimisation, troubleshooting and evaluation of myocardial recovery. Whenever possible, echocardiography is performed before ECMO cannulation to confirm significant systolic ventricular dysfunction as indication for implantation and to

Table 1: Extracorporeal membrane oxygenation indications.

<table>
<thead>
<tr>
<th>Heart failure</th>
<th>Failure to wean from CPB</th>
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<tbody>
<tr>
<td>Myocarditis</td>
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<tr>
<td>Cardiomyopathy</td>
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<tr>
<td>(bridge to recovery,</td>
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<tr>
<td>transplant or long</td>
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<tr>
<td>term MCS)</td>
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<td>Refractory sepsis</td>
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<td>with profound cardiac</td>
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<tr>
<td>depression*</td>
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<tr>
<td>Refractory cardiac</td>
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<td>arrhythmias</td>
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<td>Coronary ischaemia (if</td>
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<td>surgically amen-</td>
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<td>dable/treatable)</td>
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<tr>
<td>Pulmonary failure</td>
<td>Bridge to transplantation</td>
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<td>Neonatal respiratory</td>
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<td>distress syndrome</td>
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<td>Adult respiratory</td>
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<tr>
<td>distress syndrome†</td>
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<td>Persistent pulmonary</td>
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<td>hypertension of the</td>
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<td>newborn / persistent</td>
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<td>fetal circulation</td>
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<td>Meconium aspiration</td>
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<tr>
<td>syndrome</td>
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<tr>
<td>Pneumonia (viral/bacterial/aspiration)</td>
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<td>Air leak syndrome</td>
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<tr>
<td>Cardiac arrest from</td>
<td>Bridge to decision,</td>
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<tr>
<td>any cause†</td>
<td>underlying treatable</td>
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<tr>
<td>disease</td>
<td>disease</td>
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<tr>
<td>Transplantation</td>
<td>Pre-transplantation as</td>
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<td>bridge to Tx</td>
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<td>Elective periproce-</td>
<td>Primary graft dysfunction</td>
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<tr>
<td>dural support</td>
<td>after heart or lung Tx</td>
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<td>Congenital dia-</td>
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<td>phragmatic hernia</td>
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<td>(CPB = cardiopulmonary</td>
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<td>bypass; MCS =</td>
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<td>mechanical circulatory</td>
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<td>support; Tx =</td>
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<td>transplantation or</td>
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<td>tracheal surgery</td>
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<td>In special circumstances; centre specific</td>
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</tbody>
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Table 2: Contraindications for extracorporeal membrane oxygenation therapy.

| End-stage disease      |                          |
| Untreatable underlying |                          |
| disease and congenital |                          |
| malformations          |                          |
| Significant neurological|                          |
| impairment, genetic    |                          |
| abnormalities (e.g.,   |                          |
| trisomy 13 and 18)     |                          |
| Severe, irreversible   |                          |
| organ dysfunction      |                          |
| Extreme prematurity    |                          |
| (gestational age <35   |                          |
| weeks)                 |                          |
| Severe coagulopathy    |                          |
| or contraindication    |                          |
| for anticoagulation    |                          |
eliminate residual haemodynamic lesions that could be resolved other than by ECMO installation. Furthermore, echocardiography is used to rule out cardiac anomalies, and assure that there are competent valves and normal systemic veins.

During ECMO implantation, echocardiography can guide the insertion and correct placement of the cannulas and document the volume state of the left ventricle. If VV-ECMO with a dual-lumen cannula (AVALON®, Avalon Laboratories, LLC, California, USA) is inserted via a single site (internal jugular vein), we use echocardiographic or x-ray guidance in the cardiac catheter laboratory to ensure adequate orientation of the ports of the cannula (fig. 2). Their proper position must be confirmed with echocardiography, especially the location of the outflow lumen, which must be positioned in the centre of the right atrium with flow directed towards the tricuspid valve. The hepatic veins and the distal inferior vena cava should not be congested.

The first echocardiogram after ECMO implantation on the intensive care unit (ICU) verifies again the localization of the cannulas. Complications arising from the cannulas include displacement, malposition or obstruction [7]. Repeated echocardiographic monitoring in a child on ECMO is mandatory and includes the course of left ventricular size and contractility, aortic valve opening and mitral valve regurgitation. If the aortic valve is not opening and there is no shunt, the left ventricle of a patient on VA-ECMO will not unload. If the left ventricle than dilates, recovery is not possible. In this case an additional cannula (vent) has to be implanted in the left ventricle or atrium, or an atrioseptostomy is needed, to ensure sufficient unloading.

Complications must be anticipated and specifically screened for, and are often associated with either the cannula itself or the anticoagulation regimen. Anticoagulation can lead to bleeding, resulting in pericardial effusion and subsequently tamponade, or formation of a thrombus either in the heart, the vessels or the cannulas.

**Patient management on the ICU**

In order to achieve the desired goal of optimal pulmonary and/or myocardial support and with optimal balance of blood flow, oxygen delivery and oxygen consumption, the following aims are crucial:

1. Provision of adequate oxygenation and CO₂ removal in pulmonary dysfunction.
2. Provision of adequate blood flow to match metabolic needs in patients with insufficient cardiac output.
3. Prevention of complications from other therapies as well as from the ECMO therapy itself.

Numerous considerations need to be addressed when caring for ECMO patients, as they will influence course and outcome (e.g., anticoagulation, nutrition, infection, renal function, psychosocial family support and ethical considerations). Nevertheless, it is important at the beginning of an ECMO run to have a clear view of the likely length of support required and the ultimate destination. This may be complete recovery, bridge to decision, bridge to transplant or bridge to longstanding cardiac support such as a ventricular assist device.

ECMO support might only be necessary for as little as 3 to 6 days (e.g., myocardial recovery after intraoperative stun, persistent pulmonary hypertension of the newborn or vasoplegic shock in sepsis) [8], up to 10 to 14 days, or even significantly longer (e.g., adult respiratory distress syndrome, pneumonia, meconium aspiration syndrome, myocarditis) [9–11]. Time on ECMO support should be used wisely if uncertainties about the underlying disease process remain. If echocardiography leaves questions unanswered, a cardiac catheter study can usually safely be undertaken and should meticulously investigate the patient’s haemodynamic state or search for residual lesions, as this will probably have direct implications for the ongoing ECMO support and for immediate decisions [12]. The patient on ECMO needs precise and fastidious anticoagulation management, because bleeding, haemolysis and thrombosis should be prevented as far as possible, as they are primarily responsible for neurological sequelae and dismal outcome [13]. Near-infrared spectroscopy (NIRS) has

![Figure 2: Implanted VV-ECMO using a single-lumen cannula (AVALON) showing proper placement in the catheter laboratory.](image-url)
evolved as a reliable tool to guide therapy in order to improve neurological outcomes after ECMO therapy [14]. NIRS provides indirect monitoring of venous drainage and arterial perfusion. In contrast to echocardiography, NIRS allows permanent monitoring [15].

