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</tbody>
</table>

For access to Texas Children’s Heart Center outcomes information, visit [texaschildrens.org/heartoutcomes](http://texaschildrens.org/heartoutcomes).
Dear colleagues, parents and friends,

We are pleased to share with you the 2016 Texas Children’s Heart Center Outcomes Book. With more than 1,000 operating room cases and over 26,000 patient encounters, this year has been full of activity and growth. This report covers highlights from our Heart Center programs, including incredible patient stories and important programmatic developments.

In 2016, our Congenital Heart Surgery program earned a three-star rating from The Society of Thoracic Surgeons (STS) – the highest possible distinction. Star ratings are calculated based on overall risk-adjusted operative mortality for all patients undergoing pediatric and/or congenital heart surgery performed by an STS Congenital Heart Surgery Database (CHSD) participant. The latest analysis of data covers a four-year period, from January 2012 to December 2015, and includes 117 participants in the U.S. and Canada. Texas Children’s Hospital is one of only eight CHSD hospitals in the U.S. and Canada to earn a three-star rating. This is a well-deserved achievement, and we are grateful to everyone on our team who helped make it possible.

We also launched a one-of-a-kind animated video series designed to help children with heart problems better understand their diagnosis and potential treatment options. Released in February, the videos are an excellent resource to improve the health literacy of children and families treated at Texas Children’s Hospital and anywhere around the world.

Additionally, we made incredible progress on our newest facilities, including Legacy Tower, currently under construction at our Texas Medical Center campus, which will serve our most critically ill patients and families. Adding 19 floors and 640,000 square feet to an existing six-floor building, the tower will feature seven ICU floors, including a brand new neuro-ICU and surgical ICU, three CVICU floors, a Radiology suite and a helipad. Scheduled for completion in 2018, this will be the new home of Texas Children’s Heart Center.

Texas Children’s Heart Center strives to provide every appropriate procedure available for patients with pediatric and adult congenital heart disease. Through our innovations in research and commitment to improving all aspects of patient care, our goal is to deliver the very best possible care for every patient.

We hope you enjoy reading about our outstanding team and their activities. Thank you for your interest in our center.

Sincerely,

Charles D. Fraser, Jr., M.D.
Chief of Congenital Heart Surgery

Emad B. Mossad, M.D.
Chief, Division of Pediatric Cardiovascular Anesthesiology

John Nickens
Heart Center Executive

Daniel J. Penny, M.D.
Chief of Cardiology

Paul A. Checchia, M.D.
Medical Director, CVICU

Gail Parazynski, R.N.
Assistant Vice President

Lara S. Shekerdemian, M.D.
Chief of Critical Care
Texas Children’s Hospital and Baylor College of Medicine

Texas Children’s Hospital is one of the nation’s largest and most comprehensive specialty pediatric hospitals, with more than 3.5 million patient encounters in 2016. Texas Children’s mission is to create a healthier future for children and women throughout our global community by leading in patient care, education and research. Renowned worldwide for its expertise and breakthrough developments in clinical care and research, Texas Children’s Hospital is ranked #4 nationally by U.S. News & World Report.

Texas Children’s Hospital is located near downtown Houston in the Texas Medical Center, the largest medical center in the world. The medical center campus includes more than 600 licensed beds; the Clinical Care Tower for outpatient visits; the Feigin Center for pediatric research; and Texas Children’s Pavilion for Women for comprehensive OB/GYN care. Located nearby is the Texas Children’s Hospital Jan and Dan Duncan Neurological Research Institute®, a basic research institute dedicated to solving childhood neurological diseases. In 2018, a new pediatric tower will be completed to increase capacity for critical and surgical care.

Texas Children’s Hospital West Campus and Texas Children’s Hospital The Woodlands bring specialty pediatric care, including acute care and critical care beds, 24/7 pediatric emergency centers, surgical suites and more than 20 subspecialty clinics, to a rapidly expanding population of children west and north of Houston. Texas Children’s also operates Texas Children’s Health Plan™, the nation’s first HMO for children, and Texas Children’s Pediatrics™, the largest pediatric network in the nation. Texas Children’s Health Centers®, Specialty Care and Urgent Care locations provide enhanced access to care throughout the Greater Houston community.

In 2016, Texas Children’s Health Plan partnered with the State of Texas to form STAR Kids, a Medicaid-managed care plan for children with disabilities and complex medical needs offering streamlined management and coordination of care.

Texas Children’s Hospital is affiliated with Baylor College of Medicine in the areas of pediatrics, pediatric surgery and obstetrics and gynecology. Baylor is ranked by U.S. News & World Report as one of the nation’s top 10 medical schools for pediatrics. Currently and throughout our 62 year partnership, Texas Children’s Hospital serves as Baylor’s primary pediatric training site. The collaboration between Texas Children’s Hospital and Baylor is one of the top five such partnerships for pediatric research funding from the National Institutes of Health.

With a staff of more than 11,000 employees and more than 2,000 board-certified physicians, pediatric subspecialists, pediatric surgical subspecialists and dentists, Texas Children’s offers more than 40 subspecialties, programs and services. Physicians are employees of Baylor College of Medicine, not Texas Children’s Hospital. Because they practice at Texas Children’s Hospital, they may be referred to as “our team” or “Texas Children’s physicians” throughout this report.
Texas Children’s Heart Center

Texas Children’s Heart Center is located in the hospital’s main inpatient building, the West Tower, on floors 15 and 17 through 20. The close proximity of the Heart Center’s treatment and administrative areas, perhaps unique in pediatric cardiac care, enables team members to respond quickly to patient and family needs or emergencies and promotes collaboration among the multidisciplinary team.

In the fall of 2018, Texas Children’s Heart Center will proudly move into Texas Children’s newest building – Legacy Tower. Located at our Texas Medical Center campus, the tower will serve our most critically ill patients and families, house 130 beds for pediatric and cardiovascular intensive care and feature seven ICU floors, including a brand new neuro-ICU and surgical ICU, three CVICU floors, a Radiology suite and helipad.
National and International Reach

Texas Children’s commitment to caring for children reaches around the globe. In 2016, the Heart Center cared for patients from more than 35 states and 20 countries worldwide (shown below), demonstrating our commitment to creating a healthier future for children throughout the global community.
Pioneers in Pediatric Cardiac Care

Texas Children’s Hospital has been a leader in pediatric heart care for more than 60 years. Led by Denton Cooley, M.D., and Dan McNamara, M.D., the hospital started performing heart surgery in children in 1956. Dr. McNamara, a patriarch of pediatric cardiology, and Dr. Cooley, a pioneer heart surgeon, were among the first to demonstrate that small children could safely undergo heart surgery.

The medical community lost a legend in 2016 with the death of Dr. Denton Cooley, who passed away on November 18. Throughout his lengthy career, Dr. Cooley, founder of the Texas Heart Institute and Texas Children’s Hospital’s first chief of cardiovascular surgery, made enormous strides in both adult and pediatric cardiovascular surgery, developing many of today’s commonly used cardiovascular procedures and devices. He is best known for performing the first successful human heart transplant in the United States as well as implanting the first mechanical heart and left ventricular assist device.

Today, Texas Children’s Heart Center is one of the nation’s leading providers of pediatric cardiac care. In 2016, for the third consecutive year, U.S. News & World Report ranked Texas Children’s Heart Center #2 in the nation for pediatric cardiology and heart surgery. Comprising several multidisciplinary teams working in conjunction with pediatric subspecialists throughout the hospital, the Heart Center strives to provide unparalleled care at every point from diagnosis through treatment and follow-up.

