PEDIATRIC
HeartNews

The latest on pediatric cardiovascular clinical care and research at the Johns Hopkins Children's Center

JOHNS HOPKINS
CHILDREN'S CENTER

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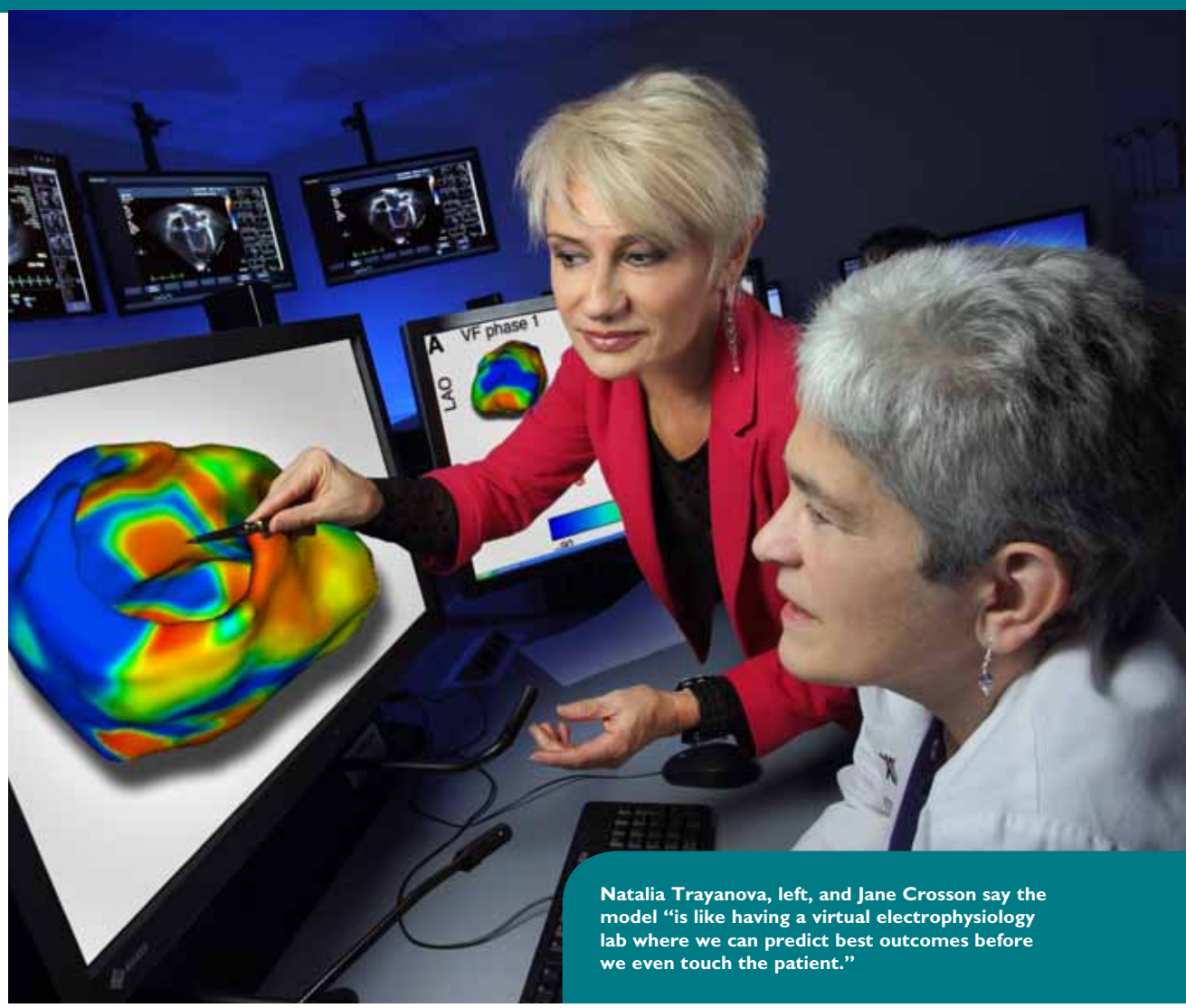
A Better Way to Guide Defibrillator Placement in Children



Natalia Trayanova, left, and Jane Crosson say the model "is like having a virtual electrophysiology lab where we can predict best outcomes before we even touch the patient."