Nursing care

The monitoring and care of children with ECMO therapy is a special nursing challenge and requires close multidisciplinary cooperation. The ICU nurses are specifically trained for ECMO therapy and are therefore able to respond to acute changes at any given time [17, 18]. During ECMO support children are rest-ventilated, sometimes with an open sternum due to a delayed sternal closure after central cannulation. Any manipulation of the positioning of the patient (e.g., wound care, pressure ulcer care or changing endotracheal tube straps) may change the position of the ECMO cannulas, which can negatively affect the ECMO flow and may even lead to failure of the ECMO circuit. Therefore, ECMO specialist nurses need to be extremely vigilant and respond to these changes. The risks of infections, cerebral haemorrhage and renal failure (e.g., due to decreased renal perfusion during non-pulsatile ECMO flow) are increased and will rise with increasing duration of ECMO therapy. Therefore, careful clinical monitoring of the patient, as well as meticulous aseptic precautions at the cannulation site, are vitally necessary. ECMO patients are exposed to an increased risk of bleeding [19]. Because of bleeding and blood trauma, some patients will need to have blood products several times daily [20]. The nurses continuously monitor every organ system and have to be able to independently and competently respond to emergencies at any time. Ideally, there are always two nurses responsible for one child on ECMO, sharing the complex supervision and care of the patient.

Our patients (children and adolescents) are always part of their personal environment – their parents and other family members. Initially, the parents and families of the children experience a tremendous shock. Especially with neonatal patients, building a relationship with their newborn child is a big challenge for parents. They are not able to hold and care for their child [21], and the uncertainty of the outcome aggravates the situation. It is part of the nursing care to support relatives during this time, as well as during grieving if the outcome is not favourable. The regular presence of parents and family at the bedside is very important for a critically ill child. To support and to build a solid relationship, as well individual contact with their child, it is important to integrate the parents in nursing interventions such as oral care, skin care, changing nappies or massages. A soothing touch, the parents’ and siblings’ voices, personal toys, music and rituals can be very helpful for the ill child, and also for the family. Parents and family members often need detailed information while their child is on ECMO support and, depending on their personalities, are also often themselves in need of encouragement and personal support, a task the ECMO specialist nurse should provide. Nurses are in a particular situation to care for these highly complex patients, and to support the whole family (table 3).

Table 3: Responsibilities of the nursing team caring for children on ECMO.

<table>
<thead>
<tr>
<th>Responsibilities of the ECMO nurse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psychological family support</td>
</tr>
<tr>
<td>Visual inspection of the ECMO circuit</td>
</tr>
<tr>
<td>Regulation of ECMO flow, sweep gas and oxygenation</td>
</tr>
<tr>
<td>Anticoagulation management</td>
</tr>
<tr>
<td>Management of the heparin infusion and administration of blood products</td>
</tr>
<tr>
<td>Haemofiltration</td>
</tr>
<tr>
<td>Emergency measures and troubleshooting of the ECMO circuit</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Responsibilities of the bedside nurse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic care</td>
</tr>
<tr>
<td>Intravenous fluid administration and medical therapy</td>
</tr>
<tr>
<td>Feeding and administration of parenteral nutrition</td>
</tr>
<tr>
<td>Vital signs monitoring</td>
</tr>
<tr>
<td>Monitoring of fluid intake and output</td>
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<tr>
<td>Nursing documentation</td>
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</table>

Conclusion

Over the last decades ECMO has become the most frequently used form of extracorporeal life support in children. Depending on the underlying disease, it can be modified for venovenous blood flow, to provide sufficient oxygenation of the blood in isolated respiratory failure, or for venoarterial support in the case of cardiac or respiratory failure. Echocardiography plays an important role at every step of ECMO, starting with the diagnosis, and including documentation of cannula position, and guidance during surgical cannulation and during troubleshooting. In contrast to adult patients, neck cannulation or central cannulation via median sternotomy are the preferred sites in children. Special circuits are available for the paediatric population in order to keep priming volume low, guarantee optimal flow and oxygenation, and reduce complica-
tion rates. Special management on the ICU is crucial to prevent or recognise complications. Interaction between the various disciplines involved is indispensable to identifying the ideal timeframe for successful weaning. Involvement of the parents throughout all stages of therapy is important and may have a positive impact.

Disclosure statement
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References
Use of echocardiography to distinguish between the various causes of shortness of breath

Value of echocardiography in chronic dyspnoea

Patrick Badertscher, Beat A. Kaufmann
Department of Cardiology, University Hospital Basel, Switzerland

Summary

In chronic dyspnoea, cardiac and pulmonary aetiologies predominate, but multiple causes are present in up to one third of patients. Because of the multiple possible aetiologies, the evaluation of chronic dyspnoea remains challenging. Initial diagnostic testing should include at least a complete blood count, chest x-ray and an electrocardiogram. If there is an ongoing suspicion of a cardiac origin, echocardiography comes into play. Echocardiography is the first-line diagnostic imaging test for detecting myocardial, valvular or pericardial disease as an aetiology for chronic dyspnoea. In addition, echocardiography may aid in the diagnosis of thromboembolic disease and in pulmonary artery hypertension. Echocardiography also provides additional important information such as the severity and extent of the disease. In our review we will discuss the different causes of chronic dyspnoea and we will highlight the strengths and limitations of echocardiography when evaluating these disorders. When interpreted together with the clinical presentation, echocardiography is a fundamental diagnostic tool for the evaluation of patients with chronic dyspnoea and contributes to directing further management.

Key words: echocardiography, chronic dyspnoea, heart failure, diastolic dysfunction, coronary artery disease, valvular heart disease, pericardial diseases

Introduction

Chronic dyspnoea is defined as shortness of breath lasting longer than one month [1]. The underlying causes can be classified into cardiac, pulmonary and other disorders which include anaemia, deconditioning or anxiety [2] (table 1). Cardiac and pulmonary pathologies as the cause for dyspnoea clearly predominate: for 85% of all cases of shortness of breath the causes are asthma, congestive heart failure, myocardial ischaemia, chronic obstructive pulmonary disease (COPD), interstitial lung disease, pneumonia or psychogenic disorders [3]. However, it is often not easy to distinguish between the various causes of shortness of breath, and the aetiology is multifactorial in up to one third of patients [1]. Before echocardiography, initial diagnostic testing in patients with chronic dyspnoea should include pulse oximetry, complete blood count, basic metabolic panel, chest x-ray and an electrocardiogram (ECG). The diagnostic yield of the clinical history, physical examination and chest x-ray was examined in 85 subjects with chronic dyspnoea by Pratter et al. [4] in 1989. Overall, the diagnosis could be reached with these three tools in two thirds of the patients (56 out of 85 cases). The clinical diagnostic impression was more accurate (81%, 47 out of 58 cases) in common diseases like asthma, COPD, interstitial lung disease or cardiomyopathy, whereas accuracy dropped drastically to 33% (9 out of 27 cases) with less common causes of dyspnoea. Thus, further tests such as echocardiography are clearly necessary to make a diagnosis or to confirm a clinical suspicion. In addition, echocardiography provides information on disease severity and more precise information on disease aetiology.