Congenital Heart Surgery program earns top rating from the Society of Thoracic Surgeons

Texas Children’s Hospital’s Congenital Heart Surgery program earned a three-star rating from The Society of Thoracic Surgeons (STS) – the highest possible distinction. Star ratings are calculated based on overall risk-adjusted operative mortality for all patients undergoing pediatric and/or congenital heart surgery performed by an STS Congenital Heart Surgery Database (CHSD) participant. The latest analysis of data covers a four-year period, from January 2012 to December 2015, and includes 117 participants in the U.S. and Canada. Texas Children’s Hospital is one of only eight CHSD participant hospitals in the U.S. and Canada to earn a three-star rating. For more information about STS Congenital Heart Surgery Public Reporting, visit sts.org.

One-of-a-kind animated video series launched to improve health literacy

In 2016, Texas Children’s Heart Center launched a one-of-a-kind animated video series designed to help children with heart problems better understand their diagnosis and potential treatment options. Featuring Ruby the armadillo and Beau the bison, the videos are an excellent resource to improve the health literacy of children and families treated at Texas Children’s and around the world. To learn more about the videos and to view them, visit texaschildrens.org/rubyandbeau.
2016 Texas Children’s Heart Center Overview

**Surgical procedures**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac operations</td>
<td>904</td>
</tr>
<tr>
<td>Heart transplants</td>
<td>25</td>
</tr>
<tr>
<td>Lung transplants</td>
<td>8</td>
</tr>
<tr>
<td>Adult congenital heart disease operations</td>
<td>64</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,001</strong></td>
</tr>
</tbody>
</table>

**Cardiac catheterizations**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic cardiac catheterizations</td>
<td>517</td>
</tr>
<tr>
<td>Interventions</td>
<td>500</td>
</tr>
<tr>
<td>Electrophysiology studies and ablations</td>
<td>167</td>
</tr>
<tr>
<td>Pacemaker and defibrillator implants</td>
<td>61</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,245</strong></td>
</tr>
</tbody>
</table>

**Diagnostic testing and cardiac imaging**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echocardiograms</td>
<td>27,111</td>
</tr>
<tr>
<td>Fetal echocardiograms</td>
<td>2,114</td>
</tr>
<tr>
<td>Electrocardiograms</td>
<td>39,381</td>
</tr>
<tr>
<td>Cardiac MRIs</td>
<td>620</td>
</tr>
<tr>
<td>Stress Cardiac MRIs</td>
<td>52</td>
</tr>
<tr>
<td>Holter® monitors</td>
<td>5,368</td>
</tr>
<tr>
<td>Stress tests</td>
<td>1,055</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>75,701</strong></td>
</tr>
</tbody>
</table>

**Cardiovascular anesthesiology**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catheterization and electrophysiology patients</td>
<td>1,226</td>
</tr>
<tr>
<td>Congenital heart surgery operating room patients</td>
<td>1,051</td>
</tr>
<tr>
<td>Interventional radiology patients</td>
<td>264</td>
</tr>
<tr>
<td>MRI patients</td>
<td>394</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2,935</strong></td>
</tr>
</tbody>
</table>

The outpatient clinic at Texas Children’s Heart Center had more than 26,000 patient encounters in 2016.
Congenital Heart Surgery

The Congenital Heart Surgery team provides individualized and comprehensive surgical care for all aspects of pediatric and adult congenital heart disease. We are experienced in the rarest of cases, such as ectopia cordis and other infrequently seen conditions. Texas Children's Heart Center performs more than 1,000 surgical procedures annually with outcomes among the best in the country.

We treat patients of all ages, from preterm and low-birth-weight newborns to adults with congenital heart disease, and we personalize treatments and procedures to best suit the situation of each patient and family. This tailored approach includes cardiopulmonary bypass and neuroprotection strategies focused on the patient’s condition and needs, helping to achieve optimal functional outcomes. The center’s Heart, Lung and Heart-Lung Transplant programs, among the largest and most successful pediatric programs in the U.S., are also part of the Congenital Heart Surgery division.

Cardiovascular and thoracic surgery cases

Volume by year

According to The Society of Thoracic Surgeons National Database Program, congenital heart surgery programs are considered high-volume programs if they perform more than 250 index operations per year on average.

Since 1995, Charles D. Fraser, Jr., M.D., and the Congenital Heart Surgery team have performed more than 15,500 operations on children and adults with congenital heart disease.
In 2016, Texas Children's Hospital performed its 10,000th heart procedure with the heart-lung bypass machine.

Our patients include children of all ages as well as adults who have been treated since infancy or who have been diagnosed with a congenital heart defect later in life.
The overall hospital discharge mortality rate for our program in 2016 was 2.2%. Data collected by The Society of Thoracic Surgeons (STS) shows the national hospital discharge mortality rate at 3.1%.

---

**Mortalities by STAT classification in 2016**

<table>
<thead>
<tr>
<th>Primary procedure</th>
<th>Number of procedures</th>
<th>Number of discharge mortalities</th>
<th>Percent mortality</th>
<th>STS national benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAT 1</td>
<td>214</td>
<td>0</td>
<td>0.0%</td>
<td>0.5%</td>
</tr>
<tr>
<td>STAT 2</td>
<td>219</td>
<td>3</td>
<td>1.4%</td>
<td>1.7%</td>
</tr>
<tr>
<td>STAT 3</td>
<td>63</td>
<td>0</td>
<td>0.0%</td>
<td>2.1%</td>
</tr>
<tr>
<td>STAT 4</td>
<td>207</td>
<td>11</td>
<td>5.3%</td>
<td>6.8%</td>
</tr>
<tr>
<td>STAT 5</td>
<td>25</td>
<td>2</td>
<td>8.0%</td>
<td>17.3%</td>
</tr>
<tr>
<td><strong>Grand total</strong></td>
<td><strong>728</strong></td>
<td><strong>16</strong></td>
<td><strong>2.2%</strong></td>
<td><strong>3.1%</strong></td>
</tr>
</tbody>
</table>

STAT Classification (The Society of Thoracic Surgeons - European Association for Cardio-Thoracic Surgery Congenital Heart Surgery Mortality Categories - STS Mortality Categories) is the risk stratification model applied to outcomes in congenital heart surgery. The most common surgeries are stratified into 5 categories. Surgeries with higher risk are in higher categories with STAT Category 5 representing congenital heart surgeries associated with the greatest risk.

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1 Source for STS National Benchmark is Table 1 of the Society of Thoracic Surgeons Data Harvest Report Jan. 2015 to Dec. 2015. The source for the overall hospital data is STAT Index Surg CHD Volume; Data pulled 4/14/2017.
Mortalities by age and operation type in 2016

<table>
<thead>
<tr>
<th>Age</th>
<th>CPB cases</th>
<th>Non-CPB cases</th>
<th>CPB discharge mortalities</th>
<th>Non-CPB discharge mortalities</th>
<th>Discharge mortality</th>
<th>Percent mortality</th>
<th>STS national benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonate (0d - 30d)</td>
<td>81</td>
<td>35</td>
<td>5</td>
<td>2</td>
<td>7/116</td>
<td>6.0%</td>
<td>9.0%</td>
</tr>
<tr>
<td>Infant (31d - 1y)</td>
<td>206</td>
<td>24</td>
<td>1</td>
<td>1</td>
<td>2/230</td>
<td>0.9%</td>
<td>2.8%</td>
</tr>
<tr>
<td>Child (&gt;1y - &lt;18y)</td>
<td>301</td>
<td>30</td>
<td>4</td>
<td>2</td>
<td>6/331</td>
<td>1.8%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Adult (18y+)</td>
<td>44</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>1/51</td>
<td>2.0%</td>
<td>1.7%</td>
</tr>
<tr>
<td>Grand total</td>
<td><strong>632</strong></td>
<td><strong>96</strong></td>
<td><strong>11</strong></td>
<td><strong>5</strong></td>
<td><strong>16/728</strong></td>
<td><strong>2.2%</strong></td>
<td><strong>3.1%</strong></td>
</tr>
</tbody>
</table>

Age appropriate surgical planning and management allows for outcomes in patients of all ages to be better than the national benchmark for all categories. Patient total combines CPB and non-CPB cases (N=728).

