Mechanical Circulatory Support for the Failing Heart
Departments of Bioengineering, Surgery & the McGowan Institute for Regenerative Medicine

University of Pittsburgh
The Heart

- Average HR: 72 BPM
  - Beats 38,000,000 times a year
- Average SV: 82ml
  - 8193 L per day
- Cardiac output
  - \( CO = HR \times SV \)
  - Average CO: 5-6 L/m
- Cardiac Index
  - \( CI = \frac{CO}{BSA} \)
  - 2.5-4.0 L/min/m\(^2\)
Diastole

Resting and Filling
Systole

Contracting and Emptying
The scourge of heart disease
U.S. Population = 327,873,532 as of 12/25/2018
(4.28% of the world population)
Percentage breakdown of deaths attributable to cardiovascular disease (United States: 2015)
Chart 25-2. The 22 leading diagnoses for direct health expenditures, United States, average annual 2013 to 2014 (in billions of dollars).
### NYHA Classification

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>No limitation of physical activity. Ordinary physical activity does not cause undue fatigue, palpitation, dyspnea, or angina.</td>
</tr>
<tr>
<td>Class II</td>
<td>Slight limitation of physical activity. Patients are comfortable at rest. Ordinary physical activity results in fatigue, palpitation, dyspnea, or angina.</td>
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<tr>
<td>Class III</td>
<td>Marked limitation of physical activity. Patients are comfortable at rest. Less than ordinary activity causes fatigue, palpitation, dyspnea, or angina.</td>
</tr>
<tr>
<td>Class IV</td>
<td>Inability to carry on any physical activity without discomfort. Symptoms of heart failure or the angina syndrome may be present even at rest. If any physical activity is undertaken, discomfort is increased.</td>
</tr>
</tbody>
</table>
CHRISTIAAN BARNARD

First heart transplant:
December 3, 1967.
Patient - Louis Washkansky.

“We did not realize it was going to be such a big thing. There were no photographers at the operation.”
### TTX Registry Database: Number of Transplants Reported

<table>
<thead>
<tr>
<th>Organ</th>
<th>Transplants Performed from July 1, 2016 through June 30, 2017</th>
<th>Total Transplants Performed through June 30, 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adult</td>
<td>Pediatric</td>
</tr>
<tr>
<td>Heart</td>
<td>4,547</td>
<td>598</td>
</tr>
<tr>
<td>Heart-Lung</td>
<td>47</td>
<td>5</td>
</tr>
<tr>
<td>Lung</td>
<td>4,095</td>
<td>91</td>
</tr>
</tbody>
</table>

2018

ISHLT • INTERNATIONAL SOCIETY FOR HEART AND LUNG TRANSPLANTATION

JHLT. 2018 Oct; 37(10): 1155-1206
All pair-wise comparisons were significant at p < 0.05 except adult lung vs. pediatric lung and adult heart-lung vs. pediatric heart-lung.
Data derived from Organ Procurement and Transplantation Network.\textsuperscript{7}
Pediatric Heart Transplants
Recipient Age Distribution (Transplants: January 2004 – June 2017)

Number of Transplants

Recipient Age (Years)

<1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

JHLT. 2018 Oct; 37(10): 1155-1206
City's 1st Jarvik heart implanted

By Jeffery Fraser

The Pittsburgh Press

Thomas Chakurda, hospital spokesman, described the bleeding problem as minor, but offered no further details.

Surgeons removed Gaidosh’s diseased heart and implanted the mechanical device in a six-hour operation which began around 4 p.m. yesterday. Hospital officials said the implant was operating “beautifully.”

Gaidosh had been transferred to Presbyterian four weeks ago from West Penn Hospital. He had been waiting 2½ weeks for a heart transplant before he became gravely ill yesterday.

He suffered from idiopathic cardiomyopathy, a virus of unknown origin which attacks and weakens the heart muscles. His condition deteriorated yesterday and doctors did not expect him to survive the day without a new heart, a hospital spokesman said.

The artificial heart was implanted so Gaidosh could survive long enough to undergo transplant surgery, which doctors consider to be the best treatment for irreversible heart disease.

As soon as an acceptable donor heart becomes available, doctors would immediately transplant the natural organ into Gaidosh, Chakurda said.