According to the European Society of Cardiology (ESC) [5], transthoracic echocardiography is appropriate when a cardiac origin of the dyspnoea is suspected. Figure 1 shows an algorithm for the assessment of heart failure according to the 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. In summary, the probability of heart failure should first be evaluated on the basis of the patient’s prior clinical history, physical examination and resting ECG. If at least one element is abnormal, plasma

| Table 1: Causes of chronic dyspnoea, Adapted from Wahls SA et al. [1]. |
|---------------------------------|-----------------------------|
| **Cardiac**                     | **Noncardiac/nonpulmonary** |
| Myocardial disease              | Thromboembolic disease      |
| Cardiac arrhythmias             | Pulmonary hypertension      |
| Pericardial disease             | Deconditioning              |
| Valvular heart disease          | Obesity                     |
|                                 | Severe anaemia              |
| **Pulmonary**                   | Gastroesophageal reflux     |
|                                 | disease                     |
| Chronic obstructive pulmonary   | Metabolic conditions        |
| disease                         |                             |
| Asthma                          | Liver cirrhosis             |
| Interstitial lung disease       | Thyroid disease             |
| Pleural effusion                | Neuromuscular disorders     |
| Malignancy                      | Chest wall deformities      |
| Bronchiectasis                  | Upper airway obstruction    |
|                                 | Psychogenic causes          |
natriuretic peptides should be measured, to identify those who need echocardiography (if the level of natriuretic peptides is above the exclusion threshold or if circulating natriuretic peptide levels cannot be assessed).

Cardiac causes of dyspnoea include systolic dysfunction (which may be caused by myocardial ischaemia, valvular diseases or cardiomyopathies) primary diastolic dysfunction, pericardial diseases, congenital heart diseases, pulmonary hypertension and cardiac masses. Most of these disorders are reliably detectable by echocardiography. We will discuss each of the conditions separately, highlighting the strengths and limitations of echocardiography and, when appropriate, comparing it with other imaging tools.

**Evaluation of left ventricular systolic function**

Assessment of left ventricular systolic function is the most frequent reason for ordering echocardiography, and reduced systolic function is the most apparent finding causing dyspnoea. Even though not optimal, the most widely measured parameter reflecting systolic function is left ventricular ejection fraction (LVEF). Over past decades, measurement of LVEF has evolved from a purely visual assessment to complex, computer assisted tracing of the left ventricular cavity throughout the cardiac cycle.

The simplest approach to measuring LVEF is so-called eyeballing. Whether visual estimation of left ventricular ejection fraction is equivalent to other methods has been examined in a number of studies. Overall, the intra- and inter-observer variability of visual estimates of LVEF is higher than for other techniques [6]. However, visual estimation of LVEF is still widely applied to confirm quantitative measures of LVEF. Also, visual estimation may still provide a rough estimate of LVEF in patients with very poor image quality where tracing of the left ventricular cavity is not possible.

The most widely used method for measuring LVEF is the simplified Simpson’s method to estimate ventricular volume from two orthogonal apical views [7]. This method is time consuming, and relies on geometric assumptions and on good image quality. The most common error is apical foreshortening, which leads to underestimation of left ventricular volumes. Simpson’s method has been shown to correlate well with other methods used for estimation of LVEF, such as magnetic resonance imaging [8]. However, it should be remembered that on an individual patient basis, the measurement variability can be quite high This needs to be taken into account for clinical decision making, which often uses discrete LVEF cutoffs, for example as indications for the implantation of implantable cardioverter-defibrillators or cardiac resynchronisation. For example, in an analysis of echocardiography data from the TIME-CHF study [9], about one fifth of all patients would have been re-assigned to an LVEF category (above or below 30%) clinically on a second reading.

Given the shortcomings of visual estimation or of Simpson’s measurement of LVEF that mainly depends on image quality, ultrasound contrast agents have been used and shown to result in less inter-observer variability and better correlation to other techniques such as cardiac magnetic resonance imaging (CMR) [8]. However, as a drawback, use of contrast agents necessarily involves an intravenous line, and measurements still rely on geometric assumptions. In this respect, three-dimensional echocardiography (3DE) is a major step forward. A systematic review and meta-analysis have assessed the performance of 3DE in measuring left ventricular volumes and LVEF [10]. The authors concluded that, compared with traditional 2D, 3DE is more precise for measuring left ventricular volumes and LVEF. However, perhaps even more than two-dimensional imaging, 3DE does depend on good image quality. Apart from the variability of the measurements, one should also be aware that LVEF is influenced by heart rate, preload, afterload and contractility. Thus, LVEF within a normal range does not necessarily indicate normal systolic function. For example, chronic severe
mitral regurgitation leads to a decrease in afterload and thus LVEF can be normal even if systolic dysfunction as a consequence of long-standing left ventricular volume overload is present. Hence, LVEF is not an ideal measurement of systolic function. There is an unmet clinical need for additional tools to better assess systolic function. Newer echocardiographic techniques have helped identify myocardial mechanical abnormalities in patients with cardiac disease and preserved LVEF (≥50%). Specifically, speckle-tracking imaging of myocardial deformation has allowed for a more refined assessment of ventricular systolic and diastolic function, and may allow the detection of subtle myocardial abnormalities that do not impact LVEF [11]. Conversely, the finding of reduced LVEF or systolic dysfunction does not automatically explain the origin of chronic dyspnoea. The demonstration of increased filling pressure or pulmonary systolic pressure is essential to conclude causality between the echocardiographic findings and the symptoms.

**Evaluation of left ventricular diastolic dysfunction**

Diastolic dysfunction with an increase in left atrial pressure (LAP) is the common mechanism responsible for dyspnoea in patients with heart failure as a consequence of left-sided heart disease, irrespective of the presence or severity of systolic dysfunction. The approach to the evaluation of diastolic dysfunction depends on the presence of reduced ejection fraction. In patients with a normal ejection fraction, heart failure with preserved ejection fraction (HFpEF) is a possible cause for dyspnoea. According to current guidelines [5], the diagnosis of HFpEF requires the following conditions to be fulfilled: (1) The presence of symptoms and signs of heart failure; (2) normal or “preserved” LVEF (≥50%); (3) elevated levels of natriuretic peptides (BNP ≥35 pg/ml, NT-proBNP ≥125 pg/ml); and (4) at least one additional criterion representing objective evidence of relevant structural heart disease (left ventricular hypertrophy, dilated left atrium) or evidence of diastolic dysfunction. However, it should be noted that the cut-off point of 50% is arbitrary, as many clinical studies considered patients with an LVEF between 40 and 49% as having HFpEF [12]. Remarkably for the first time, 2016 guidelines describe an LVEF between 40 and 49% as heart failure with mid-range ejection fraction (HFmrEF). In patients with HFpEF as a possible cause of dyspnoea, assessment as to whether diastolic dysfunction is present or not is the first step. Although a large number of indices that reflect diastolic function have been developed, it should be noted that in general there is a large overlap of values in normal subjects and those with diastolic dysfunction. Therefore, a diagnosis of diastolic dysfunction should never be based on single measurements. Current guidelines recommend the measurement of early mitral inflow peak velocity (E), septal and lateral annulus tissue velocities (e’), peak tricuspid regurgitation velocity (TR velocity) and left atrial volume. The diagnosis of diastolic dysfunction is then based on whether a majority of the measured parameters falls into the abnormal range (fig. 2). Following this, additional parameters are then used to assess whether LAP is elevated at the time of investigation. With regards to additional criteria for structural heart disease, left ventricular mass index (LVMI) ≥115 g/m² for males and ≥95 g/m² for females should be considered pathological. Echocardiographic assessment of left ventricular mass is done with either the linear method or 2D-based formulas [7]. The linear method, which uses linear measurement from the parasternal window at the level of the mitral valve leaflet tips, is fast, widely used and a simple method to screen for left ventricular hypertrophy. However, this method tends to overestimate left ventricular mass in subjects with hypertrophy that is limited to the base of the left ventricle. In contrast to the linear methods, 2D-based formulas, such as the area length and truncated ellipsoid methods, underestimate mass in basal septal hypertrophy. Apart from these technical considerations, the indexing of left ventricular mass allows comparisons in subjects with different body sizes, but can lead to underestimation of hypertrophy in obese patients.