*Source for STS National Benchmark is Table 7 of the Society of Thoracic Surgeons Data Harvest Report January 2015 to December 2015. The source for the overall hospital data is STAT Index Surg CHD Volume; Data pulled 4/14/2017.*
Atrial septal defect repair
Volume by year

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>24</td>
</tr>
<tr>
<td>2008</td>
<td>14</td>
</tr>
<tr>
<td>2009</td>
<td>33</td>
</tr>
<tr>
<td>2010</td>
<td>15</td>
</tr>
<tr>
<td>2011</td>
<td>22</td>
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<td>2012</td>
<td>27</td>
</tr>
<tr>
<td>2013</td>
<td>35</td>
</tr>
<tr>
<td>2014</td>
<td>42</td>
</tr>
<tr>
<td>2015</td>
<td>39</td>
</tr>
<tr>
<td>2016</td>
<td>37</td>
</tr>
</tbody>
</table>

OVERALL HOSPITAL DISCHARGE MORTALITY RATE: 0%
STS NATIONAL BENCHMARK: <1%

Ventricular septal defect repair
Volume by year

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>53</td>
</tr>
<tr>
<td>2008</td>
<td>59</td>
</tr>
<tr>
<td>2009</td>
<td>53</td>
</tr>
<tr>
<td>2010</td>
<td>54</td>
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<tr>
<td>2011</td>
<td>64</td>
</tr>
<tr>
<td>2012</td>
<td>60</td>
</tr>
<tr>
<td>2013</td>
<td>86</td>
</tr>
<tr>
<td>2014</td>
<td>59</td>
</tr>
<tr>
<td>2015</td>
<td>70</td>
</tr>
<tr>
<td>2016</td>
<td>79</td>
</tr>
</tbody>
</table>

OVERALL HOSPITAL DISCHARGE MORTALITY RATE: 0%
STS NATIONAL BENCHMARK: <1%

3 Hospital mortality is calculated over the last four years from 2013-2016; Data pulled 4/14/2017.
4 Source for STS national benchmark is the Society of Thoracic Surgeons Data Harvest Report January 2012 to December 2015.
Atrioventricular canal repair

Volume by year

OVERALL HOSPITAL DISCHARGE MORTALITY RATE\(^5\) 1.7%  
STS NATIONAL BENCHMARK\(^6\) 2.2%

Tetralogy of Fallot repair

Volume by year

OVERALL HOSPITAL DISCHARGE MORTALITY RATE\(^5\) 0.9%  
STS NATIONAL BENCHMARK\(^6\) 1.6%

\(^5\) Hospital mortality is calculated over the last four years from 2013-2016; Data pulled 4/14/2017.

\(^6\) Source for STS national benchmark is the Society of Thoracic Surgeons Data Harvest Report January 2012 to December 2015.
Arterial switch operation
Volume by year

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>16</td>
</tr>
<tr>
<td>2008</td>
<td>12</td>
</tr>
<tr>
<td>2009</td>
<td>15</td>
</tr>
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<td>2010</td>
<td>16</td>
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<td>2011</td>
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<td>10</td>
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<tr>
<td>2014</td>
<td>18</td>
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<tr>
<td>2015</td>
<td>16</td>
</tr>
<tr>
<td>2016</td>
<td>18</td>
</tr>
</tbody>
</table>

OVERALL HOSPITAL DISCHARGE MORTALITY RATE\(^7\): **0%**
STS NATIONAL BENCHMARK\(^8\): **4.0%**

Norwood operation
Volume by year

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>18</td>
</tr>
<tr>
<td>2008</td>
<td>28</td>
</tr>
<tr>
<td>2009</td>
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<td>2010</td>
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<td>2011</td>
<td>24</td>
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<td>2012</td>
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<tr>
<td>2013</td>
<td>17</td>
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<tr>
<td>2014</td>
<td>17</td>
</tr>
<tr>
<td>2015</td>
<td>10</td>
</tr>
<tr>
<td>2016</td>
<td>20</td>
</tr>
</tbody>
</table>

OVERALL HOSPITAL DISCHARGE MORTALITY RATE\(^7\): **12.5%**
STS NATIONAL BENCHMARK\(^8\): **14.8%**

---

\(^7\) Hospital mortality is calculated over the last four years from 2013-2016; Data pulled 4/14/2017.

\(^8\) Source for STS national benchmark is the Society of Thoracic Surgeons Data Harvest Report January 2012 to December 2015.
Single Ventricle Program

The Single Ventricle Program at Texas Children’s Heart Center is focused on the care of infants with single ventricle congenital heart defects, which include hypoplastic left heart syndrome (HLHS) and variants, unbalanced atrioventricular septal defects, complex single ventricle and heterotaxy syndrome, and others. Most of these infants will require at least two or three operations within the first few years of life. The goals of these operations are to: (1) allow free flow of blood from the heart out to the body; (2) protect the lungs from high pressure and too much blood flow; and (3) create separate paths for blood to flow to the lungs and out to the body. Infants will typically undergo placement of a shunt or conduit to provide blood flow to the lungs within the first few days of life. For infants with HLHS, reconstruction of the vessel that allows blood to flow to the body (the Norwood operation) is typically performed within the first week of life. The second stage (bidirectional Glenn shunt) is performed at around 3-6 months of age. The period between these operations is called interstage period.

The importance of a home monitoring program

The interstage period is an important phase in the infant’s well-being and outcome. It is common for infants with single ventricle congenital heart defects to have poor oral intake and weight gain, which may affect their well-being. They may require multiple daily medications, modified feeding and interstage interventions. Common childhood illnesses, such as a cold or diarrhea, can be life-threatening for these children. Early recognition of signs and symptoms is thus necessary to be able to obtain immediate evaluation and intervention. The home monitoring program allows parents and caregivers to actively participate in the care of their babies outside of the hospital by watching for and addressing many of the problems that can be seen in the interstage period. Our program provides support, resources and clinical care to help families transition successfully to the second surgery.

A team approach to treatment

Texas Children’s Congenital Heart Surgery team subscribes to a collaborative approach to all patients, from fetal diagnosis through surgery and home monitoring. Comprehensive care is provided by a multidisciplinary team of experts from Cardiology, Congenital Heart Surgery, Cardiac Critical Care, Cardiovascular Anesthesiology, Genetics and Nutrition, among others.

Research and quality improvement

We are leaders in research involving the many aspects of care of infants with single ventricle heart disease, including genetics, critical care, nutrition and epidemiology. We are part of several studies with the Pediatric Heart Network aiming to further understand and address important clinical questions that impact a patient’s care and outcomes.

Our program is also an active member of the National Pediatric Cardiology Quality Improvement Collaborative, a multicenter group focused on improving quality and outcomes for children with single ventricle heart defects who have undergone a Norwood operation.
Heart Failure and Transplant

Since its inception in 1984, Texas Children’s Heart Center has performed more than 350 heart transplants, making it one of the largest and most successful pediatric programs in the nation. As the number of diagnoses for pediatric heart failure has increased, so has our depth and breadth of experience in treating patients, as has our ability to offer the right mechanical circulatory device to support each child in heart failure. For more information on the Heart Transplant program, please visit texaschildrens.org/transplant.