Doctors were not available for comment following the implant. Assisting Griffith in surgery were Drs. Robert Hardesty and Alfredo Trento, all of whom are members of the University of Pittsburgh School of Medicine faculty. After the implant, members of the surgical team took part in a heart transplant at the hospital, sources reported.

The implant marks the first time an artificial heart was used by a Pittsburgh hospital.

Last Friday, surgeons at the Hershey Medical Center implanted a mechanical heart in Anthony Mandia, a 44-year-old Philadelphia recreation department worker. He is reported to be in critical but stable condition as he begins his second week with an artificial heart developed at Pennsylvania State University.

Mandia's mechanical heart, which is similar to the Jarvik-7, is also intended to be temporary. Both devices are powered by a pump which is inserted into the polyurethane heart chambers through hoses that penetrate the patient's chest.

Gaidosh was described as a large man who stands about 6 feet, 5 inches tall and at times weighed as much as 220 pounds. Because of his size, doctors said he would not be competing with Mandia for the same type of donor heart.

The Jarvik-7 and Penn State heart can be used as permanent life-support systems, if necessary.

About 2½ years ago, Gaidosh's heart condition forced him to take a disability-retirement from Cameron Electronics in Pottstown, Pa.
1992 Gala
The Novacor® Left Ventricular Assist System
1st Gen. VADs

http://surgery.med.umich.edu/cardiac/images/content

Heartmate XVE

Sintered Surface

Novacor LVAS
2nd Gen. VADs

Do you really need a pulse?
- Continuous flow: rotary impeller
- Axial or centrifugal configuration
- Ceramic or jewel bearing support
- Smaller, simpler, improved battery life & better washing
HEARTMATE II

Rogers et al. NEJM 2017;376(5):451-60
Bearing-less VADs (3rd Gen)

- Hydrodynamic bearing
  - As the rotor spins, fluid flow levitates the impeller creating a "blood cushion"
  - When the motor stops spinning, this "hydrodynamic bearing" disappears

- Ventracor® Ventrassist®
- Heartware® HVAD®
Centrifugal-Flow Pump

Blood flow from left ventricle

Aorta

Left ventricle

Outflow graft

Diaphragm

Pericardial sac

Centrifugal-flow pump designed for intrapericardial placement

Percutaneous drive line connects to external battery pack and controller

Blood flow to aorta

Short inflow cannula

Motor

Pump housing

Percutaneous drive line

Magnetic hydrodynamically levitated impeller

40mm

Continuous Flow LVAD/BiVAD Implants: 2008 – 2016, n=17633

n=17633, Deaths=5398

Months % Survival
1 95%
12 81%
24 70%
36 59%
48 49%

Months post implant
Cardiac assist devices (Ped)
Berlin Heart Update

John Woodard, PhD
CTO
Pediatric Circulatory Support Devices for Infants and Small Children in U.S.

Berlin Heart
EXCOR® Pediatric Worldwide Experience

Clinical Experience

- More than 1,800 patients
- More than 164 pediatric heart centers in 37 countries
- 26 years implant experience
- Longest time on device > 3.5 years
A few of our UPMC patients
Total MCS Implants in UPMC System

1985 to Present

1,298

- 72 Pediatric
- 25 Imported
- 1201 Adult
Andrea McConaughy
CELEBRATING 20 YEARS!
8/21/96

14 Years Old
DIAGNOSED WITH
Hypertrophic cardiomyopathy

WAITED 156 Days on an LVAD
Left Ventricular Assist Device
UPMC
(University of Pittsburgh Medical Center)

1st person to leave hospital on an LVAD
WENT TO A PLAYOFF PENGUIN HOCKEY GAME

RECEIVED Heart transplant 8/21/96 3:30 PM

Because of my donor Michael & a 2nd chance at life...

HAD ANDREW
3/2002

MARRIED ROB
AUGUST 26
2000

ADOPTED COLIN
12/2009

I'VE BEEN ZIP LINING PARASAILING Hiked Mountain in 2003
Walked the Pan 5K Bike Riding
TRAVELED TO Canada Italy Iceland England France Germany Austria

COLIN IS AN ANGEL 2012

COLIN IS AN ANGEL 2012
Cardiac assist devices (Adverse events)
HEARTMATE II
Distributions of Types of Device Malfunctions as a Percentage of the Total Malfunctions Seen in Kormos et al (2018)