An enlarged left atrium is associated with adverse cardiovascular outcomes [13]. Historically, left atrial
size was measured as the anteroposterior diameter derived from M-mode tracings from a parasternal window. However, it is important to realise that the left atrium often dilates asymmetrically along its long axis, and thus measurement in one dimension is inaccurate. Therefore, according to current guidelines the left atrial volume should be measured with the Simpson’s method on two orthogonal planes from apical windows. Also, 3DE holds promises for assessing left atrial volume accurately [34, 15].

Lastly, patients with reduced ejection fraction invariably have diastolic dysfunction, and assessment is limited to determining whether there is elevated LAP, as shown in figure 3.

Evaluation of the right heart

Chronic dyspnoea caused by right heart disorders is not uncommon. Right ventricular function plays an important role in clinical outcomes of many cardio-pulmonary diseases causing chronic dyspnoea. Therefore, in all studies the investigator should systematically evaluate the right heart as well as the left. The assessments should include measurement of right ventricular and right atrial size, and evaluation of right ventricular function as fractional area change (FAC) or tricuspid annular plane systolic excursion (TAPSE). In addition, systolic pulmonary artery pressure (SPAP) should be measured and right atrial pressure approximated [16].

The apical four-chamber view allows estimation of the right heart dimensions. To avoid foreshortening, the image plane should include the base and the apex of the right ventricle. Right ventricular dimensions at end-diastole are obtained at the base (diameter >42 mm), at mid-level (>35 mm) and longitudinally (>86 mm); this differs from measurement of right atrial dimensions, where most often the right atrial area is traced (>18 cm²). Information for estimation of right atrial pressure is provided in subcostal views by measurement of inferior vena cava (IVC) size and collapse ability. In general, an IVC with diameter ≤2.1 cm that collapses >50% suggests normal right atrial pressure (range 0–5 mm Hg), whereas an IVC diameter ≥2.1 cm that collapses ≤50% suggests high right atrial pressure (10–20 mm Hg).

The assessment of right ventricular function is discussed in detail in the context of echocardiographic findings in pulmonary disease.

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**Figure 3:** Algorithm for estimation of left ventricular filling pressures and grading left ventricular diastolic function in patients with depressed left ventricular ejection fraction (LVEF) and patients with myocardial disease and normal LVEF after consideration of clinical and other 2D data. Adapted from Nagueh SF et al. [38]. CAD = coronary artery disease; E/A = ratio of early mitral inflow velocity to mitral diastolic inflow velocity; E/e’ = ratio between early mitral inflow velocity and mitral annular early diastolic velocity; LA = left atrial; LAP = LA pressure; TR = tricuspid regurgitation.
Aetiology of myocardial disease

Besides the detection of ventricular dysfunction causing dyspnoea, echocardiography can also detect the underlying aetiology. First and foremost, coronary artery disease needs to be considered in all patients with chronic dyspnoea, especially when regional wall motion abnormalities at rest or with stress (exercise or dobutamine infusion) are present. Regional wall motion assessment is usually performed by grading the contractility of individual myocardial segments. To provide a standardised classification, the left ventricle is divided into three levels (basal, mid, apical) and 16 segments [17].

Are patients with the primary symptom of dyspnoea at high risk of having coronary artery disease? In a recent study [18] of patients with dyspnoea (but no chest pain) referred for exercise echocardiography, 42% had echocardiographic evidence of ischaemia. During a 3-year follow-up, myocardial infarction, coronary revascularization or death occurred in one fifth of these patients. Hence, patients with dyspnoea have a high likelihood of ischaemia, and cardiac events during follow-up are frequent.

Less common entities, but important causes of chronic dyspnoea, for example non-compaction cardiomyopathy, hypertrophic obstructive cardiomyopathy or amyloidosis can also be identified with echocardiography (fig. 4).

Valvular heart disease

Echocardiography has developed into the first-line diagnostic method for detecting valvular heart disease in recent decades. Aortic stenosis is usually easily diagnosed by using transthoracic imaging. However, in some cases image quality or difficulties in aligning the continuous wave Doppler beam correctly with the flow acceleration through the stenotic aortic valve can preclude grading of aortic valve stenosis when using the transthoracic approach. Thus, in patients with chronic dyspnoea with no other explanation except for a thickened aortic valve on transthoracic echocardiography, a further investigation with transoesophageal echocardiography should be considered. Echocardiography is the standard means for the evaluation of aortic stenosis severity; cardiac catheterisation is no longer recommended as a routine method [19]. Aortic stenosis jet and left ventricular outflow tract (LVOT) velocity measurements have a very low intra- and interobserver variability of 3–4% in an experienced laboratory [20]. Apart from severe aortic stenosis with normal LVEF and a mean gradient of 40 mm Hg or more, other conditions should be considered: severe low-flow low-gradient aortic stenosis (aortic valve area <1 cm², reduced LVEF) and paradoxical low-flow low-gradient severe aortic stenosis (aortic valve area <1 cm², low gradients, preserved ejection fraction and a small stroke volume <35 ml/m²) [21]. Apart from valvular aortic stenosis, rare cases such as subvalvular aortic stenosis

Figure 4: Examples of less common causes of chronic dyspnoea. (A) Hypertrophic obstructive cardiomyopathy; arrow denotes severely hypertrophic interventricular septum. (B) Amyloidosis; arrows denote diffusely thickened myocardium of both the left and right ventricle. (C) Non-compaction cardiomyopathy; non-compacted myocardium (red line) and thin layer of compacted myocardium (white line).
However, shortness of breath is one of the characteristics of chronic dyspnoea. Mitral regurgitation is the most frequent valvular lesion in adults. Evaluation of mitral regurgitation is critical in patients presenting with chronic dyspnoea and a heart murmur. Both the severity and etiology of mitral regurgitation can be assessed with transthoracic echocardiography.

**Constrictive pericarditis**

In patients with chronic dyspnoea combined with signs of right heart failure, constrictive pericarditis is a differential diagnosis. As constrictive pericarditis is potentially reversible, accurate diagnosis is crucial. Constrictive pericarditis is characterised by impaired diastolic cardiac filling and elevated ventricular filling pressures due to a fibrotic, thickened and adherent pericardium [22]. Interestingly, it was one of the very first pathological conditions to be recognised [23]. The main causes in the developed world range from pericarditis to cardiac surgery and mediastinal irradiation. Most frequently the cause remains idiopathic or is, in developing countries, still mainly tuberculosis [24]. Echocardiographic recognition remains challenging, as in up to one fifth of cases the pericardium is not thickened and constrictive pericarditis is present with a normal pericardium [25].