Since 2011, Texas Children’s Heart Center has been an active member of the Pediatric Heart Transplant Study, which is dedicated to the advancement of the science and treatment of children during listing for and following heart transplantation. The purpose of the group is to establish and maintain an international, prospective, event-driven database for heart transplantation, to use the database to encourage and stimulate basic and clinical research in the field of pediatric heart transplantation, and to promote new therapeutic strategies.

Ventricular Assist Device (VAD) program

Mechanical circulatory support is often used as a bridge to transplantation in children. At Texas Children’s Heart Center, we select a VAD from a variety of options to meet the needs of the individual patient. Texas Children’s Heart Center implants 20-30 VADs annually.

VAD implantations

<table>
<thead>
<tr>
<th>Device</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berlin Heart EXCOR® Pediatric</td>
<td>46</td>
</tr>
<tr>
<td>Bio-Medicus®</td>
<td>22</td>
</tr>
<tr>
<td>Rotaflow®</td>
<td>29</td>
</tr>
<tr>
<td>HeartMate II®</td>
<td>17</td>
</tr>
<tr>
<td>Total Artificial Heart</td>
<td>2</td>
</tr>
<tr>
<td>SynCardia®</td>
<td>11</td>
</tr>
<tr>
<td>TandemHeart®</td>
<td>3</td>
</tr>
<tr>
<td>HeartWare®</td>
<td>31</td>
</tr>
<tr>
<td>Micromed®</td>
<td>3</td>
</tr>
<tr>
<td>Thoratec P-VAD®</td>
<td>11</td>
</tr>
<tr>
<td>Impella®</td>
<td>11</td>
</tr>
</tbody>
</table>

*VADs placed from 1995-2016.
Advancing the field of pediatric ventricular assist devices

In 2012, the United States Food and Drug Administration (FDA) granted humanitarian device exemption for the Berlin Heart EXCOR® Pediatric Ventricular Assist Device. This approval was the successful result of a multi-year, multi-institution study led by Texas Children's Hospital. This landmark event opened the era of pediatric VAD support in North America. The Berlin Heart EXCOR® is the only FDA-approved pediatric VAD.

Today, Texas Children’s Hospital continues to advance the field of pediatric ventricular assist devices. Because there are significantly more adult patients with heart failure than pediatric patients, device development is far more advanced in the adult world. Texas Children’s VAD program strives to achieve improved outcomes by finding ways to utilize adult VADs in children. These VADs include the HeartWare HVAD® and Impella catheter VAD®. Since HeartWare is implantable, children on this device can live at home and even attend school – a significant quality-of-life advantage over devices that require inpatient management.

Texas Children’s Hospital is also working on the development of a next-generation, miniaturized, implantable VAD specifically designed for small children, known as the Infant Jarvik VAD. The device is named for Robert Jarvik, M.D., inventor of the first successful total artificial heart. With support from the federal government through the National Heart, Lung and Blood Institute, this AA-battery-sized device has undergone preclinical testing and will further expand the use of implantable VADs in small children, including babies.
Heart transplants

Volume by year

Texas Children’s Hospital ranked as the No. 1 pediatric heart transplant program in the country in 2016, based on volumes.

Heart transplant patient survival rates

Pediatric age <18

10 Heart transplant cases included multi-organ transplants with heart and other solid organs.

11 Scientific Registry of Transplant Recipients (SRTR). Program Specific Reports. Table 11 – srtr.org.
Heart transplant survival curves

The following graphs show the survival rates for patients by the number of years after heart transplantation. The lines show the expected survival rates for our patients a number of years after their transplant. Because these are estimates, the shaded areas show the 95 percent confidence limits of the expected survival rates.

Survival curves\(^1\)\(^2\)

By era

\(^1\) Wilcoxon test 1984-1998 vs 1999-2004 \(p = 0.9684\), 1984-1998 vs 2005-2016 \(p = 0.0008\), 1999-2004 vs 2005-2016 \(p = 0.0004\).

\(^2\) Texas Children’s data: 2005-2016, 333 Txs. Aged between 0 and 22 years. Retransplant and multiorgan transplant recipients excluded from datasets.
Survival curve vs. UNOS
Era III (2005-2016)

Wilcoxon test TCH vs UNOS, p = 0.3770.
Texas Children’s data: 2005-2016, 189 Txs. Aged between 0 and 22 years.
UNOS data: 2005-2015, 4017 Txs aged between 0 and 18 years.
Retransplant and multiorgan transplant recipients excluded from both datasets.
HEART TRANSPLANT PATIENT BONDS WITH NFL SUPERSTAR

Born with multiple heart defects, Jeston Adams underwent his first heart surgery at just 6 months old. At the age of 8, he moved to Houston with his mom, Danielle, in January of 2016 searching for a new heart. A team of congenital heart surgeons implanted a ventricular assist device (VAD), the HeartWare HVAD®, into Jeston as he awaited a much-needed transplant.

Throughout his journey, Jeston caught the eye of his hero, three-time NFL Defensive Player of the Year and Houston Texans defensive end, J.J. Watt. They shared multiple special visits at the hospital and at Houston Texans Training Camp, developing a unique bond. As Jeston describes it, “It’s big brother, little brother… something like that.”

In August 2016, a team of surgeons at Texas Children’s Hospital performed a 14-hour heart transplant. Today, Jeston’s infectious smile is wider than ever following the lifesaving procedure. He is healthy and happy, and looks forward to the day he can step out onto the football field like his “big brother” Watt.
Coronary Artery Anomalies

In 2012, Texas Children’s Hospital created the Coronary Artery Anomalies program, a multidisciplinary team to care for patients with rare congenital heart defects associated with coronary ischemia, myocardial infarction and sudden death. Coronary artery anomalies are the second-leading cause of sudden cardiac death in children and young adults.

Diagnosing these anomalies can be challenging because many individuals with the conditions have no symptoms, and their first manifestation can be sudden cardiac arrest or death. Those who do have symptoms complain most often of chest pain, palpitations, dizziness or fainting during or just after exercise.

How to best treat children and young adults with coronary artery anomalies is a subject of debate in the medical community. Most physicians agree that surgery is necessary for patients who show evidence of decreased blood flow to the heart muscle, but how to treat patients who have no physical complaints and show no evidence of reduced blood flow to the heart is unclear.

Texas Children’s Hospital hosted two conferences focused on this topic in 2013 and 2014. In September 2016, Texas Children’s Hospital partnered with Children’s Hospital of Philadelphia to host the 3rd Symposium on Coronary Artery Anomalies in Philadelphia. During the conferences, speakers from leading heart institutions across the country provided a dedicated forum to discuss the diagnosis and management of patients with coronary artery anomalies.

