

## ADVANCES IN MOTION

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# PIONEERING MACHINE LEARNING TOOLS TO INFORM DECISION MAKING IN SPINE SURGERIES

ARTICLE PUBLISHED ON SEPTEMBER 14, 2018



### IN THIS ARTICLE

- The Orthopaedic Department of Massachusetts General Hospital leads the innovative use of probabilities and prediction models to improve decision-making to help patients understand the risks and outcomes of spine surgeries
- People mistakenly fear that the rise of ML (machine learning) and AI (artificial intelligence) will supplant the physician-patient relationship. Research suggests otherwise
- Decision-making is the basis of optimal clinical and surgical outcomes, and ML, AI-based tools are a potentially valuable adjunct to help guide decisions

In the traditional clinical consult, a physician makes decisions based on an understanding of probability—and in particular, the probability that she or he can improve the patient's outcome.

However, despite the most sophisticated command of probabilities, cognitive science research shows that people are prone to making decisions based on faulty information or assumptions.

"Most human decisions are based on ideas that are frankly wrong," says [Joseph H. Schwab, MD](#), chief of the [Orthopaedic Spine Center](#) at Massachusetts General Hospital, and co-director of the

[Stephan L. Harris Center for Chordoma](#) memory, cognitive bias, limited experience and emotional filtering can influence a person's decisions.

"Yet decision-making is the foundation of medicine," Dr. Schwab says. He and colleagues are at the forefront of developing machine learning (ML) algorithms to help patients understand the risks and outcomes of their surgeries, and to mitigate inborn human biases in decision making.

## Probability Modeling for Surgical Outcomes

In the last five years, the rise of ML and its advanced mathematics that drive artificial intelligence (AI) have accelerated dramatically. The confluence of these trends with the development of graphic processing unit (GPU) computer chips from the gaming industry means computers can now parallel process large amounts of data at speeds never before possible.

Dr. Schwab and his team have used this technology to develop a probability model of surgery outcomes to inform treatment choices, and are developing another model to assess the probability that patients will experience complications. The models are relatively broad, with some used to predict which factors are associated with long-term opiate usage after surgery, to others that predict which patients are most likely to have a major complication after surgery.

"The models are developed by comparing several different machine learning algorithms," says Dr. Schwab. "We compare the ability of the algorithms to discern differences between two groups, and then we compare the accuracy of the models over a range. We select the best algorithm for each case on an individual basis."

While Dr. Schwab and his team have used nationally available data to design algorithms, they prefer to use the extremely large spine database that includes 15,000 patients belonging to Mass General and affiliated hospitals through Partners HealthCare. It includes many more parameters than the national databases, such as those from Medicare and the [National Surgery Quality Improvement Program](#) (NSQIP) collection of inpatient data.

The Partners data provides the level of granularity missing in the government resources, and can help predict such practical outcomes as identifying which patients should go to a skilled nursing facility and the probability of the risk for complications.

"The real benefit of using our data is the ability to follow patients longitudinally. It is not limited by pre-selected data points, such as the ones in national databases," says Dr. Schwab. He also points out that the Partners data can be linked to genetic data via the biobank. Patient-reported outcomes measures (PROMS) are soon to be available for research efforts.

## Advantages of Machine Learning

People often fear the application of machine learning in medicine as a way of supplanting the physician-patient relationship, and the many aspects of intimate knowledge that embodies. Dr. Schwab believes these concerns can be overcome by the clear and demonstrable advantages that machine learning can bring to certain kinds of decisions. He is confident machine learning will not replace or diminish the role of humans in medicine.

"It will augment and extend it," he says, "because machine learning provides better or more accurate tools to make decisions."

For example, consider this common scenario. In developing the care plan for a patient with metastatic cancer, you are trying to decide if surgery is going to improve the patient's quality of life. A key question here, Dr. Schwab says is, "How long is the patient likely to survive?" This is a good application for AI-based tools, because the whole treatment goal is to palliate the condition during the time remaining.

"If they are going to live one month, and it takes them three months to recover from surgery, it doesn't make much sense to undergo surgery," Dr. Schwab says.

## Future Directions

Despite the proven clinical utility of applying ML to some aspects of patient care, Dr. Schwab emphasizes that probabilities in any field are still calculated likelihoods and not crystal ball divinations.

"Eighty percent probability of condition X means that if the model were run 100 times, the condition would occur 80 times," he says. "That means it would not occur 20 times out of 100. If condition X does not occur, the model is still valid even though the condition did not occur. This is akin to the weather report stating there is an 80% chance of rain. One still has to decide whether or not to bring

an umbrella. But the weather forecast is  $\approx$  than our human ability to predict outcomes."

Research by Dr. Schwab and others shows that a patient's preoperative depression and anxiety scores are correlated with surgical outcomes for degenerative spinal surgery such as laminectomy for lumbar stenosis.

"Perhaps incorporating preoperative scores into prediction models would hopefully change the way we treat the patient," Dr. Schwab says. By treating anxiety before the procedure, the outcome might improve.

Dr. Schwab explains that knowing when and how to enlist the power of machine learning in patient care is key to its widespread use. He adds that Mass General is uniquely suited to lead the field because of its broad multidisciplinary medical, surgical and research network, coupled with leadership partners in computational sciences. Mass General also has experts who treat many rare conditions, such as bone tumors, which are now captured in the medical records. This provides researchers with fertile ground to study these conditions using new methods including machine learning, which may shed new light on treatment options. It is therefore invaluable in training high-precision machine learning systems and algorithms to aid in the diagnosis.

The goal is to harness the power of machine learning to help create a future of individualized medicine serving empowered patients.

"If patients have this information, they'll be able to make better decisions about their care," he says.