With their heart model, Jane Crosson, Natalia Trayanova and colleagues hope to predict the ICD configuration for individual patients that uses the least amount of energy and gentlest shock.

The small size and abnormal anatomy of children born with heart defects often mean that a defibrillator must be placed entirely outside the heart. Johns Hopkins researchers, however, report* that it may be possible to use a virtual 3-D heart model that analyzes a child's unique anatomy and pinpoints the best location for the device before it is implanted.

"Pediatric cardiologists have long sought a way to optimize device placement in this group of cardiac patients," says Johns Hopkins biomedical engineer **Natalia Trayanova**, "and we believe that our model is a critical first step toward bringing computational analysis to the pediatric cardiology clinic."

To build the model, the team began with low-resolution MRI heart scans of a child born with tricuspid valve atresia who'd had a modified Blalock–Taussig shunt, bilateral bidirectional Glenn shunts and a Fontan procedure using an extracardiac conduit. Based on these images, investigators developed a 3-D computer model that allowed them to simulate ventricular fibrillation and then predict how effectively the defibrillator would terminate the arrhythmia when located in each one of 11 positions around the heart. The model revealed that two particular positions rendered therapy optimal.

A particular advantage of the model is that the team used digital representations of the heart's subcellular, cellular, muscular and connective structures—from ions and cardiac proteins to muscle fiber and tissue—and also included the bones, fat and lungs that surround the heart.

"Heart function is astounding in its complexity and person-to-person variability," Trayanova says, "and subtle shifts in how one protein interacts with another may have profound consequences on pumping and electric function. We wanted to capture that level of specificity to ensure predictive accuracy."

Less-than-precisely positioned defibrillators can fire unnecessarily or, worse, fail to fire when needed to shock a child's heart back into normal rhythm. In addition, devices that are not positioned well can deliver ultra-strong, painful jolts that can damage heart cells and increase risk of death.

"These are lifesaving devices," says Johns Hopkins pediatric cardiologist and arrhythmia specialist **Jane Crosson**, a member of the study team. "But they can feel like a horse kick to the chest and really traumatize children."

In their study, the researchers considered the best configuration to be the placement that exhibited the lowest defibrillation and cardioversion thresholds. If further studies show the model has value in patients, it could spare many children with heart disease from repeat procedures that are sometimes needed to reposition the device. ■

* Rantner LJ, Vadakkumpadan F, Spevak PJ, Crosson JE, Trayanova, NA. Placement of implantable cardioverter-defibrillators in paediatric and congenital heart defect patients: a pipeline for model generation and simulation prediction of optimal configurations. *J Physiol* 2013;591:4321–4334.

The research was funded by the National Institutes of Health under grant number R01HL103428.

A 'One-in-a-Million' Patient

Emily Yang's case was as clinically complex as cardiac care gets. Diagnosed with osteosarcoma, the 14-year-old from Virginia underwent below-the-knee amputation of her left leg and chemo and radiation therapy. But the chemotherapy took a toll on her heart and lungs, and on the Thanksgiving eve following her surgery, Emily could hardly breathe. In Johns Hopkins Pediatric Emergency Department, pediatric cardiologist **William Ravekes** gave Emily and her mom the news—Emily was in heart failure with severe left ventricular dysfunction and had an acute viral infection.

"Her heart was vulnerable from the chemotherapy, and getting the viral infection seemed to have pushed her right over the edge," says Ravekes.

Emily's ejection fraction was a mere 12 percent. Moreover, because her cardiac output was worsening, she was admitted to the pediatric intensive care unit (PICU) and placed on extracorporeal membrane oxygenation by pediatric cardiac surgeon **Luca Vricella**.

After nine days on ECMO, Emily's lungs improved, but her heart needed the support of both a left ventricular assist device (LVAD) and a right VAD, a so-called tandem heart. Emily also needed an aortic balloon pump implanted to improve blood flow.

"The balloon pump inflates during diastole to force blood flow back into the coronary arteries and also forward to give a little more oomph for blood moving to the liver, the kidneys and everything else," says Ravekes. "It's a rare surgery in kids, but she needed it because both her ventricles were so dysfunctional."