Outcomes of patients with anomalous aortic origin of a coronary artery

Texas Children’s Coronary Artery Anomalies program began tracking outcomes in December 2012 and as of February 2017 has recorded:

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total patients</td>
<td>163</td>
</tr>
<tr>
<td>Surgery treatment</td>
<td>44</td>
</tr>
<tr>
<td>Surgical mortality</td>
<td>0</td>
</tr>
<tr>
<td>Complications</td>
<td>4</td>
</tr>
</tbody>
</table>
Interventional Cardiology

Thanks to advances in the field, an increasing number of heart conditions can be treated with minimally-invasive catheter-based interventions. Texas Children’s Heart Center, the largest program in the region to offer interventional cardiac catheterization for infants, children and adolescents, performed more than 1,200 cardiac catheterization procedures in 2016. The full-service cardiac catheterization laboratory performs interventions including:

- Balloon valvuloplasty
- Balloon angioplasty (using standard as well as “cutting” balloons)
- Stent placement (for pulmonary artery stenosis, coarctation of the aorta, etc.)
- Device closure of atrial septal defects, arterial and venous collaterals, coronary fistulae, etc.
- Device closure of patent ductus arteriosus, including in low-birth-weight and premature babies
- Transcatheter pulmonary valve replacement using the Melody® valve

In addition to these relatively common procedures, the Interventional Cardiology team at Texas Children’s Hospital has developed cutting-edge treatment strategies for rare and debilitating conditions such as:

- Pulmonary vein stenosis
- Venous thrombosis
- Multiple muscular ventricular septal defects (“Swiss cheese” septum)
- Congenital portosystemic shunts (Abernethy malformation)
- Pulmonary arteriovenous malformations (congenital and acquired)
- Pulmonary hypertension
- Renal artery stenosis
- Mid-aortic syndrome
- Critical aortic stenosis and hypoplastic left heart syndrome

In addition, we provide percutaneous ventricular assist device placement for heart failure (using the Impella® device).

Despite being a regional and national referral center for the most complex forms of acquired and congenital heart disease, our team has an extraordinarily low complication rate from cardiac catheterizations (see chart on the following page). In addition, we have a strong culture of attention to radiation safety and continuous quality improvement, and we strive to promote these concepts locally and nationally. Our interventional team is actively involved in research into new treatment strategies for congenital heart disease and is invited to lecture on these topics nationally and internationally.
### Cardiac catheterization laboratory complications

By rate

- Cases without complications: 94.91%
- Cases with significant complications: 0.81%
- Cases with minor complications: 4.28%

### Electrophysiology

The Electrophysiology program at Texas Children’s Hospital offers a broad complement of diagnostic and therapeutic options to evaluate and manage heart rhythm abnormalities. We have one of the highest volume pediatric centers in the country for invasive electrophysiology studies and pacemaker/defibrillator implantations, and we maintain success rates for ablations that exceed the national average. Innovation, research and experience have made Texas Children’s Heart Center one of the leading centers in the world for the diagnosis and treatment of arrhythmias in children and adults with congenital heart disease.

The Electrophysiology team runs a robust Genetic Arrhythmia Clinic. In 2016, there were more than 500 patient visits for assessment of inherited arrhythmia syndromes, and the team is actively involved in research to improve the management and outcomes of these patients. In collaboration with the Cardiovascular Research Institute, work is underway to identify novel genes and the molecular mechanisms that underlie arrhythmias and sudden death syndromes. Our group has also discovered new insights into Wolff-Parkinson-White syndrome, catecholaminergic polymorphic ventricular tachycardia, SCN5A overlap syndromes, Long QT syndrome and the muscular dystrophies. Our research spans both the clinical and basic sciences, encompassing a “bed to benchside” approach that strives to improve the overall care of our patients.
Supraventricular tachycardia ablation outcomes

<table>
<thead>
<tr>
<th>2016 ACUTE SUCCESS RATE</th>
<th>Texas Children’s Hospital</th>
<th>National benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>98.9%</td>
<td>95.2%</td>
</tr>
</tbody>
</table>

## Stereotaxis

Texas Children’s Hospital is one of only a few hospitals in the U.S. with a remote magnetic navigation (MN) system called Stereotaxis for catheter manipulation. Stereotaxis has been utilized for over 250 ablation cases at Texas Children’s Hospital over the past several years.

MN offers theoretic advantages in the treatment of children. The catheter is more flexible and atraumatic than standard catheters, potentially eliminating the risk of heart perforation. It can also be navigated with more precision, allowing for movements as small as one millimeter or deflections as small as one degree. This may result in enhanced accuracy and safety during mapping and ablation of certain arrhythmias in this patient population.

Additionally, in order to decrease morbidity associated with radiation exposure during ablation cases, the Electrophysiology team has established protocols utilizing non-fluoroscopic mapping techniques to minimize radiation. This has resulted in a three-fold reduction in fluoroscopy times, with over 200 procedures being performed with minimal radiation (<1 minute) over the past three years.

## Changes in fluoroscopy time for ablation procedures

By month

![Graph showing changes in fluoroscopy time for ablation procedures](image-url)

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Mean and median of fluoroscopy time

By year

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean (SD)</th>
<th>Median (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>32.89 (22.87)</td>
<td>25.17 (4.15,104.4)</td>
</tr>
<tr>
<td>2013</td>
<td>17.99 (19.85)</td>
<td>9.45 (0.00, 90.42)</td>
</tr>
<tr>
<td>2014</td>
<td>4.44 (6.38)</td>
<td>1.91 (0.00, 32.15)</td>
</tr>
<tr>
<td>2015</td>
<td>3.62 (4.77)</td>
<td>1.54 (0.00, 24.68)</td>
</tr>
<tr>
<td>2016</td>
<td>1.78 (3.13)</td>
<td>0.12 (0.00, 18.68)</td>
</tr>
</tbody>
</table>

Diagnostic Testing and Cardiac Imaging

Our noninvasive imaging lab performs more than 27,000 echocardiograms annually for fetuses, infants, children and adults with congenital or acquired heart disease. The imaging lab provides transesophageal, epicardial, intracardiac and transthoracic echocardiogram support in the catheterization labs and operating rooms on a daily basis. The main echocardiography lab consists of 10 rooms with a four-bed sedation bay and a state-of-the-art physician work area that houses five reading stations. In addition, we have an ancillary imaging lab at Texas Children's Hospital West Campus to support our services in the community.

Fetal echocardiograms

Volume by year

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>607</td>
</tr>
<tr>
<td>2008</td>
<td>767</td>
</tr>
<tr>
<td>2009</td>
<td>953</td>
</tr>
<tr>
<td>2010</td>
<td>899</td>
</tr>
<tr>
<td>2011</td>
<td>946</td>
</tr>
<tr>
<td>2012</td>
<td>1,253</td>
</tr>
<tr>
<td>2013</td>
<td>1,592</td>
</tr>
<tr>
<td>2014</td>
<td>1,781</td>
</tr>
<tr>
<td>2015</td>
<td>1,831</td>
</tr>
<tr>
<td>2016</td>
<td>2,114</td>
</tr>
</tbody>
</table>
**Fetal cardiac interventions**

For some fetuses with cardiovascular conditions, fetal cardiac intervention is available at Texas Children’s Hospital to try to improve the physiology of the heart before birth. Texas Children’s Fetal Center® is one of only a few centers in the world capable of providing the full array of fetal cardiac interventions, which involves a coordinated effort among a large, multidisciplinary team of fetal cardiologists, obstetricians and gynecologists, interventional cardiologists, congenital heart surgeons, fetal imaging experts, maternal and fetal anesthesiologists, and other clinical specialists.

We offer the following fetal cardiac interventions:

- **Fetal arrhythmia evaluation and treatment** – While some abnormal fetal rhythm problems are benign, others may result in fetal heart failure and can pose a risk to the fetus and mother. We offer a variety of therapies that are customized for both the fetus and mother. We collaborate closely with adult cardiologists to protect the safety of both fetus and mother during treatment.

- **Fetal hypoplastic left heart syndrome (HLHS) and related conditions** – We offer three fetal cardiac interventions for babies with small left heart structures, with the type of therapy depending on the fetal heart anatomy.

  - For the most severe form of fetal aortic valve stenosis, which may progress to HLHS, we offer aortic valvuloplasty. This procedure is performed by a multidisciplinary team and consists of placing a small balloon across the fetal aortic valve to enlarge it and to promote blood flow through the left side of the heart.