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## INSIDE THIS ISSUE

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## Innovative Management Strategy for a Fetus with Hypoplastic Left Heart Syndrome and Intact Atrial Septum



Rodrigo Ruano, MD, Nathaniel W. Taggart, MD, M. Yasir Qureshi, MBBS, Sameh M. Said, MD

Hypoplastic left heart syndrome (HLHS) with an intact or severely restrictive atrial septum carries the highest risk of mortality within the first few hours of life, and constitutes about 10% of all patients with HLHS. Having a decompressing vein (that diverts blood flow from the hypertensive left atrium and pulmonary veins into a systemic vein) or antegrade flow through patent mitral and aortic valves may allow for a limited time of hemodynamic stability after birth. However, emergent relief of obstruction at the atrial level is needed for survival. The best strategy to obtain this relief is not yet established. "Fetal interventions, postnatal transcatheter interventions and postnatal surgical resection have all been used, but the mortality risk continues to be high in this subgroup of patients," says M. Yasir Qureshi, MBBS, pediatric cardiologist at Mayo Clinic in Rochester, Minnesota. Dr. Qureshi led a team of pediatric cardiologists, pediatric cardiac surgeons and maternal-fetal specialists in a novel, sequential approach

to managing this pathology in a fetus with HLHS with intact atrial septum (HLHS-IAS) which was developing hydrops. This approach consisted of percutaneous in-utero fetal atrial septostomy followed by Ex-utero Intrapartum Treatment (EXIT) to surgical atrial septectomy.

### Case Presentation

A 28-year-old Grava 4 Para 2 mother was referred to Mayo Clinic for further management of prenatally diagnosed fetal HLHS. Fe-

tal echocardiogram performed at 28 weeks gestation demonstrated HLHS-IAS with mitral valve hypoplasia, aortic valve atresia, hypoplastic left ventricle and hypoplastic ascending aorta. The atrial septum was thick and muscular. Pulmonary venous Doppler showed to-and-fro flow with prominent flow reversal during atrial systole consistent with severe restriction at the atrial level resulting in hypertensive left atrium. There was no decompressing vein or any antegrade flow through the left heart. Follow-up fetal echocardiogram performed the following week showed the new development of a small right-sided plural effusion and pericardial effusion (fetal hydrops). Due to the development of these early signs of fetal hydrops, percutaneous fetal intervention was recommended.

### Ultrasound-Guided Percutaneous Fetal Atrial Septostomy

The fetal atrial septostomy was performed under

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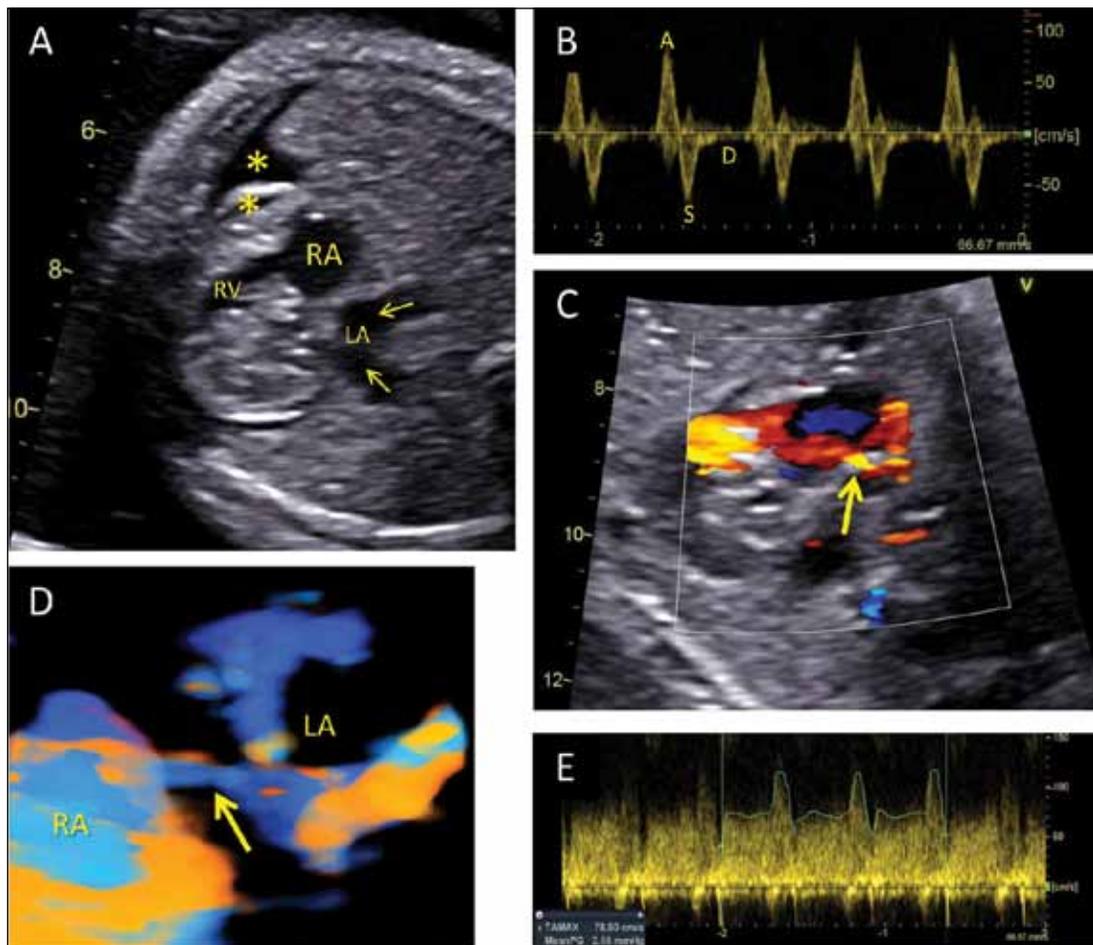
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**Figure 1.** Ultrasound-guided intrauterine fetal atrial septostomy. A, Four-chamber view on fetal echocardiogram showing pleural and pericardial effusions (\*). Arrows indicate dilated left and right pulmonary veins. LA, left atrium; RA, right atrium; RV, right ventricle. B, Pulmonary venous Doppler showing prominent atrial reversal of flow (A) with no early diastolic forward flow (D). C & D, Color Doppler and 3D power Doppler demonstrating atrial level shunt (arrows) after fetal intervention. E, Pulse wave Doppler interrogation of atrial shunt showing 2-3 mmHg gradient across the atrial septum.

local maternal anesthesia and sedation (Figure 1). The fetus was gently positioned in order to have the correct needle access. A combination of anesthetic medications was injected percutaneously into the left arm of the fetus under ultrasound guidance. Again, under ultrasound guidance, a trocar needle was advanced percutaneously into the amniotic space and was directed through the fetal chest wall and into the right atrium. The atrial septum was punctured with the needle trocar, and the trocar was removed. A coronary wire was advanced through the needle into a pulmonary vein. A coronary angioplasty balloon was advanced over the wire and inflated multiple times to dilate the atrial septum. Once flow across the atrial septum was demonstrated by color Doppler, the balloon was withdrawn into the needle and the needle, balloon and wire were removed. A small pericardial effusion was observed but did not progress or require drainage. Fetal heart rate remained stable between 120 - 140 bpm and

ventricular function remained normal during the entire procedure.