Cardiac surgeon **Ashish Shah** carried out the complex operation and admitted Emily to the adult ICU, where staff are more experienced in caring for bi-VAD and intra-aortic balloon pump patients. After three days, Emily's right ventricle recovered and she was taken off the RVAD and balloon pump and transferred to the PICU under the care of critical care specialist **Kristen Nelson**. Her weakened left ventricle required her to stay on the LVAD, but because the device was implanted she was able to go home.

In caring for Emily Yang, says William Ravekes, "what has been great is the collaboration of pediatric oncology, pediatric and adult cardiac surgery, and both pediatric and adult intensive care."

Since then, Emily has attended regular school and resumed playing the guitar and piano. Meanwhile, her team has been monitoring her left ventricular function to determine whether she needs a new heart. If in a year there are no signs of recurring cancer, Ravekes says, Emily could be placed on the heart transplant list.

"If her heart function is still severely depressed, she would stay on the LVAD," says Ravekes. "If the function is better but still marginal, we would support her with medications and put her on the transplant list but remove the device. If her heart is functioning really well, we'll keep transplant on the back burner as long as possible—there is a possibility that she could avoid it." ■

Marshall Jacobs is coordinating outcomes research across three congenital heart surgery programs.

Surgical Lessons from Adults Born with Congenital Heart Disease

At age 12, Austin Cole had a Ross procedure at The Johns Hopkins Hospital to replace his diseased aortic valve. Cole was born with aortic valve stenosis and over the years had multiple balloon valvotomies to open the valve and postpone the open heart surgery that would eventually be required. The delay allowed his body to mature enough to better accommodate the new pulmonary valve that would be put in as part of the Ross procedure.

"It was a major operation. It took me several months to recover," says Cole, now 18.

However, two years later, the function of the donor pulmonary homograft began to deteriorate. Fortunately, by the time Cole needed a new pulmonary valve, Johns Hopkins pediatric cardiologist **Richard Ringel** was among the first clinicians in the country to offer a minimally invasive new procedure and a new device to replace pulmonary valves in the cath lab rather than in the OR.

"My recovery was much quicker compared with the operation I had when I was 12," says Cole. "It has definitely made a big difference."

Cole's experience is an example of the many refinements that have been made in treating congenital heart problems since the world's first "blue baby" operation was performed at Johns Hopkins in 1944.

The minimally invasive valve procedure is also helping people born with tetralogy of Fallot. Although the blue baby operation was a lifesaving turning point, it later became clear that many patients would need subsequent procedures. "They have a valve that's too small or badly obstructed, and we need to create an opening, sacrificing the valve to get over the obstruction," says Johns Hopkins Cardiac Surgery Director **Duke Cameron**. "We've learned that over time, the opening we created is leaking and the right side of the heart is struggling."

Because of that, Cameron says it's important to replace the pulmonary valve before the regurgitation causes the heart to become enlarged and weak. That knowledge has influenced how the operation for tetralogy of Fallot now is performed. "Today, we bend over backwards to preserve the patient's own valve," says Cameron. "It's a balance to tolerate the slight blockage in order to avoid a lot of leakage down the road."

Among the keys for further refining treatment for congenital heart defects, says Cameron, is evaluating outcomes through databases that combine the experience of many large programs. Cameron has recruited cardiac surgeon **Marshall Jacobs** to coordinate outcomes research and share experience and expertise across the congenital heart surgery programs at The Johns Hopkins Hospital, All Children's Hospital Johns Hopkins Medicine in St. Petersburg, Florida, and Florida Hospital for Children in Orlando.

"Better medical and surgical techniques and greater understanding of the disease processes have led to a much improved outlook and quality of life," says Jacobs. "There are now as many adults living with congenital heart disease as there are infants and children. Our goal is to develop ways to provide even better care of these patients. ■

Boning Up on Loeys-Dietz Syndrome

Earlier diagnosis and better management of vascular and cardiac complications have led to dramatic improvements in the lives of patients with the connective tissue disorder Loeys-Dietz syndrome (LDS). But a recent Johns Hopkins study, believed to be the largest examination of skeletal fragility in LDS patients, shows that people with the condition are also prone to bone fractures and low bone mineral density.

In a survey and chart review of 57 LDS patients, researchers found that 33 patients (58 percent) had at least one fracture, and 14 (25 percent) had two or more. Participants reported a total of 51 fractures—35 in the upper extremity, 14 in the lower extremity and two in the spine; the forearm and wrist were most commonly injured. Most fractures resulted from falls.