  - For fetuses with HLHS or mitral valve dysplasia and a restrictive or intact atrial septum, we offer fetal atrial septal intervention. For this procedure, either a balloon or a stent is placed across the atrial septum of the heart to decrease the pressure in the left atrium and to help the fetal lungs recover before birth.

  - For fetuses with small left-sided structures who may need neonatal heart surgery but do not meet the criteria for the above procedures, we are conducting an experimental study protocol in which we provide daily home oxygen to mothers, also known as maternal hyperoxygenation, to promote fetal left heart growth.

**Cardiac MRI**

Cardiac MRI is a valuable imaging modality for those with congenital and acquired heart disease, but has become particularly essential in the evaluation of teens and adults with congenital heart disease. In 2016, Texas Children’s Hospital performed more than 600 cardiac MRIs.

**Stress Cardiac MRI**

At Texas Children’s Hospital, we are one of the few pediatric centers in the country to offer stress cardiac MRI to accurately assess myocardial perfusion in both acquired and congenital heart defects, utilizing pharmacologic stress agents to mimic exercise. This technology has been shown to be superior to many other noninvasive modalities in the adult population, and Texas Children’s Hospital has adopted many of these same principles and applied them to the pediatric population. These examinations involve the dedicated and coordinated efforts of a pediatric cardiologist, pediatric radiologist, cardiac pharmacologist, cardiac MRI technician and MRI physicist. In 2016, more than 50 stress cardiac MRIs were performed.
MULTIDISCIPLINARY TEAM GIVES YOUNG BOY CHANCE AT LIFE

Diagnosed prenatally with absence of the ductus venosus, which resulted in an enlarged heart, Mohammad Usman’s parents were advised by other physicians to terminate the pregnancy. However, the Usmans were not ready to give up and made the decision to transfer care to Texas Children’s Hospital.

Closely monitored and delivered full term at Texas Children’s Pavilion for Women, Mohammad’s parents prepared for surgery shortly after he was born. But then, miraculously, his heart began to shrink back to a normal size.

Throughout the next three years, Mohammad continued to hit growth milestones and was monitored closely by the Texas Children’s team. As he neared his 4th birthday, cardiologists found that Mohammad had developed a hole in the wall between his heart’s upper chambers, as well as a diaphragmatic hernia, which would both need to be surgically repaired.

To mitigate the risks, a congenital heart surgeon and pediatric surgeon worked together to repair Mohammad’s heart and hernia during one surgery, and it was a success. Today, his doctors are optimistic that he will live a long and healthy life.
Adult Congenital Heart Disease

The Adult Congenital Heart Disease (ACHD) program at Texas Children’s Hospital offers a single point of care for patients with congenital heart disease from birth throughout adulthood. Our program offers the full range of ACHD services and specialties including surgery, diagnostic and interventional cardiac catheterization, noninvasive imaging (including cardiac MRIs and coronary CT angiography), arrhythmia services and more.

Adult clinic encounters

Volume by year

Congenital heart disease diagnoses of ACHD patients
MOTHER ADOPTS DAUGHTER WITH SAME HEART DEFECT

Diagnosed with pulmonary atresia at birth, Stephanie Granger had two surgeries as a baby and another at age 6. Years later, she developed secondary problems from her heart defect. “I started having some abdomen pain, so I went to my primary doctor,” Granger said. “They ran a CT scan and found there was a problem with my liver due to my heart.” Following several tests and an echocardiogram, it was determined she was in congestive heart failure and the right side of her heart was enlarged.

Stephanie was referred to Texas Children’s Hospital for further care, just one week before she and her husband, Bobby, flew to China to pick up their adopted daughter, Zoey, who was also born with a congenital heart defect. “When we adopted her, we told them we were open to various conditions,” Granger said. “We told them we had a family history of congenital heart disease and that we fully understood it.” Soon thereafter, Granger scheduled heart surgery at Texas Children’s Hospital not only for herself but for Zoey, as well.

Several months after the surgeries, both mom and daughter were doing extremely well.
Preventive Cardiology

The Preventive Cardiology program at Texas Children’s Hospital is part of our mission to provide the best possible care and outcomes for our patients. Focused on medically managing the risk factors of acquired heart disease in children, the Preventive Cardiology program cares for patients with a strong personal or family history of cardiac disease, elevated cholesterol, and high blood pressure or Kawasaki disease. Our goal is to prevent future cardiac disease and events such as heart attack and stroke through early detection and intervention and by educating children and families on how to better care for themselves.

Abnormal cholesterol and high blood pressure are well recognized conditions in adults. It surprises many people that these conditions can also arise in childhood, and that they lay the foundation for heart disease in adulthood. Research shows that normalizing cholesterol values and reducing high blood pressure in children may help prevent or slow the development of heart disease as they reach adulthood.

The goal of the Preventive Cardiology program is to prevent heart attack, stroke and other acute cardiac events later in life, to decrease mortality and to increase a child’s future quality of life. Typically, our patients have abnormal cholesterol levels or high blood pressure or have been diagnosed with Kawasaki Disease, which can increase the risk of cardiac disease in adulthood.

Our patients may have other conditions such as liver disease, obesity, diabetes or metabolic syndrome that directly cause cholesterol or blood pressure abnormalities. Others, perhaps through a poor diet, lack of physical activity or other lifestyle factors, may be at a higher risk for cardiac disease and on an early pathway to acquired heart disease in adulthood.

The Preventive Cardiology program uses a collaborative approach to treating patients, drawing on the expertise of a multidisciplinary team of specialists, including experts in pediatric cardiology, heart disease prevention, physical activity, nephrology, endocrinology and nutrition.
Cardiovascular Anesthesiology

The Cardiovascular Anesthesiology program at Texas Children’s Hospital provides sedation and anesthesia services for all congenital cardiac operations and for children with congenital heart disease undergoing various noncardiac procedures. Services are also provided for catheterization and electrophysiology procedures as well as imaging studies in MRI, CT and interventional radiology.

Cardiovascular Anesthesiology cases
By location

The Cardiovascular Anesthesiology team treated more than 2,900 patients in 2016. Beyond anesthetic care, the division actively participates in the daily care of patients in the Cardiovascular Intensive Care Unit.
Collaborative outreach

The Cardiovascular Anesthesiology team partnered with three pediatric hospitals in 2016 to support and advance the care of children with heart disease throughout Texas and in Mexico. We worked with The Children’s Hospital of San Antonio (CHOSA) to help establish a Cardiovascular Anesthesiology program by providing care and assisting with physician recruitment efforts. Starting in August 2016, the Cardiovascular Anesthesiology service provided a team of anesthesiologists and C.R.N.A.s to cover the Heart Center needs in San Antonio, to establish procedures and policies, and collaborate with the different services at CHOSA. The Cardiovascular Anesthesiology team also partnered with Covenant Children’s Hospital in Lubbock, Texas and ABC Hospital in Mexico City, Mexico to provide care and share Texas Children’s Hospital’s standards and model of care.

Advanced analytics

The Cardiovascular Anesthesiology research group, led by Eric Vu, M.D., is studying advanced predictive analytics to diagnose early warning signs of cardiac arrest in single ventricle patients. New metrics such as ST vector instability have been developed at Texas Children’s Hospital and included in machine learning algorithms, which have been shown to detect deterioration events one to two hours before cardiac arrest15,16. The long term goal is to create automated, intelligent tools which can alert the medical care team of patients with impending cardiac arrest so that interventions may be applied.