Welch et al. [26] compared 130 patients with surgically confirmed constrictive pericarditis with 36 patients with restrictive myocardopathy or severe tricuspid regurgitation in whom constrictive pericarditis was ruled out. Respiration-related ventricular septal shift, preserved/increased mitral annular E’ velocity, and prominent hepatic vein expiratory diastolic flow reversals were independent predictors for the diagnosis of constrictive pericarditis. The combination of ventricular septal shift with either mitral E’ ≥9 cm/s or a hepatic vein reversal ratio ≥0.79 corresponded to a sensitivity of 87% and a specificity of 91% for diagnosing constrictive pericarditis. Therefore, when performing echocardiography on patients with chronic dyspnoea and the suspicion of constrictive pericarditis these specific assessments should always be included in the examination.

**Echocardiography findings in pulmonary disease**

Thus far we have focused on left ventricular diseases. However, shortness of breath is one of the characteristic features of pulmonary artery hypertension (PAH) [27]. Certain two-dimensional echocardiographic features suggest right ventricular pressure overload, for example right ventricular hypertrophy, a dilated right ventricle or a “D-shaped” left ventricular cavity due to leftward displacement of the interventricular septum. Doppler echocardiography is the primary tool for estimating pulmonary artery pressures by measuring tricuspid regurgitation velocity [28]. As a result of the asymmetrical shape of the right ventricle and because the contraction mainly occurs along the longitudinal plane [29], many investigators have tried to identify echocardiographic parameters for the proper evaluation of right ventricular function. Forfia et al. [30] showed that systolic displacement of the tricuspid annulus toward the right ventricular apex (longitudinal plane), referred to as tricuspid annular plane systolic excursion (TAPSE), closely correlates with right ventricular ejection fraction and reflects prognosis in PAH. The percentage right ventricular fractional area change (RVFAC), defined as (end-diastolic area minus end-systolic area)/end-diastolic area × 100, is another way to measure right ventricular systolic function [16]. A recent study showed that RVFAC is the best of commonly utilised echocardiographic 2D measures of right ventricular function and correlates best with MRI-derived right ventricular ejection fraction [31]. RVFAC was found to be an independent predictor of heart failure and mortality in patients after thrombolysis for pulmonary embolism [32]. To evaluate RVFAC a proper tracing of the endocardial border in apical four-chamber (A4C) view is required (fig. 5).

Any patient with unexplained PAH should be evaluated for chronic thromboembolic pulmonary hypertension (CTEPH). CTEPH causes intermittent symptoms, mainly dyspnoea and exercise intolerance, which start when there is a functional loss of more than 60% of the pulmonary vasculature [33]. As a general rule, mean pulmonary artery pressure is lower in CTEPH than it is in PAH [34]; a possible explanation is the assumption that right ventricular adaptation may be poorer principally because of the older age of CTEPH patients. If the suspicion for CTEPH clinically and on echocardiography is high, the next diagnostic step is the detection of a mismatch perfusion defect on ventilation/perfusion scan [35].

We have already mentioned the difficulties of assessing right ventricular function. Despite their widespread application, TAPSE and RVFAC represent indirect and imperfect measurements. Deformation imaging using 2D-speckle tracking strain analysis appears to be a more robust technique to assess right ventricular function. In the setting of CTEPH, it was re-
Recently shown that greater right ventricular strain correlated with higher 6-minute walk time prior to pulmonary thromboendarterectomy. Several studies suggested an improvement of the 6-minute walk time after pulmonary thromboendarterectomy [36], leading to the assumption that right ventricular strain could represent a marker for functional improvement after the procedure [37].

In summary, we would like to emphasise that the mentioned alterations and diseases are just examples of the diagnostic value of echocardiography in patients with chronic dyspnoea. Certainly, other relevant disorders causing chronic dyspnoea, such as mitral stenosis or chronic pericardial effusion, which are missing from our discussion, may also be evaluated by means of echocardiography.

Conclusion

Chronic dyspnoea remains challenging to evaluate because of the many diverse causes for this symptom. Echocardiography is the first-line diagnostic imaging test to evaluate myocardial, valvular or pericardial disease as an aetiology for chronic dyspnoea. Echocardiography may aid in the diagnosis of thromboembolic diseases and pulmonary artery hypertension as well. When interpreted together with the clinical presentation, transthoracic echocardiography is a fundamental diagnostic tool for the evaluation of patients with chronic dyspnoea and contributes to directing further management.

Disclosure statement

No financial support and no other potential conflict of interest relevant to this article was reported.

References

The full list of references is included in the online version of the article at www.cardiovascmed.ch.
Echocardiographic predictors of post-implantation right ventricular failure

Right ventricular function before LVAD implantation


*Service de Cardiologie, Département Cœur-Vasculaire, Centre Hospitalier Universitaire Vaudois, Université de Lausanne, Switzerland

Summary

Left ventricular assist devices are increasingly used to treat selected advanced heart failure patients, because of the limited number of donors available for heart transplantation. Newer generation devices portend a lower complication rate, and outcomes are now similar to orthotopic heart transplantation. However, despite an increase in the number of implants in the last years, 25% of patients develop right ventricular failure, which remains a major concern. Careful preoperative right ventricular function evaluation is mandatory, and novel echocardiographic load-independent right ventricular function parameters are validated as outcome predictors in these patients. We report the two first HeartMate III implantations in Switzerland, with description of the echocardiographic work-up that helped the perioperative management in regard to the right ventricular function.

Key words: advanced heart failure, right ventricular function, left ventricular assist device

The incidence of advanced heart failure is increasing despite recent progress with heart failure treatment [1]. Heart transplantation still remains the gold standard treatment for selected patients with advanced heart failure; however, the paucity of donor hearts has mandated the development of other treatment options. The arrival of third-generation rotational-flow pumps has significantly decreased the number of technical complications compared with former assist devices. Today, short-term survival after left ventricular assist device (LVAD) implantation and after orthotopic heart transplantation (HTx) are similar [2], suggesting that this technology is a reasonable therapeutic option in advanced heart failure. As a consequence, the number of implants has substantially increased in the last years. Right ventricular (RV) failure after LVAD implantation, however, still remains a major concern affecting up to 25% of all patients [3]. Several studies have identified scores including clinical, laboratory and haemodynamic parameters for prediction of RV failure after LVAD implantation but, unfortunately, these scores have not been evaluated outside of the cohort in which they were derived [3]. More recently, Dandel et al. proposed measurement of two RV echocardiographic contractile parameters for prediction of RV failure: RV load-corrected peak systolic longitudinal strain rate (Corr-PSSrL) and right ventricular load adaptive index (LAIA). Both parameters reflect the RV adaptability to load. The Corr-PSSrL cut-off >24 mm Hg/s plus the LAI cut-off >14 identifies patients who remain free from postoperative RV failure. The Corr-PSSrL cut-off ≤24 mm Hg/s plus LAI cut-off ≤14 suggests RV failure will occur after LVAD implantation (positive predictive values: 97 and 83%, respectively; negative predictive values: 87% and 97%, respectively) [4].