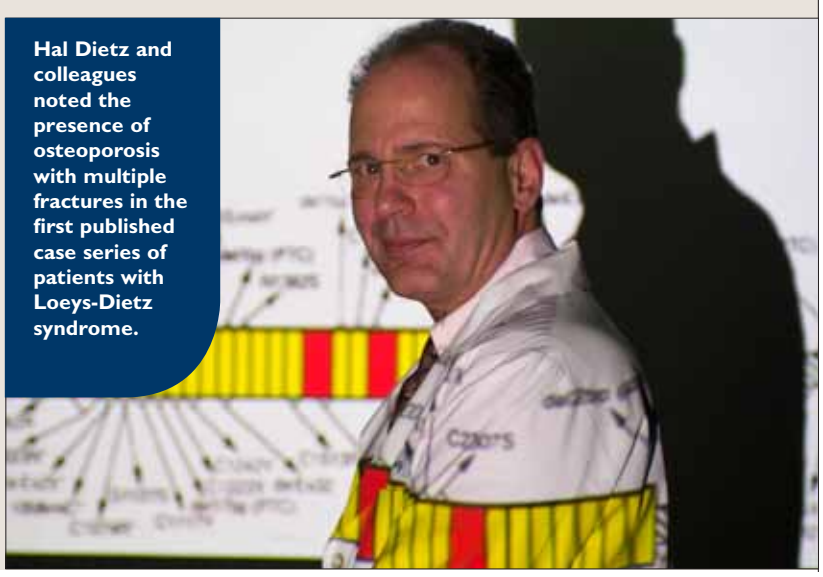
Investigators calculated that LDS patients had a 50 percent risk of fracture by age 14 and greater overall incidence of fractures compared with the general population.

In a subset of patients who had dual-energy X-ray absorptiometry scans available for review, at least 60 percent had low or very low bone mineral density in the spine, hip and/or femoral neck, potentially increasing their propensity for fractures.

First described by Johns Hopkins cardiologist **Hal Dietz** and colleagues in 2005, LDS is characterized by vascular aneurysms and blood vessel tortuosity, hypertelorism and bifid uvula or cleft palate. Patients with LDS are at high risk for progressive arterial aneurysms commonly leading to aortic dissection and rupture. Early recognition of the condition, combined with advances in medical and surgical management of its vascular complications, can improve life expectancy, the authors say.

"In light of our findings about patients' increased risk for osteopenia and osteoporosis," Dietz says, "physicians should counsel their patients with the condition about their predisposition to low bone mineral density and higher fracture risk. We are hopeful that this issue will prove amenable to medical therapies, diet and exercise."

Adds orthopedic surgeon and senior study author **Paul Sponseller**, "Further studies focusing on bone structure and function, as well as on the molecular mechanisms that drive increased fracture risk and osteopenia, will pave the way to developing targeted therapies." ■



Hal Dietz and colleagues noted the presence of osteoporosis with multiple fractures in the first published case series of patients with Loeys-Dietz syndrome.

Richard Ringel now has a better way to locate obstructions in the coronary arteries.

A **Three-D** Cath Lab

A state-of-the-art pediatric catheterization suite can make quite a difference in diagnosing and treating complex cardiac conditions in children, says pediatric interventional cardiologist **Richard Ringel**.

"Looking at the pulmonary artery in two dimensions, as we did in the past, you could often miss important obstructions and narrowing," he says. "I had to take multiple pictures because I knew there was a blockage, but I couldn't find it from the standard projections."

No more. When Johns Hopkins' Charlotte R. Bloomberg Children's Center opened in May 2012, it also unveiled a modern pediatric catheterization lab featuring the very latest cardiovascular X-ray biplane imaging designed with three-D capability to improve accuracy and results in procedures like stenting and dilation of narrowed pulmonary vessels.

"You can have the frontal plane swing all around the patient to create a three-dimensional image not unlike that of a CT scan," says Ringel. "It's a fantastic option for imaging the child at many different projections and from many different positions to get the necessary information to make the diagnosis." Also, because the technology has replaced vacuum tubes and image intensifiers with flat panel receptors, Ringel adds, radiation exposure has been reduced by a third. ■

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