For the recent study, continuous high-resolution physiologic recordings were obtained from 25 children with parallel systemic and pulmonary circulation who were admitted to the cardiovascular intensive care unit of Texas Children’s Hospital between their early neonatal palliation and stage 2 surgical palliation. Instances of cardiorespiratory deterioration (defined as the need for cardiopulmonary resuscitation or endotracheal intubation) were found via a chart review. A classification algorithm was applied to both primary and derived parameters that were significantly associated with deterioration. The algorithm was optimized to discriminatepredeterioration physiology from stable physiology.

Twenty cardiorespiratory deterioration events were identified in 13 of the 25 infants. The resulting algorithm was both sensitive and specific for detecting impending events one to two hours in advance of overt extremis (receiver operating characteristic area = 0.91, 95% confidence interval = 0.88-0.94).

Automated, intelligent analysis of standard physiologic data in real-time can detect signs of clinical deterioration too subtle for the clinician to observe without the aid of a computer. This metric may serve as an early warning indicator of critical deterioration in patients with parallel systemic and pulmonary circulation.


Three dimensional reconstruction of ST segment vector

Sample patient vital signs and risk index over time
Prior to critical deterioration event
Risk stratification

The survival of children with congenital heart defects is continuing to improve, and the population of children with repaired and palliated heart disease reaching adulthood is growing. These patients will present for many noncardiac procedures throughout their childhood, such as dental work or the placement of ear tubes, in addition to diagnostic and imaging studies related to their condition that require anesthesia and sedation. Since exposure to anesthesia and sedation can affect brain development, it’s important to carefully consider its use in patients expected to have higher amounts of exposure than most.

The Cardiovascular Anesthesiology program at Texas Children’s Hospital is committed to supporting the optimal health and development of these patients, and is leading efforts to develop a risk stratification model that can be used to identify the most appropriate and efficient resources for various noncardiac procedures.

**Noncardiac procedures in children with congenital heart defects in 2016**

- Radiology: 55%
- Other: 3%
- Dental: 8%
- Gastroenterology & Urology: 4%
- Neurosurgery & Ophthalmology: 3%
- Orthopedics & Plastic Surgery: 3%
- Otolaryngology: 14%
- Pediatric Surgery: 10%

**Age distribution of children with congenital heart defects undergoing noncardiac surgery in 2016**

- Neonate (<=1 month): 2%
- Infant (1 month to 2 years): 39%
- Children (2 to 12 years): 39%
- Adolescent (13 to 18 years): 10%
- >18 years: 10%
Anesthesia providers for children with congenital heart defects undergoing noncardiac surgery in 2016

Anesthesia team takes proactive response to new FDA guidance

In February 2017, Dr. Dean Andropoulos, M.D., M.H.C.M., anesthesiologist-in-chief at Texas Children’s Hospital, partnered with Dr. Michael Greene, M.D., chief of Obstetrics at Massachusetts General Hospital, to author a perspectives article for the New England Journal of Medicine, “Anesthesia and Developing Brains – Implications of the FDA Warning.”

The piece reviewed the Food and Drug Administration’s (FDA) decision to release a safety announcement in December 2016 warning that prolonged (>3 hours) or repeated use of general anesthesia and sedation drugs in children less than 3 years of age or in pregnant women in their third trimester may affect brain development. Although the timing of the announcement was unexpected, Andropoulos and Greene agree that the implications of this decision will affect both the need for new patient education and provider consideration around procedures requiring anesthesia.

The authors emphasized that anesthesia is a necessary part of many surgeries and procedures and plays an important role in ensuring the comfort and safety of the patient. They conclude by urging parents, patients and physicians to carefully consider the risks of delaying indicated procedures and stating their support of further research and outcome studies regarding this vulnerable population.

Andropoulos is working with physician and administrative leadership at Texas Children’s Hospital to begin implementing changes such as having anesthesia-related conversations with patients and families prior to the day of procedure. His efforts include creating a project committee, distributing new education documents to both patients and health care professionals, and adapting clinical workflows to incorporate this information into several steps along the pre-procedure process.
Cardiovascular Intensive Care Unit

The Cardiovascular Intensive Care Unit (CVICU) team of cardiac intensivists, advanced practice providers, nurses, respiratory therapists, social workers, dietitians, pharmacists and support staff provides intensive care to newborns, infants, children and young adults with congenital and acquired heart disease. With a total of 33 beds, the CVICU cares for patients undergoing surgery for congenital and acquired heart disease, as well as those with end-stage heart failure before and after heart transplantation.

Heart Failure Intensive Care Unit

The Heart Failure Intensive Care Unit is the first of its kind in the nation. This highly specialized 12-bed unit focuses on the treatment of children with heart failure, as well as those requiring intensive care before and after heart transplant, and those on mechanical cardiac support. We have seen incredible growth in this area, and we are consistently at or near 100 percent capacity with this new model of care.

Renowned faculty and training programs

CVICU faculty includes leaders in pediatric cardiac intensive care who have certification in pediatric critical care, pediatric cardiology and pediatric anesthesiology. Texas Children’s Hospital also has the largest dedicated CVICU advanced training program in the country. The Pediatric Cardiac Critical Care Instructorship is a 12-month didactic and clinical training program for individuals who have completed fellowships in pediatric critical care medicine or pediatric cardiology and wish to pursue an additional year of training in pediatric cardiac intensive care. This training program provides a unique interface among critical care medicine, cardiology, cardiothoracic surgery and cardiac anesthesia. We also offer a fourth year of specialized training in neonatal cardiac critical care. The first of its kind in the nation, this program provides one position each year to neonatologists who desire additional training in newborn critical heart disease.

Nursing care in the Cardiovascular Intensive Care Unit

The CVICU at Texas Children’s Hospital has 130 specialized pediatric intensive care registered nurses on staff. The hours per patient day equivalent in the CVICU are 22.8 compared to the national benchmark of 26.16.17 All newly admitted surgical cases receive a minimum ratio of 1:1 nursing care. More than 95 percent of the CVICU registered nurses have a bachelor’s degree in nursing with a 52 percent rate of attainment of certification in critical care nursing for eligible staff. With the opening of the new pediatric tower and expanded CVICU space, many efforts were made in 2016 to streamline and update the orientation program for new nurses.

Cardiology Patient Care Unit

The Cardiology Patient Care Unit is a 22-bed mixed intermediate and acute care unit caring for newborns, infants, children and young adults with heart disease. The unit is staffed by pediatric cardiologists, as well as a team of cardiology fellows, cardiac advanced practice providers, medical residents and cardiac trained registered nurses. In 2016, there were 1,102 patient encounters in this unit.

17 Benchmark data is pulled from a Children’s Hospital Association analysis of like units.
Nursing care in the Cardiology Patient Care Unit
The Cardiology Patient Care Unit at Texas Children’s Hospital has 51 registered nurses on staff. The hours per patient day equivalent in the acute care unit are 14.8, compared to the national benchmark of 15.9. The unit has a 55 percent rate of attainment for certification in pediatric nursing. 98 percent of the cardiology acute care registered nurses have a bachelor’s degree in nursing, with the remaining 2 percent currently pursuing their bachelor’s degree in nursing.

Cardiovascular Simulation Program
Texas Children’s Heart Center developed an in-situ simulation program in 2012 that brings simulation to the bedside. With a dedicated simulation room on the inpatient unit and a team of trained simulation instructors based in the Heart Center, the program ensures that all providers receive regular, relevant preparation for patient emergencies and other high-risk clinical scenarios. The goals of the program are to improve patient safety through early identification of patient issues and to improve crisis resource management and teamwork skills. Program leaders established a curriculum and learning matrix in order to track objectives and progress. In 2016, the simulation program expanded to include mobile capacity, meaning it can now go to any room bringing simulation even closer to the bedside and in unscheduled or surprise circumstances.
Cardiac Developmental Outcomes

Until recently, most neurodevelopmental follow-up of congenital heart disease patients has been in the context of research studies. The Cardiac Developmental Outcomes program at Texas Children’s Heart Center is a clinical service that focuses on medical, social and developmental health in order to help children reach their maximum potential.