Here, we report application of RV load Corr-PSSrL and LAIA measurement for prediction of RV function in the Switzerland’s first two cases of HeartMate III implantation.

The first patient was a 54-year-old man, who underwent implantation of the HeartMate III left ventricular assist device in November 2015 (table 1). The medical history is noteworthy for inferior posterior and anteroseptal ST segment elevation myocardial infarction (STEMI) at

Table 1: Baseline characteristics.

<table>
<thead>
<tr>
<th></th>
<th>Patient 1</th>
<th>Patient 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>54</td>
<td>61</td>
</tr>
<tr>
<td>Aetiology</td>
<td>Ischaemic</td>
<td>Idiopathic</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>NT pro-BNP (ng/l)</td>
<td>2579</td>
<td>35668</td>
</tr>
<tr>
<td>Haemoglobin (g/l)</td>
<td>111</td>
<td>126</td>
</tr>
<tr>
<td>Creatinine (mmol/l)</td>
<td>95</td>
<td>141</td>
</tr>
<tr>
<td>Total bilirubin (mmol/l)</td>
<td>12</td>
<td>86</td>
</tr>
<tr>
<td>PVR (Wood units)</td>
<td>4.5</td>
<td>3.1</td>
</tr>
<tr>
<td>mPAP (mm Hg)</td>
<td>52</td>
<td>46</td>
</tr>
<tr>
<td>Cardiac index (l/min/m²)</td>
<td>1.8</td>
<td>1.9</td>
</tr>
</tbody>
</table>

LVEF = left ventricular ejection fraction; PVR = pulmonary vascular resistance; mPAP = mean pulmonary arterial pressure; NT pro-BNP = N-terminal of B-type natriuretic peptide

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with an ejection fraction (LVEF) of 25% and severe functional mitral regurgitation. Because of a QRS width of 154 ms, the implanted cardioverter defibrillator (ICD) was up-graded with a cardiac resynchronisation therapy-defibrillator (CRT-D). Cardiopulmonary exercise testing revealed a significantly reduced peak oxygen consumption (12.9 ml/min/kg; 39% of the predicted peak VO\textsubscript{2}); therefore, the patient was listed for HTx. In the following weeks, the patient suffered from intermittent episodes of sustained slow ventricular tachycardia successfully treated with amiodarone; however, severity of heart failure symptoms progressed to INTERMACS level 4 and, in parallel, cardiac index at rest decreased to 1.8 l/min × m\textsuperscript{2}, which indicated a need of LVAD implantation.

Preoperative echocardiographic RV assessment showed a severely dilated right ventricle with important dysfunction. However, the LAI\textsubscript{RV} (measured value 52) and Corr-PSSrL (70.6 mm Hg/s) predicted perioperative adaptability of RV function despite of increased pulmonary pressures (table 2 and fig. 1). Implantation was uneventful; pulmonary artery pressures with LVAD support remained high (pulmonary artery pressure 52/21 mm Hg, mPAP 30 mm Hg); nevertheless, the calculated cardiac output of 4.4 l/min (pump rotor speed 5500 rpm, pump power 4.3 watts) indicated adequate RV function. At discharge, 3 weeks after implantation, the patient was in NYHA functional class II and heart failure drug treatment was re-established. In August 2016, the patient had a successful HTx.

The second case was a 61-year-old male with dilated cardiomyopathy of nonischaemic origin (table 1). Despite optimal medical therapy, the LVEF decreased from 33% to 24%, and with the advent of left bundle-branch block the patient was implanted with a CRT-pacemaker (he refused defibrillator implantation). He returned for hospitalisation with anasarca and clinical signs of peripheral vasoconstriction several months later. The echocardiogram at that time showed biventricular dilation with severe biventricular dysfunction but absence of greater than grade 2 mitral or tricuspid regurgitation; systolic pulmonary artery pressure was 50 mm Hg as measured with echocardiography. Catecholamine treatment in combination with intravenous diuretics provided clinical stabilisation, but the patient remained dependent on vasoconstrictor treatment (INTERMACS level 2), which was the reason for LVAD implantation. Preoperative right ventricular function (table 2 and fig. 1) showed a LAI\textsubscript{RV} of 19 (cut-off >14) and a Corr PSSrL of 18 mm Hg/s (cut-off >24 mm Hg/s) indicating an increased risk of postoperative RV failure. In fact, bilirubin was already increased, suggesting an impact of RV dysfunction on

Table 2: Preoperative assessment.

<table>
<thead>
<tr>
<th></th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Normal values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right heart dysfunction</td>
<td>Important</td>
<td>Important</td>
<td></td>
</tr>
<tr>
<td>TAPSE (mm)</td>
<td>15</td>
<td>12</td>
<td>&gt;17</td>
</tr>
<tr>
<td>TAPSm (S’ wave) (cm/s)</td>
<td>8.4</td>
<td>8.5</td>
<td>&gt;9.5</td>
</tr>
<tr>
<td>RVD1 (mm)</td>
<td>44</td>
<td>51</td>
<td>&lt;41</td>
</tr>
<tr>
<td>FAC (%)</td>
<td>15</td>
<td>23</td>
<td>&gt;35</td>
</tr>
<tr>
<td>MPI</td>
<td>0.6</td>
<td>N/A</td>
<td>&lt;0.4</td>
</tr>
<tr>
<td>dP/dT (mm Hg/s)</td>
<td>400</td>
<td>240</td>
<td>RV dysfunction if &lt;400</td>
</tr>
<tr>
<td>TR max gradient (mm Hg)</td>
<td>72</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>LAI</td>
<td>52</td>
<td>19</td>
<td>&gt;14</td>
</tr>
<tr>
<td>RV Load Corr PSSrL (mm Hg/s)</td>
<td>70.6</td>
<td>18</td>
<td>&gt;24</td>
</tr>
</tbody>
</table>

TAPSE = tricuspid annular plane systolic excursion; TAPSm = tricuspid annular plane systolic motion; RVD1 = basal RV diameter, end-diastolic; FAC = fractional area change (%); MPI = myocardial performance index; dP/dT of TR jet between 1 m/s and 2 m/s; LAI = load adaptive index; RV Load Corr PSSrL = load corrected peak right ventricular systolic longitudinal strain rate

Figure 1: Load adaptive index and load-corrected peak systolic longitudinal strain rate. Patient 1 (left panels A to C); patient 2 (right panels D to F). A+D: continuous-wave Doppler used to measure the tricuspid regurgitation jet velocity-time integral; B+E: end-diastolic modified apical 4 chambers views used to define end-diastolic right ventricular area and end-diastolic RV length RVD3; C+F: peak systolic longitudinal Strain Rate measurements (Panels C and F).
hepatic function. Therefore, LVAD implantation was complemented by a temporary external right ventricular assist device (venovenous extracorporeal circulation, Levitronix) in the operating room. Postoperative course was noteworthy for haemodynamic instability but the patient was completely weaned from RV support on postoperative day 9.