“Follow-up fetal echocardiogram performed 1 week after the intervention demonstrated resolution of pericardial and plural effusions,” says Nathaniel W. Taggart, MD, pediatric cardiologist at Mayo Clinic in Rochester, Minnesota. The atrial septum was still restrictive, but with blood flow across the septum. The patient was closely followed by a maternal fetal medicine specialist and a pediatric cardiologist weekly. Fetal echocardiogram performed at 33 weeks of gestation showed reappearance of a right-sided plural effusion. Percutaneous re-intervention was not deemed appropriate in this setting due to thick and muscular atrial septum. Due to evolving hydrops fetalis, EXIT to surgical atrial septectomy with possible need of extracorporeal membrane oxygenator was recommended. The likelihood of a poor outcome and the added risks of EXIT procedure were discussed in detail with the patient. Alternative

management options were discussed. After an extensive multidisciplinary discussion, the patient elected to proceed with EXIT procedure and open septostomy. Ethical approval was obtained from the Pediatric Ethics Board.

### EXIT to Surgical Atrial Septectomy

An EXIT delivery was performed at 34 weeks of gestation under maternal general anesthesia (Figure 2). The fetus was partially delivered and the fetal-placental circulation was maintained. After transthoracic echocardiographic confirmation of the diagnosis, a median sternotomy was performed. "The external inspection of the heart likewise confirmed the fetal diagnosis of HLHS with severely hypoplastic ascending aorta, large main pulmonary artery and a large ductus arteriosus that supplied the descending aorta," says Sameh M. Said, MD, pediatric cardiac surgeon at Mayo Clinic in Rochester, Minnesota. A central line was placed in the right atrium and secured to the chest wall to enable medication administration and fluid resuscitation. A long purse-string suture was placed in the right atrial free wall. The superior and inferior venae cavae were temporary clamped with vascular clamps and the heart was allowed to empty. Entry into the right atrium was made through an incision within the purse-string

suture. The septum primum was resected and the heart was de-aired by removing the temporary clamps on the venae cavae. Finally, the purse-string was pulled to control the bleeding. Acidosis and anemia were corrected. Epicardial echocardiography confirmed adequate communication between the right and left atria and no restriction at the interatrial septum. The fetus was then intubated and ventilated. ECMO (extra-corporeal membrane oxygenation) was on standby but since the fetus responded well to ventilation, it was not needed. The fetus was then completely delivered by clamping the umbilical cord. The neonate was then transferred to a separate operating room for completion of the procedure, where umbilical arterial and venous catheters were placed. The chest was then temporarily closed after placing the standard surgical drains and was transferred to the cardiac surgical intensive care unit (ICU). No intraoperative complications for either the mother or the neonate were encountered.

### Discussion

"Intact or severely restrictive atrial septum poses a high risk of mortality in patients with HLHS," according to Rodrigo Ruano, MD, chair of the Department of Maternal and Fetal Medicine. Development of hydrops commonly portends in utero

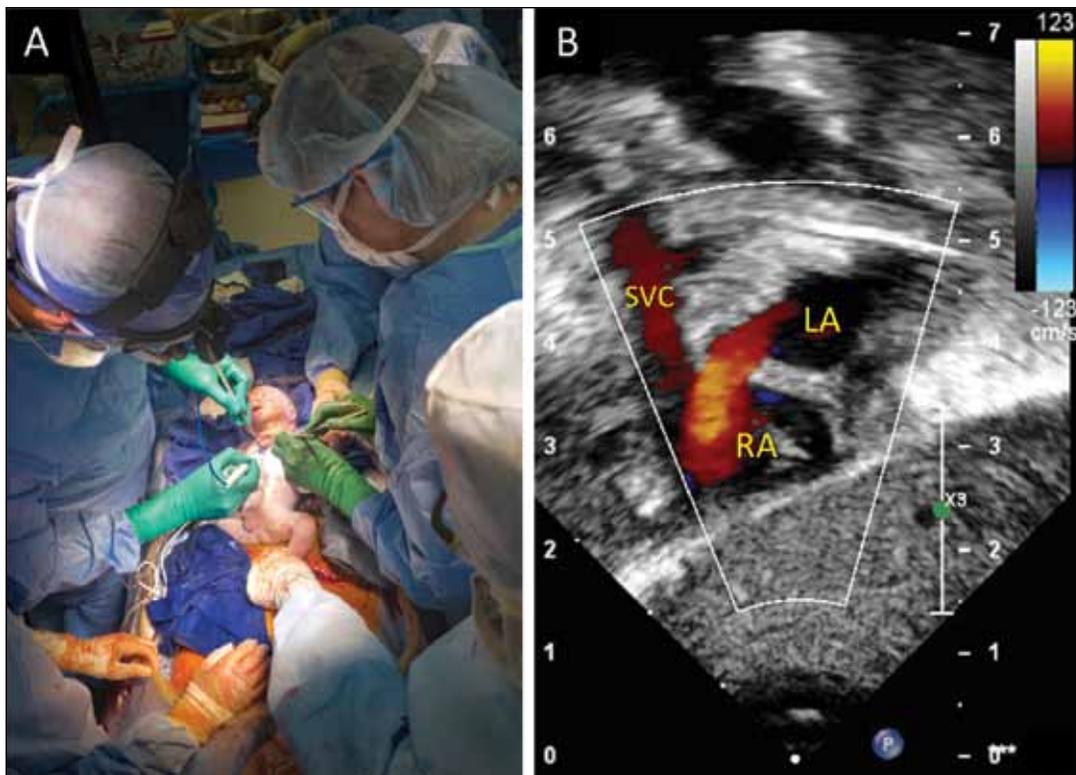


Figure 2. EXIT to surgical atrial septectomy. A, The fetus is lying on the mother's thighs while still attached to the mother via umbilical cord, and the cardiac surgical team is proceeding with atrial septectomy. B, Postoperative subcostal echocardiographic image showing surgically created interatrial communication between the left atrium (LA) and the right atrium (RA). SVC, superior vena cava.