Launched in April 2013, the program was created to provide routine neurodevelopmental assessments for babies and children with heart disease. Since the program’s creation, our team has assessed nearly 600 babies and children, and this number continues to grow every month. As well as providing detailed developmental evaluations throughout childhood, we refer patients for ancillary services including speech/language, occupational, physical, and behavioral therapies.

The Cardiac Developmental Outcomes team includes two developmental pediatricians and two psychologists who work with the Texas Children’s Heart Center team to identify any problems at the earliest possible stage. This provides an opportunity for early intervention in order to minimize the impact of issues during childhood.

The program provides family-centered care, in which the child’s parents or caregivers are directly consulted and involved in their child’s assessment and interventions for developmental progress. We also help families find resources in their communities that support their child’s development.

For more information, please visit texaschildrens.org/departments/cardiac-developmental-outcomes.

Outcomes & Impact Service

The Outcomes & Impact Service at Texas Children’s Hospital measures important clinical outcomes and the impact of care on the quality of life and functional status of our patients over time. The team’s goal is to deliver the highest value of health care to the patient.

By tracking outcomes, we learn about what happens to our patients, and we also learn about our performance as a health care delivery organization. We know we must continue to strive toward excellence in care delivery. In addition to providing statistics, we strive to engage patients and families in a conversation about the choices they face that will impact their health.

Our team includes outcomes nurses dedicated to different clinical specialties, computer programmers, data architects and specialists, and a statistician who works closely with clinical and administrative teams to measure, improve and share our outcomes. The goals of our service are to:

• Track and improve our clinical outcomes
• Understand the impact of those outcomes on the lives of our patients and families over time
• Make our outcomes data available in a form accessible by the general public
• Partner with patients and families in understanding outcomes data
• Help patients and families know what questions to ask when seeking medical treatment

For more information, please visit texaschildrens.org/outcomes-and-impact-service.
Meet Our Leaders

Charles D. Fraser, Jr., M.D., is surgeon-in-chief, co-director of Texas Children’s Heart Center and chief of the Congenital Heart Surgery program at Texas Children’s Hospital. His academic appointments include professor of Surgery in the Michael E. DeBakey Department of Surgery (tenured) at Baylor College of Medicine, professor of Pediatrics at Baylor College of Medicine and adjunct professor of Bioengineering at Rice University. Dr. Fraser holds the Clayton Chair in Surgery and the Donovan Chair in Congenital Heart Surgery at Texas Children’s Hospital.

Dr. Fraser’s education began as an undergraduate at the University of Texas at Austin, where he graduated with honors in mathematics. He received his medical degree with honors from the University of Texas Medical Branch at Galveston. His residency and fellowship training took place at The John Hopkins Hospital. He completed additional fellowship training in congenital heart surgery at the Royal Children’s Hospital in Melbourne, Australia. After joining the faculty at Cleveland Clinic, Dr. Fraser was recruited to Texas Children’s Hospital in July 1995 to establish a dedicated pediatric congenital heart surgery program.

Daniel J. Penny, M.D., Ph.D., M.H.A., is chief of Cardiology at Texas Children’s Hospital, co-director of Texas Children’s Heart Center and professor of Pediatrics at Baylor College of Medicine. Dr. Penny obtained his medical degree from the National University of Ireland and received a doctoral degree for his thesis, “Functional Analysis of Fontan Circulation,” from the University of London. He completed fellowship training in pediatric cardiology at the Royal Children’s Hospital in Melbourne and received a second doctoral degree at Monash University, Australia, for his studies on neonatal circulation. Dr. Penny worked as a pediatric cardiologist at the Royal Brompton Hospital and Great Ormond Street Hospital in London. Before coming to Texas Children’s Hospital, he was the chief of Cardiology at the Royal Children’s Hospital of Melbourne and a professor in the Department of Pediatrics within the University of Melbourne.
Emad B. Mossad, M.D., is chief of the division of Pediatric Cardiovascular Anesthesiology at Texas Children's Hospital and co-director of Texas Children's Heart Center. He is also a professor of Anesthesiology at Baylor College of Medicine. Dr. Mossad's training began as an undergraduate at Cairo University, Egypt. His medical degree is from University of Cairo Medical School, and his residency and fellowship training in cardiac anesthesia took place at the Cleveland Clinic Foundation. He completed a pediatric anesthesia fellowship at Children's National Medical Center of George Washington University and an echocardiography fellowship at the Cleveland Clinic. Prior to joining Texas Children's Hospital in 2008, Dr. Mossad served as section head for Congenital Cardiac Anesthesia at the Cleveland Clinic from 1997-2008.

Dr. Mossad is actively involved in several professional societies, including service on committees for the Society of Cardiovascular Anesthesiologists and Society for Pediatric Anesthesia. He is also a founding board member and currently serves as president of the Congenital Cardiac Anesthesia Society. Additionally, Dr. Mossad has 38 peer-reviewed publications and eight book chapters, mostly in his field of interest of coagulation management and perioperative care of children and adults with congenital heart disease. He also has a strong interest in the training and education of fellows and residents in the disciplines of pediatric and cardiac anesthesia.

Lara S. Shekerdemian, M.D., F.R.A.C.P., M.H.A., is chief of Critical Care at Texas Children's Hospital and co-director of Texas Children's Heart Center. She also serves as the vice chair of Clinical Affairs for the Department of Pediatrics and professor of Pediatrics at Baylor College of Medicine. She graduated from Birmingham University Medical School and was awarded a postgraduate doctoral degree for her thesis, “Cardiopulmonary Interactions in Congenital Heart Disease,” from the University of Birmingham. Dr. Shekerdemian trained in pediatrics and pediatric cardiology and undertook postgraduate research in London. She trained in critical care in London and Toronto. She was previously on faculty at the Great Ormond Street Hospital in London and was most recently the chief of Critical Care at The Royal Children's Hospital in Melbourne. Her research and clinical interests include extracorporeal life support, brain injury in infants and children with heart disease, and outcomes in children after admission to the intensive care unit.
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With more than six decades of experience in caring for children’s hearts, Texas Children’s Heart Center combines leading, world-class technology with a compassionate, family-centered approach to pediatric cardiac care. Our multidisciplinary team of pediatric cardiologists, cardiovascular surgeons, cardiovascular anesthesiologists, perfusionists, adult congenital heart disease specialists, cardiac intensivists, nurses, child life specialists and support staff work together to surround patients with expertise at every point from diagnosis through treatment, in order to provide the best possible results.

**Meet the Texas Children’s Heart Center team ▶**

**Referrals**

To refer a patient to Texas Children’s Heart Center, please visit [texaschildrens.org/refer](http://texaschildrens.org/refer) or contact the following departments directly:

**Congenital Heart Surgery**

The Congenital Heart Surgery program at Texas Children’s Hospital offers same-day surgical consultation appointments. To make an appointment for a same-day consultation, call 832-TCH-APPT (832-824-2778). For additional appointment information or to speak with a division administrator, please call 832-826-2030.

**Heart Transplant**

866-683-8032

**Cardiology, Adult Congenital Heart Disease and Cardiovascular Intensive Care Unit**

832-82-HEAR T (832-824-3278)

**Cardiovascular Anesthesiology**

832-826-5831

**Cardiac Developmental Outcomes Program**

832-826-5979

Learn more about Texas Children’s Heart Center at [texaschildrens.org/heart](http://texaschildrens.org/heart).