Introduction

Mechanical Circulatory Support Systems (MCSS) are successfully used in the treatment of acute and chronic heart failure. Extracorporeal Membrane Oxygenation (ECMO) is the most frequently used MCCS in the postoperative cardiac failure; however, complication rates significantly increase after the second week of implementation [1]. The mid- and long-term implementations include Intra Aortic Balloon Counter Pulsation (IABP), Ventricular Assist Devices (VAD) and Total Artificial Heart (TAH). Intra aortic balloon counter pulsation has a very limited utility when the pediatric patient population is considered. Today, the most effective treatment option for cardiac failure is Cardiac Transplantation (CTx).

There are Six Targets to Be Addressed When MCSS Is to Be Implemented

Bridge to transplantation

The patients in the waiting list for CTx are included.

Destination therapy

This rare target is the final treatment modalities for the patients who are not candidates for CTx. Rare examples in the pediatric population include the patients with Duchenne muscular dystrophy [2].

Bridge to recovery

The MCSS is implemented for the period of convalescence from a transient myocardial dysfunction such as colchicum intoxication.

Bridge to decision

The patient is supported until a decision is made whether CTx or destination therapy will be considered.

Bridge to bridge

The patients in whom the short term device support is changed to a long term MCCS are involved under this heading.

Bridge to eligibility

This target includes the patients who become eligible for CTx after a period of MCCS due to the transiently increased pulmonary arterial blood pressure and/or vascular resistance.

Mechanical circulatory support systems have been developed with pioneering efforts by DeBakey in early 1960’s [3,4]. On the other hand, the device-patient size mismatch has been encountered as an important problem when the pediatric MCCS are considered. Although the pediatric assist device implementations raised as modifications of adult MCCS, the well-known pediatric VAD, Berlin Heart Excor was approved by US Food and Drug Administration (FDA) in 2011 [5].
Another important milestone in pediatric MCCS development is the PumpKIN (Pumps for kids, infants and neonates) program which is focused on pediatric MCCS since 2008 [6].

**Patient Selection**

The common property of all the indications for implementation of MCCS is clinically significant acute or chronic heart failure despite maximal medical treatment. In general, in cases where irreversible organ system damage and active infections are considered, MCCS are contraindicated. There are several exceptions for this general overview, such as treatment of postoperative heart failure and active respiratory infections with ECMO [7]. In cases with prematurity, low birth weight and some types of chromosomal abnormalities, MCCS implementation may be contraindicated [8]. On the other hand, recent reports state that infants with small gestational age have a cardiovascular profile which carries more risk for ventricular dysfunction [9]. Therefore, development of smaller MCCS for implementation in infants with smaller body weight is mandatory in future.

**Device Selection**

Three types of variables are encountered while selecting an appropriate device for the pediatric patient. The type of support (cardiac or cardiopulmonary), possible duration of the support and the patient size (body surface area). Short term MCCS devices are described as duration less than 14 days. The most common options are ECMO, Jostra Rota Flow Centrifugal Pump (Maquet Cardiovascular, Wayne, NJ, USA), Thoratec PediMag (Thoratec Co., Pleasanton, CA, USA) and Tandem Heart (Cardiac Assist Inc., Pittsburgh, PA, USA). Long term support devices are Berlin Heart EXCOR (Berlin Inc., Berlin, Germany), Thoratec VAD (IVAD/PVAD; Thoratec Co., Pleasanton, CA, USA), Heart Ware HVAD (Heart Ware Systems, Farmington, MA, USA), Heart Mate-II (Thoratec Co., Pleasanton, CA, USA), (Table 1) summarizes the main technical properties of these MCCS devices [8]. (Figure 1) represents the commonly used ventricular assist devices.

**Complications**

Probably the most feared complication during the MCCS period is stroke. Stroke may be caused either by embolization or hemorrhage. However, cases with embolic stroke are more commonly encountered, especially in cases where pulsatile devices are used [10]. The MCCS where the hemorrhage may become a major complication is ECMO. On the other hand, infections, renal-hepatic dysfunction, pancreatitis and other complications may be encountered.

**Pediatric Cardiac Transplantation**

Pediatric CTx has developed since the initial efforts of Dr. Adrian Kantrowitz, who transplanted hearts to infants [11]. Surgical technique, technological developments and more importantly, development of new drugs for immunosuppression had effects on this successful history. More than 11,000 pediatric cardiac transplantations have been performed since 1967 [12]. The transplanted patients are followed up with life-long immunosuppressive treatment. Several complications may be encountered in this follow up period such as coronary allograft vasculopathy, infections and malignancies. A recent paper reports the survival of pediatric CTx as (median) 19.7 years in infants, 16.8 years in 1-5 years of age, 14.5 years in 6-10 years of age and 12.4 years in 11-17 years of age [13]. The mortality rates are the highest at the first postoperative year which steadily decreases afterwards. Acute and chronic rejection are the leading causes of mortality in the early postoperative period, however, coronary allograft vasculopathy is responsible for most of the mortalities in the following years. The etiology of coronary allograft vasculopathy is thought to be multifactorial including viral infections, hypertension, rejection episodes, hyperlipidemia and secondary diabetes mellitus.

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Table 1: Properties of the mechanical circulatory support devices implemented in children [12].

<table>
<thead>
<tr>
<th>Device Location</th>
<th>Flow</th>
<th>Power Supply</th>
<th>SV (mL) or (rpm)</th>
<th>Flow capacity (L/min)</th>
<th>Body Surface Area (m²)</th>
<th>Patient Mobilization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short Term</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rota Flow</td>
<td>EC</td>
<td>Continuous</td>
<td>EM</td>
<td>0-5000 rpm</td>
<td>0-10</td>
<td>no lower limit</td>
</tr>
<tr>
<td>Pedi Mag</td>
<td>EC</td>
<td>Continuous</td>
<td>EM</td>
<td>0-5500 rpm</td>
<td>&lt;1.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Tandem Heart</td>
<td>EC</td>
<td>Continuous</td>
<td>Electric</td>
<td>3000-7500 rpm</td>
<td>&lt;5</td>
<td>&gt;1.3</td>
</tr>
<tr>
<td><strong>Uzun Dönem</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excor</td>
<td>EC</td>
<td>Pulsatile</td>
<td>Pneumatic</td>
<td>10,25,30,50, 60, 80 mL</td>
<td>Variable</td>
<td>0.2-1.3</td>
</tr>
<tr>
<td>Pvad/Ivad</td>
<td>EC/IC</td>
<td>Pulsatile</td>
<td>Pneumatic</td>
<td>65 mL</td>
<td>&lt;7</td>
<td>&gt;0.7</td>
</tr>
<tr>
<td>Heart Ware HVAD</td>
<td>IC</td>
<td>Continuous</td>
<td>EM</td>
<td>2400-3200 rpm</td>
<td>&lt;10</td>
<td>&gt;1</td>
</tr>
<tr>
<td>Heart Mate II</td>
<td>IC</td>
<td>Continuous</td>
<td>Electric</td>
<td>6000-15000 rpm</td>
<td>&gt;2.5</td>
<td>&gt;1.4</td>
</tr>
</tbody>
</table>

Result

Although the gold standard treatment option for end-stage pediatric heart failure is cardiac transplantation, mechanical circulatory support systems are deemed mandatory both for prolonging the lives of the selected patients in the waiting list and for the ones who are not eligible for transplantation.

References