fetal demise. Many of the in utero or postnatal interventions, including ECMO support, can be futile due to abnormal pulmonary vasculature (diffuse hypoplasia of pulmonary arteries, "arterialization" of pulmonary veins with muscular media, and severe pulmonary hypertension). Initial percutaneous intervention in this case allowed resolution of developing hydrops early on, avoiding fetal demise. The atrial septum had some flow but continued to be restrictive due to its muscular nature. Recurrence of hydrops required more definitive management. Waiting until term would

have likely led to in utero fetal demise; as a neonate starts breathing and the lungs expand, there is an increase in pulmonary blood flow which results in severe pulmonary congestion and pulmonary edema if the obstruction is not relieved. EXIT to surgical septectomy allowed for the relief of atrial level obstruction prior to the neonate's first breath, avoiding need for ECMO. This is the first reported case where an EXIT procedure has been used without cardiopulmonary bypass for an open-heart operation in humans and provides a promising alternative strategy for management of HLHS-IAS.

## RECOGNITION



Virend Somers, MD, PhD is one of two recipients of the 2017 Distinguished Mayo Clinic Investigator Award. This award is presented to individuals whose research career demonstrates evidence of great distinction, highly distinguished scholarship, creative achievement, and evidence of excellence in education and administrative responsibilities. Dr. Somers is a consultant in the Division of Cardiovascular Diseases and holds joint appointments in the

Division of Nephrology and Hypertension and the Department of Physiology and Biomedical Engineering. He holds a named professorship in medicine as the Alice Sheets Marriott Professor. Dr. Somers directs the Mayo Clinic Sleep Core Laboratory and the Cardiovascular Core Laboratory. Dr. Somers' research spans the continuum of discovery–translation–application, and he has received continuous NIH funding since 1989. He and his colleagues were among the first to demonstrate the effects of sleep and sleep apnea on cardiovascular conditions, such as irregular heart rhythms, myocardial infarction, and sudden death occurring during sleep.



Naima Covassin, PhD, a senior research fellow in the Department of Cardiovascular Medicine at Mayo Clinic in Rochester, Minnesota, was awarded first prize in the Council on Cardiometabolic Disease Young Investigator Award.



Randal J. Thomas, MD was elected to a 2-year term as Chair of the American Heart Association Council on Clinical Cardiology beginning July 1, 2017. Dr. Thomas is a preventive cardiologist at Mayo Clinic in Rochester, Minnesota.

## RECOGNITION



W. Bruce Fye, MD delivered the 22nd Annual Robert L. Frye Lecture, entitled "An Illustrated History of Modern Cardiology and Cardiac Surgery" to the staff at Mayo Clinic in Rochester, Minnesota on September 27, 2017. Dr. Fye is Emeritus Professor of Medicine and the History of Medicine at Mayo Clinic in Rochester, Minnesota. He is past president of the American College of Cardiology, and past president of the American Association for the History of Medicine. Dr. Fye (right) is pictured with Dr. Frye (left).

## RECOGNITION



Patrick T. O'Gara, MD delivered the 2nd Annual Carole A. Warnes Lecture, entitled "Professionalism in 21st Century Cardiovascular Medicine", to the staff at Mayo Clinic in Rochester, Minnesota on November 2, 2017. Dr. O'Gara is the Director of Strategic Planning for the Cardiovascular Division at Brigham and Women's Hospital, Professor of Medicine at Harvard Medical School, and past president of the American College of Cardiology. Dr. O'Gara (right) is pictured with Dr. Warnes (left), past director of the Adult Congenital Cardiology Clinic at Mayo Clinic in Rochester, Minnesota.

# Stroke Reduction in Nonvalvular Atrial Fibrillation with the Left Atrial Appendage Closure Device: An Update



Paul A. Friedman, MD, David R. Holmes, Jr., MD, Charanjit S. Rihal, MD, MBA

Atrial fibrillation (AF) remains the most common significant cardiac arrhythmia in the United States, with a prevalence estimated to be approximately 7 million patients and predicted to increase to 16 million by 2050. This arrhythmia may occur in patients with no associated cardiovascular disease (sometimes termed lone AF), or more commonly with a variety of underlying cardiac conditions. The prevalence increases with age so that 25% of patients older than 45 years of age have experienced one or another of the types of AF.

Symptoms related to AF vary widely; the predominant concern has been the relationship between AF and stroke, combined with the observation that both AF and stroke increase with advancing age. It has been estimated that AF accounts for 20-30% of all stroke in patients over 75 years of age. In patients with nonvalvular AF, specifically defined as patients without mitral valve obstruction to flow, studies have identified that the left atrial appendage is the source of cardioembolic stroke in approximately 90% of patients. "These cardioembolic strokes are associated with the highest morbidity and mortality as well as an increased rate of recurrence and hemorrhagic transformation," according to David R. Holmes Jr., MD, interventional cardiologist at Mayo Clinic in Rochester.