Discussion

RV failure after LVAD implantation occurs in 15–25% of patients and is associated with high perioperative morbidity and mortality [3, 4]. It is caused by either myocardial RV dysfunction, or elevation of filling pressures and/or pulmonary vascular resistance. In the former situation, improvement of RV function after LVAD implantation is rare and these patients have a high risk of RV failure after LVAD implantation. In contrast, RV function should improve in the latter case, because LVAD treatment decreases LV and, subsequently, RV filling pressures if precapillary pulmonary hypertension is absent. Usual RV function parameters such as visual evaluation, fractional area change or tricuspid annular plane systolic excursion (TAPSE) are load-dependent [3, 4]. Therefore, measurement of these parameters does not allow conclusive assessment of RV myocardial contractility because of the direct impact of RV volume on these parameters. Doppler-derived indices (such as dP/dt and myocardial performance index) are load-dependent too. Peak longitudinal systolic strain rate (PSSrL) is likewise load-dependent; however, correction of PSSrl by the right ventricular-atrial gradient (PSSrL · ΔP RV–RA = Corr PSSrL) permits derivation of a load-independent parameter that reflects RV contractility. RV PSSrl is measured by using a RV modified apical 4-chamber view. Of importance, the narrowest ultrasound sector width possible should be used since the frame rate must be >50 Hz in order to achieve an adequate speckle tracking. To ensure correct speckle tracking, the RV lateral free wall must be correctly visible, which is difficult in about 10% of cases [4].

The LAIEdv is a distinctly different approach to assessment of RV contractile function and based on the relationship between RV load and RV dilatation, taking into account the right atrial pressure. It is calculated using the following formula:

\[
\text{LAIEdv} = \frac{\Delta P_{RV-RA}}{\text{RVEDV} \cdot L_{ID}} = \frac{\text{VTI}_{10} \times L_{ID}}{A_{ID}}
\]

where VTI10 is the tricuspid regurgitation velocity-time integral corresponding to the RV-RA pressure gradient, (ΔP0) is the easily measurable RV end-diastolic area replacing RV end-diastolic volume (RVEDV), and LID is the long-axis length in end-diastole. In summary, measurement of Corr PSSrL and LAIEdv permits evaluation of RV myocardial performance before LVAD implantation. However, other echocardiographic parameters of RV function merit consideration, in particular in patients with tricuspid regurgitation of greater than grade 2 and a systolic pulmonary artery pressure <50 mm Hg. These patients present a high risk for RV failure after LVAD implantation (predictive value 92.9%), especially if TAPSE is <8 cm/s in addition (predictive value for RV failure >92.9%).

Conclusion

RV failure after LVAD implantation is a concern because of high perioperative morbidity and mortality. Preoperative evaluation of RV function on the basis of the load-independent parameters Corr PSSrL and LAIEdv permits prediction of post-operative RV function. Therefore, these parameters should be taken into account when LVAD treatment is an option for patients with end-stage heart failure. In practice, low risk of postoperative RV failure identifies the end-stage heart failure patient who should benefit from LVAD placement alone. For the heart failure patient with moderate to high risk for postoperative RV failure, temporary external right ventricular assist device placement in the operating room should be considered.

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References

A rare complication of a rare tumour

Right ventricle metastasis of pulmonary sarcomatoid carcinoma

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A 79-year-old female was diagnosed with a pulmonary sarcomatoid carcinoma (PSC) of the left lower lobe (stage IB) and underwent an open lobectomy and systematic lymph node dissection. Because of the early tumour stage, the molecular genetic characteristics of the tumour and the patient’s advanced age, adjuvant chemotherapy was not given. The patient was followed up every 3 months and, except for slight tiredness and dyspnoea, she did well.

One year later, the patient went to her general practitioner (GP) because of weakness, weight loss, diarrhoea and exertional dyspnoea. The GP sent her for the annually scheduled computed tomography scan (CT), which showed a soft tissue density mass measuring 6x6 cm in the right ventricle of the heart, pulmonary embolism in a right segmental artery and suspect lesions in the right upper lobe of the lung and both adrenal glands. Echocardiography revealed that the right ventricular mass was almost completely filling the ventricle including the tricuspid valve (fig. 1a). There was no sign of right heart failure. Cardiac magnetic resonance imaging showed that the mass involved the myocardium, originating from the anterior wall of the heart (fig. 2). The most likely differential diagnosis included a metastasis or a primary tumour. Because of the moderate contrast uptake, an entire thrombus was unlikely.

The case was discussed on an interdisciplinary basis. On the basis of the patient’s history, an intracardiac recurrence of the sarcomatoid carcinoma was very likely. Because initial molecular genetic analysis had shown

![Figure 1: TTE parasternal short-axis and apical four-chamber view at a) day 0, b) day 12 and c) day 53 showing an astonishing decrease of tumour mass on Erlotinib treatment with tumour relapse after treatment had been stopped intermittently.](image-url)
an activating EGFR mutation, tyrosine kinase inhibitor therapy with erlotinib was initiated. The risk of an imminent pericardial tamponade or myocardial rupture was discussed and surgical options were evaluated, but due to the high risk, no surgical procedure seemed reasonable. Seven days after initiating erlotinib the echocardiography already showed a shrunken right ventricular mass and another 5 days later the tricuspid valve became visible again (fig. 1b), leading to a moderate to severe tricuspid insufficiency. The patient was discharged in a good general condition and erlotinib treatment was continued.

In the following weeks the patient suffered from Clostridium difficile colitis and erlotinib had to be stopped intermittently. The tumour mass in the right ventricle regrew immediately (fig. 1c). Shortly after, CT showed a new big tumour mass in the central abdomen and progression of the metastases of the adrenal glands.

Heart metastases have an incidence at least 100 times higher than that of primary tumours of the heart [1]. Usually, cardiac metastases are small and multiple; intracavitary growth of single large tumour lesions is rare. Pulmonary sarcomatoid carcinoma (PSC) is a rare, poorly differentiated subtype of non-small-cell lung cancer and generally runs an aggressive clinical course with a poor prognosis. PSC metastasises via lymph and blood vessel routes to the same anatomical sites as other non-small-cell lung cancers [2]; heart metastases of PSC are very rare. According to the literature there is only one case report of PSC involving the heart: Campagnoli et al. reported a case of PSC with left atrial extension through the pulmonary vein [3].

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Dyspnoea and epigastric discomfort after an emotional event

Loss of biventricular pacing: What is the problem?

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Case presentation
A 74-year-old man with a long history of ischaemic dilated cardiomyopathy and a severely depressed left ventricular ejection fraction (LVEF) of 15% went to the hospital because of dyspnoea and epigastric discomfort for six days, triggered by an emotional event.
Seven days before, he had a scheduled ambulatory cardiological assessment, including a clinical and biological work up, interrogation of his cardioverter resynchronisation therapy-defibrillator device (CRT-D), which showed biventricular pacing of 99% without any arrhythmia, and echocardiography; the global clinical situation was considered stable under both maximal medical and resynchronisation therapies.

The day after, the patient suffered a violent emotional shock (the death of his beloved cat), which was followed by epigastric discomfort and progressive dyspnoea. He waited a week before the present consultation. Clinically the patient was normotensive and normocardiac; he showed signs of hypoperfusion with cold extremities and discreet marbling on legs. Lung auscultation was normal. The rest of the physical examination was unremarkable.
The initial ECG is shown in figures 1 and 2.