For the prevention of cardioembolic strokes, anticoagulation has been the mainstay of therapy. Initially, warfarin was the sole agent available and was found to reduce the incidence of stroke in the setting of AF by approximately 60%. However, warfarin administration is complicated due to individual variability in dosing, need for fre-

quent monitoring and dosage adjustment, drug-drug interactions, and bleeding hazards. Direct oral anticoagulants (DOACs) are increasingly used, and as a whole, they are more effective than warfarin in stroke prevention with a lower risk of intracerebral hemorrhage. Additional advantages include the lack of need for periodic monitoring of their effect and a set dosage (although dosing needs to be adjusted for some of the DOACs based upon renal function). Despite the advantages, these agents have not been as widely adopted as predicted because of the incidence of gastrointestinal bleeding (which is similar or even slightly increased compared to warfarin), cost, inconvenience (some of the DOACs require twice-daily dosing), and lack of widely available reversal agents. Despite the availability of multiple agents, approximately 40% of patients at risk for stroke are not treated with anticoagulation because of a relative or absolute contraindication such as prior intracerebral hemorrhage or frequent falls. Finally, in large scale studies, anticoagulation therapy is discontinued in 50-60% of patients within one year after initiation of treatment and they remain at increased risk of stroke.

For all of these reasons, local site-specific therapy with mechanical closure of the left atrial appendage has received increasing attention. Multiple devices are available globally either in clinical trials or in development; however, only one device is currently approved in the United States (Watchman™). The device was approved based on the results of two randomized clinical trials and two accompanying registries. Subsequently, it has been evaluated in a large international registry and a post-approval U.S. trial. In the largest patient meta-analysis comparing the two randomized trials, both of which evaluated device versus warfarin control, the overall composite of all-cause stroke or systemic embolism was similar; there was, however, an 80% reduction in hemorrhagic stroke. There was also marked 70% reduction in longer term bleeding in the device limb and a 50% reduction in cardiovascular or unexplained death (Figure 1). Procedural success has exceeded 90% in all trials, especially with experienced operators, and the incidence of

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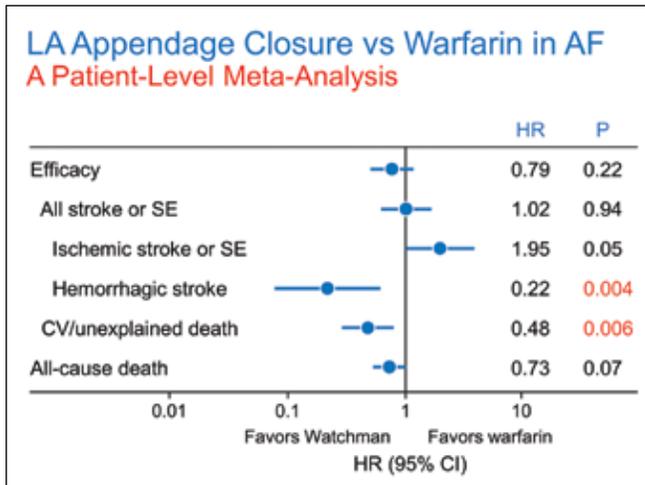


Figure 1. Meta-analysis of patients receiving Watchman™ device versus warfarin for overall stroke, ischemic stroke, and all-cause death in PROTECT AF and PREVAIL trials. (*J Am Coll Cardiol*; 65:2614, 2015)

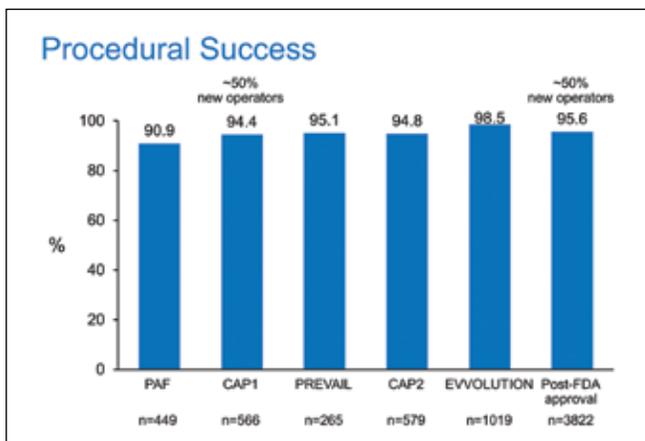


Figure 2. Procedural success in individual Watchman™ trials defined as deployment and release of the device into the left atrial appendage and no leak greater than 6 mm.

### Aggregate Compilation of Incidence of Procedural Complications in Watchman Studies

Complication	%
Pericardial tamponade	1.28
Pericardial effusion – no intervention	0.40
Procedure-related stroke	0.18
Device embolization	0.25
Death	
Procedure-related mortality	0.06
Additional mortality within 7 days	0.07

Figure 3. Aggregate compilation of procedural complications in Watchman™ studies.

complications has been low (Figures 2 and 3).

Indication for Use (IFU) of the Watchman™ device is to reduce the risk of stroke or systemic thromboembolism from the left atrial appendage in patients with non-valvular AF who:

- Are at increased risk for stroke and systemic embolism based on CHADS2 or CHA2DS2-VASc scores and are recommended for anticoagulation therapy;
- Are deemed by their physicians to be suitable for short-term warfarin; and
- Have an appropriate rationale to seek a non-pharmacologic alternative to warfarin, taking into account the safety and effectiveness of the device compared to warfarin.

U.S. reimbursement status for this device was clarified in the CMS National Coverage Decision 2-8-16, which outlined criteria for coverage:

- CHADS2 score  $\geq 2$  or CHA2DS2-VASc score  $\geq 3$
- A formal shared decision-making interaction with an independent noninterventional physician using an evidence-based decision tool on oral anticoagulation in patients with non-valvular AF
- Suitable for short-term warfarin but deemed unable to take long-term oral anticoagulation

Given this information, who should be considered for the Watchman™ device? At the present time it includes patients meeting the FDA IFU criteria:

- Non-valvular AF at high risk for stroke (CHA2DS2-VASc score  $\geq 3$ )
- Deemed suitable to take an anticoagulant for 6 weeks post implant (for facilitative endothelialization) following which they can be treated with antiplatelet agents alone
- Not considered good candidates for long-term anticoagulation

In patients in whom anticoagulation is felt to be contraindicated, there is a dilemma. At the present time there is an FDA trial randomizing patients to either Watchman™ + aspirin versus a control condition of aspirin or aspirin + Plavix. The results of this trial will have important implications for the field. However, globally these devices are used without anticoagulation and instead patients are treated only with antiplatelet therapy. Accordingly, some patients in the U.S. with an absolute contraindication to any anticoagulation may be offered a Watchman™ device after very careful consideration of the alternatives by a team of physicians. It must be remembered that this is an off-label indication.

The steps involved in evaluating a Watchman™ candidate:

- Documentation of nonvalvular AF
- Assessment of underlying comorbidities and risk assessment for stroke using the CHA2DS2-VASc score
- Imaging of the left atrial appendage to evaluate other potential causes of stroke and exclude residual thrombus as well as documenting suitable anatomy for implantation. This can be performed with TEE either alone or in combination with CT.

- Careful evaluation and shared decision-making about risks and benefits of the procedure. This evaluation may be carried out by a variety of individuals in general cardiology, electrophysiology and neurology. “Left atrial occlusion devices are not appropriate for every patient with AF. However, they are an option for those patients at significant risk for thromboembolic stroke for whom long-term anticoagulation is either contraindicated or felt to be suboptimal,” says Dr. Holmes.

## NEW STAFF



M. Sertaç Çiçek, MD has joined the Department of Cardiovascular Surgery at Mayo Clinic in Rochester, Minnesota. Dr. Çiçek completed his medical education at Ankara University Faculty of Medicine and GATA Gülhane Faculty of Medicine, graduating summa cum laude in 1985. He completed a 5-year residency in cardiovascular surgery at GATA, followed by cardiac surgery and cardiopulmonary transplantation fellowships at the Texas Heart Institute and the Mayo Clinic. He also completed an extended pediatric cardiac surgery and transplantation fellowship at Children's Hospital in Los Angeles, California. Dr. Çiçek was instrumental in the establishment of leading pediatric and adult cardiac units in his home country of Turkey, and most recently he served as director of Heart and Vascular Care Center at Anadolu Medical Center in Istanbul before joining staff at Mayo Clinic. Dr. Çiçek has an ongoing interest in the surgical treatment of pediatric and adult congenital heart diseases, structural heart diseases, re-operative cardiac surgery, minimally invasive surgical approaches, and pulmonary thromboendarterectomy for chronic thromboembolic pulmonary hypertension.



Gabor Bagameri, MD has joined the staff of the Division of Cardiovascular Surgery at Mayo Clinic in Rochester, Minnesota. He received his medical education at Semmelweis University in Budapest, Hungary. He completed his general surgery residency and vascular surgery fellowship at Thomas Jefferson University Hospital, Philadelphia, followed by cardiothoracic surgery training at University of Pennsylvania, Philadelphia. He arrives from Virginia Commonwealth University, Richmond, where he worked in the structural heart program and developed the aortic disease program along with colleagues in vascular surgery, radiology, cardiology and genetics. As a surgeon, he has unique skills in vascular and cardiac surgery and is board-certified in both. Dr. Bagameri's interests include open and endovascular aortic interventions and minimally invasive valve interventions.

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**Phone:** 800-283-6296, 507-266-0677, or 507-266-6703

### Echocardiography Review Course for Boards and Recertification

June 9-11, 2018  
Rochester, MN

### Heart Failure Up North

June 23-24, 2018  
Lake Brainerd, MN

### Cardiac Rhythm Device Summit: Implantation, Management, and Follow-Up

June 29 – July 1, 2018  
Dana Point, CA

### Echocardiographic Symposium at Vail: New Technol- ogies, Live Scanning, and Clinical Decision Making

July 23-26, 2018  
Vail, CO

### Success With Failure: Strategies for the Evaluation & Treatment of Heart Failure in Clinical Practice

July 15-17, 2018  
Stevenson, WA

### 2018 Pediatric and Adult Congenital Cardiology Review Course

August 19-24, 2018  
Dana Point, CA

### Cardiovascular Review for Boards & Recertification Including Post-Course Echo Focus Session

August 25-30, 2018  
Rochester, MN

### Electrophysiology Review for Boards and Recertification

TBD  
Rochester, MN

### Challenges in Clinical Cardiology: A Case-Based Update

September 14-16, 2018  
Chicago, IL

### NPPA - Annual Internal Medicine Review for Nurse Practitioners, Physician Assistants and Primary Care Providers

September 19-21, 2018  
Rochester, MN

### Basic to Advanced Echocardiography

September 27-30, 2018  
Hilton Head, SC

### Interventional Cardiology Board Review

TBD  
Rochester, MN

### Heart Disease in Women: A New Era of Understanding, Recognition, Prevention, Diagnosis, and Treatment

October 4-5, 2018  
Rochester, MN

### Echo Revolution: Adult Echocardiography for Physicians & Sonographers

October 5-7, 2018  
Boston, MA

### Echocardiography in Pediatric & Adult Congenital Heart Disease

October 5-7, 2018  
Phoenix, AZ

### The Genetics of Heart & Vascular Disease

October 12-13, 2018  
Hilton Head, SC

### Advanced Ablation Course

September 14-17, 2018  
San Francisco, CA

### Echocardiography in Pediatric & Adult Congenital Heart Disease

October 5-7, 2018  
Phoenix, AZ

### Cases in Echocardiography, Cardiac CT, and MRI

October 24-27, 2018  
Napa, CA

### Echo for the Sonographer and Practitioner Including Point of Care Ultrasound

November 2-4, 2018  
Rochester, MN

### Coronary Artery Disease: Case-Based Learning

November 1-3, 2018  
Dana Point, CA

### The Heart Beat of Cardiology

December 13-15, 2018  
Chicago, IL

### Echo on Marco Island: Case-Based Approach

December 17-20, 2018  
Marco Island, FL

### CARDIOVASCULAR SELF-STUDY

<https://cveducation.mayo.edu/selfstudy>

MAYO CLINIC | [mayoclinic.org](http://mayoclinic.org)