Question
What is the problem on the ECG?

Figure 1: Standard 12-lead ECG at admission.
Commentary

The ECG shows a regular wide-complex (QRS duration of 160 ms), normocardiac rhythm (95/min) with an atypical right bundle-branch block morphology (qR in leads V1 to V4) and right axis deviation. Positive P waves without any relation with QRS complexes can easily be seen in lead I and in inferior leads and negative in aVR suggesting a sinus node origin (arrows). All these features are diagnostic of a slow ventricular tachycardia (VT) [1, 2]. The last visible QRS complex is a ventricular premature beat and a red mark is superimposed to the fifth QRS complex in the extremity leads and to the second QRS complex in precordial leads.

The laboratory workup showed increased N-terminal pro-B-type natriuretic peptide (NT-proBNP) to twice the reference value. A transthoracic echocardiogram confirmed the pre-existing poor LVEF. Interrogation of the CRT-D showed incessant episodes of nonsustained and sustained VT for six days and, accordingly, depressed biventricular pacing to 70%. The arrhythmias were classified as ventricular sense episodes by the device and not as VT because of the slow frequency of 95 bpm, which was below the programmed VT detection rate of 128 bpm (470 ms). The VT was successfully overdriven with an accelerated resynchronised pacing rate of 100 bpm.

The patient underwent an electrophysiology study that could not induce any ventricular arrhythmia: local abnormal ventricular activities were diffusely eliminated and a line around a large anterior infarct scar was ablated.

After the procedure, the ECG showed a resynchronised paced rhythm at 75 bpm (fig. 3). After a long discussion, destination therapy was accepted by the patient.

This case reminds us that a patient with a CRT-D may present with prolonged unrecognised slow VT leading to a loss of resynchronisation and haemodynamic instability [3]. In these situations, an ECG is mandatory as simple pulse check by the patient or the physician will be confusing.

Indeed, VT above the tachycardia detection interval may be associated with clinical symptoms such as angina, palpitations, heart failure and syncope [4, 5]. Independent predictors of slow VTs are impaired left ventricular function, inducible and spontaneous

Figure 2: Standard 12-lead ECG at admission showing regular wide-complex (QRS 160 ms), normocardiac rhythm with an atypical right bundle-branch block morphology (qR in leads V1 to V4) and right axis deviation. Sinus P waves are indicated with purple arrows. See text for details.
monomorphic VTs, and class III anti-arrhythmic drugs (amiodarone).

This case also reminds us that a violent emotional event may trigger ventricular arrhythmias and be the cause of a sudden cardiac death.

Disclosure statement
No financial support and no other potential conflict of interest relevant to this article was reported.

References
Letter to the editor

LAA ocluders for all patients with atrial fibrillation – an overreaching statement

With great interest we read the article by Ghenzi et al. on “The evolving role of left atrial appendage (LAA) occlusion” published in the November 16th issue of Cardiovascular Medicine. However, the three conclusions drawn by the authors warrant some comments. The conclusion that “LAA occlusion should be considered a first-line therapy for stroke prevention and discussed as a treatment option with all patients with atrial fibrillation” is daring. Based on the 2016 ESC Guidelines for the management of atrial fibrillation, LAA occlusion is currently considered a IIb (level of evidence C) indication in patients with atrial fibrillation, an indication for oral anticoagulation (OAC) and at the same time a clear contraindication for OAC. The data presented by the authors shows that in the patients undergoing LAA occlusion there were reasons for withholding OAC in the vast majority of cases, with a fair share (42.5%) of the patients having previous relevant bleeding. This means that the authors actually appear to use LAA occlusion in patients with an absolute or relative contraindication to OAC. Therefore, the statement that LAA occlusion should be considered a first-line therapy is not only not supported by current guidelines but also not backed by the presented data.

The conclusion that “LAA occlusion could be performed with a low complication rate” is at least debatable and depends on the “willingness-to-accept complications” threshold discussed with the patient. A major complication rate of 4.9% may be acceptable if there are no alternatives (i.e., in patients with a clear contraindication to OAC) but may be considered high when starting to use LAA occlusion as first-line therapy.

Finally, the conclusion that “LAA occlusion can be performed with high success rate” is supported by the presented data with a reported procedural success rate of 98.4%. A high procedural success rate may rightfully hold an established preventive therapy from patients and wait until they experience a complication. The authors criticise left atrial appendage occlusion (LAAO), but leave the reader without any alternatives. Knowing that non-vitamin-K-antagonist oral anticoagulants (NOACs) have a discontinuation rate of at least 15% (RE-LY [1]) and >15% major and clinically relevant bleedings per year [2], the complication rate of 4.9% for LAAO is at least competitive.

During the years 2012–2015, a total of 273 LAAO have been performed at the University Hospital Zurich, 428 at the University Hospital Berne and only 25 at the University Hospital Basel. We respect our colleagues who wait until stronger evidence becomes available, but we believe that it is the duty of a university hospital to change daily practice for the better for our patients and to create new evidence. Since we share the same passion for quotes as the authors do, we would like to give Kühne et al. two quotes along the way: the former US president John F. Kennedy said in 1963 “Change is the law of life. And those who look only to the past or the present are certain to miss the future.” And in contrast to the previous quote, Wilhelm II Emperor of Germany (1916) once said “I believe in the horse, the automobile is a temporary appearance.”

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Authors’ reply

With pleasure we read the letter to the Editor by Kühne et al. We highly respect the conservative opinion of our colleagues. However, in our daily practice we are confronted with an important question: should we really withhold an established preventive therapy from patients and wait until they experience a complication? The authors criticise left atrial appendage occlusion (LAAO), but leave the reader without any alternatives. Knowing that non-vitamin-K-antagonist oral anticoagulants (NOACs) have a discontinuation rate of at least 15% (RE-LY [1]) and >15% major and clinically relevant bleedings per year [2], the complication rate of 4.9% for LAAO is at least competitive.

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Special communication

Bereifung von PD Dr. Ronald K. Binder als Chefarzt Kardiologie am Universitären Lehrkrankenhaus Wels-Grieskirchen

Die Leitung des Klinikums Wels-Grieskirchen hat PD Dr. Ronald K. Binder, FESC und Oberarzt an der Klinik für Kardiologie des Universitären Herzcentrums Zürich, zum neuen Chefarzt für Kardiologie ernannt.

Die Klinikum Wels-Grieskirchen ist als Universitäres Lehrkrankenhaus der Medizinischen Universität Wien das zweitgrößte interventionalle kardiologische Zentrum in Österreich nach dem Allgemeinen Krankenhaus in Wien. Es umfasst 100 Betten, 10 „Intermediate Care Unit“-Betten, 3 Katheterlabors und bietet sämtliche modernen perkutanen Eingriffe und 24-Stunden-Service für primäre perkutane koronare Interventionen an (transarterielle Klappenimplantationen, MitraClip u. a.m.). Ebenso verfügt die Klinik über ein ausgebautes Device-Programm mit ICD- und CRT-Implantationen und Pulmonalvenen-Isolations-Operationen.


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