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Rochester, MN 55905

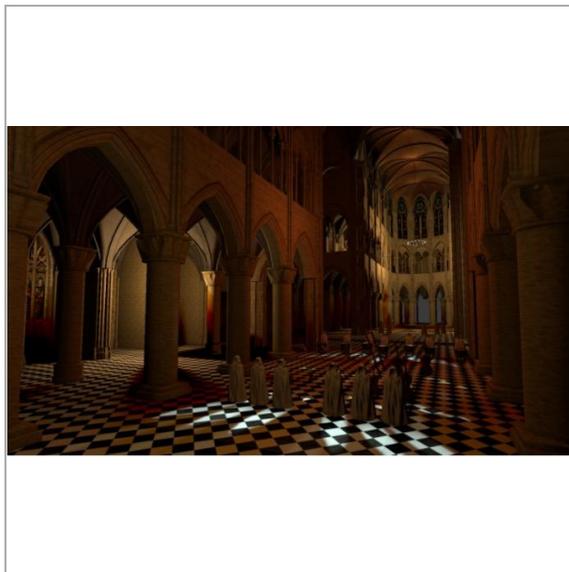
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Scottsdale, AZ 85259

PUBLIC RELEASE: 25-JUN-2017

# Seeing with your ears

*Novel acoustics project aims to improve virtual reality and explore ear shape effects on 3-D sound*

ACOUSTICAL SOCIETY OF AMERICA



**IMAGE:** THIS IS A SCREENSHOT OF A VISUAL RENDERING MODEL OF NOTRE DAME CATHEDRAL, CREATED BASED ON PLANS, LASER SCAN DATA AND SITE VISITS. [view more >](#)

CREDIT: GHOST ORCHESTRA PROJECT/LIMSI

WASHINGTON, D.C., June 25, 2017 -- Paris' Cathedral of Notre Dame has a ghost orchestra that is always performing, thanks to a sophisticated, multidisciplinary acoustics research project that will be presented during Acoustics '17 Boston, the third joint meeting of the Acoustical Society of America and the European Acoustics Association being held June 25-29, in Boston, Massachusetts.

In the project, computer models use recordings from a live concert held at the cathedral and detailed room acoustic simulations to produce a novel type of audience experience: a virtual recreation of the live performance using spatial audio and virtual reality.

Researchers reproduced the recordings using computerized acoustical data and enhanced it with computer-generated virtual navigation -- 3-D visualizations made with immersive architectural rendering that float the viewer through the complex acoustics of the acclaimed medieval gothic cathedral.

Combined, the multimodal sound and image footage of the ghost orchestra produce a spectral tour to the sounds of the 19th century opera "La Vierge" -- The Virgin -- performed live during the 2012-2013 concert season to celebrate the Cathedral's 850th anniversary.

Multimodal virtual reality integration is central to the project's significance, said Brian F.G. Katz, lead investigator and CNRS Research Director at the Institute Jean Le Rond d'Alembert, Pierre and Marie Curie University, in Paris.

"3D-audio is the hot topic today in virtual reality (VR) that is currently a very active subject in both academic and industrial research," Katz said. "With the commercialization of affordable VR systems -- the cheapest allowing for VR on smartphones -- spatial audio is rapidly immersing from the laboratory."

The next stage in spatial audio is personalized audio rendering that involves being able to adjust the rendering to match one's individual head and ear details.

"The importance of multimodal interactions, how visual and auditory cues balance in spatial perception, is key to VR and the sense of immersion, of being 'in' the VR world," Katz explained.

He envisions many applications emerging from the investigation.

"For me, spatial audio is a domain on the boundary of physical acoustics, psycho-acoustics, perception and cognition, and digital signal processing."

His work focuses on using each of the fields to learn more about the others -- from virtual audio scenes exploring how visually impaired people understand and remember architectural spaces, to improving understanding of spatial audition, to refining virtual reality rendering capabilities.

Created in the context of the French funded research projects FUI-BiLi, (Binaural Listening and ANR-ECHO), the acoustical foundation of the project is a 45 channel close-mic recording of the live concert made by the Conservatoire de Paris combined with a detailed geometrical room acoustics computational model that was created and calibrated based on in situ measurements of reverberation and clarity parameters.

Next, the team will apply the methodology to other complex multimodal environments such as theatre simulations.

"Aside from the acoustics in this project, I think we definitely learned a lot about computer graphics and VR content production, which has opened up a lot more dialogue with those communities that we intend to pursue," Katz said.

###

For more information about the project: <https://groupeaa.limsi.fr/projets:ghostorch>

Session 1aAAb1, "Experience with a virtual reality auralization of Notre-Dame Cathedral" by Brian F. Katz, is at 10:40-11:00 a.m. EDT, Sunday, June 25, 2017 in Room 208 of the John B. Hynes Veterans Memorial Convention Center.

## **MORE MEETING INFORMATION**

Acoustics '17 Boston, the third joint meeting of the Acoustical Society of America and the European Acoustics Association.

The meeting is being held June 25-29, 2017 at the John B. Hynes Veterans Memorial Convention Center in Boston, Massachusetts.

## **USEFUL LINKS**

Main meeting website: <http://acousticalsociety.org/content/acoustics-17-boston>

Technical program: <http://acousticalsociety.org/content/program-acoustics-17-boston>

Meeting/Hotel site: <http://acousticalsociety.org/content/acoustics-17-boston#reservation>

Press Room: <http://acoustics.org>

## **WORLD WIDE PRESS ROOM**

In the coming weeks, ASA's World Wide Press Room will be updated with additional tips on dozens of newsworthy stories and with lay-language papers, which are 300-800 word summaries of presentations written by scientists for a general audience and accompanied by photos, audio, and video. You can visit the site during the meeting at: <http://acoustics.org/world-wide-press-room/>.

## **PRESS REGISTRATION**

We will grant free registration to credentialed journalists and professional freelance journalists. If you are a reporter and would like to attend, contact Julia Majors ([jmajors@aip.org](mailto:jmajors@aip.org)) at AIP Media, 301-209-3090. For urgent requests, please contact [media@aip.org](mailto:media@aip.org) who can also help with setting up interviews and obtaining images, sound clips, or background information.

## **LIVE MEDIA WEBCAST**

A press briefing featuring will be webcast live from the conference on Monday, June 26, 2017 in the afternoon and Tuesday, June 27, 2017 in the morning in room 111 of the John B. Hynes Veterans Memorial Convention Center in Boston, Massachusetts.

Register at <https://www1.webcastcanada.ca/webcast/registration/asa617.php> to watch the live webcast. The schedule will be posted here as soon as it is available.

## **ABOUT THE ACOUSTICAL SOCIETY OF AMERICA**

The Acoustical Society of America (ASA) is the premier international scientific society in acoustics devoted to the science and technology of sound. Its 7,000 members worldwide represent a broad spectrum of the study of acoustics. ASA publications include The Journal of the Acoustical Society of America (the world's leading journal on acoustics), Acoustics Today magazine, books, and standards on acoustics. The society also holds two major scientific meetings each year. For more information about ASA, visit our website at <http://www.acousticalsociety.org>.

## **ABOUT THE EUROPEAN ACOUSTICS ASSOCIATION**

The European Acoustics Association (EAA) is a non-profit entity established in 1992 that includes in its membership societies predominantly in European countries interested in to promote development and progress of acoustics in its different aspects, its technologies and applications. EAA gathers 33 societies of acoustics and serves public citizens and more than 9000 individual members all over Europe with yearly events as well as scientific conferences and publications such as Acta Acustica united with Acustica and Acoustics in Practice. The European Acoustics Association (EAA) is an Affiliate Member of the International Commission for Acoustics (ICA) and of Initiative of Science in Europe ISE. Visit our website at <https://euracoustics.org/>.

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<http://acousticalsociety.org/> ↗

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# Inventing Green



Photo Credit: Clipart.com.

With support from the Lemelson Foundation, this collection offers an introduction to invention education, with an emphasis on thinking critically about environmental implications.

Aspiring to educate the next generation of inventors to be environmentally aware and responsible, these resources offer a framework, teaching strategies, and student activities related to innovation and engineering, with suggestions for considering environmental implications during the invention process.

These Science NetLinks resources provide a variety of hands-on and digital learning experiences to help students learn more about invention, collaboration, and entrepreneurship.

Filter Resources by Grade: [ALL](#) [K](#) [1](#) [2](#) [3](#) [4](#) [5](#) [6](#) [7](#) [8](#) [9](#) [10](#) [11](#) [12](#)

## LESSONS



### Rewriting the World Water Script: Defining the Freshwater Access Crisis

9-12

In this lesson, students will work to understand and empathize with the challenges to daily living that a lack of access to freshwater poses, and to imagine innovative green solutions to it.



### From Woodpeckers to Water: Designing Models to Ease Freshwater Access Crisis

9-12 | HANDS-ON

In this lesson, students work on engineering solutions for solving the problem of access to freshwater sources in developing countries by examining case studies of design and exploring models.



## Design Challenge

9-12 | HANDS-ON

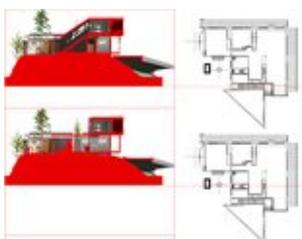
In this lesson, students build and evaluate prototypes for water transport in a design challenge using evaluation criteria.



## Mitigating Climate Change through Passive Solar Design

6-8 | HANDS-ON

This lesson helps students understand our impact on climate change by researching passive solar design and technologies in the context of the environmental impact of the burning of fossil fuels and global warming.



## Designing a Building Using Passive Solar Energy

6-8 | INTERACTIVE

In this lesson, students learn how building design, construction, and location can mitigate the use of energy for heating and cooling.



## Modeling Passive Solar Homes

6-8 | HANDS-ON

In this lesson, students build architectural models of a passive solar house to help them visualize a design and explain their passive solar house design to the building team.

## TOOLS



## The Lemelson Foundation -- The Inventor's Pathway

6-12 | VIDEO

Learn more about The Lemelson Foundation and the ways it inspires, educates, and supports the next generation of inventors.



## Lemelson-MIT Program

K-12 | WEBSITE

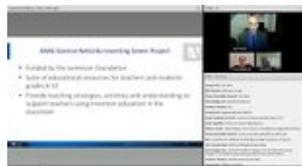
The Lemelson-MIT Program celebrates outstanding inventors and inspires young people to pursue creative lives and careers through invention.



## Books about Invention and Innovation

3-12 | TEACHING AID

This list of engaging books for all ages, compiled by the editors of SB&F, centers on the theme of invention and innovation.



## Bringing Invention Education into the Classroom Webinar

6-12 | VIDEO

A recording of the Science NetLinks webinar from January 26, 2017, in which we discuss our new inventing green resources and ways to challenge students with invention education with AAAS's Bob Hirshon and STEAM educators Doug Scott and Kristin Moon.

## VIDEOS

### Turning Ideas into Inventions

3-12 | VIDEO

Learn how to turn your ideas into inventions through inspiration, education, and iteration.

### Inventing Green

6-12 | VIDEO

Find out what inventing green means in this video from Science NetLinks. Hear from current inventors and learn about other green products, technology, and techniques.

## LINKS

### Science NetLinks Receives Lemelson Foundation Grant for Invention Education

(<http://sciencenetlinks.com/blog/snl-educator/lemelson-foundation-grant/>)

The Lemelson Foundation has awarded Science NetLinks a grant to fund a collection of resources on inventing for sustainability aimed at K–12 students and educators. Learn more in this Science NetLinks blog post.

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## **Introducing the Inventing Green Advisory Board** **(<http://sciencenetlinks.com/blog/snl-educator/introducing-inventing-green-advisory-board/>)**

Meet the members of the AAAS Science NetLinks Inventing Green advisory board in this Science NetLinks blog post.

---

## **The Inventing Green Project** **(<http://sciencenetlinks.com/blog/snl-educator/inventing-green-project/>)**

Find new ways to incorporate invention education -- and inventing green -- into your school through a new collection of Science NetLinks resources and an upcoming webinar. Learn more in this Science NetLinks blog post.

---

## **5 Questions for a Scientist: Inventor and Cybersecurity Expert Bertrand Cambou** **(<http://sciencenetlinks.com/blog/snl-educator/5-questions-scientist-inventor-bertrand-cambou/>)**

Learn what it's like to work in science with the Science NetLinks' blog series of interviews with STEM professionals. Today's subject: inventor and cybersecurity expert Bertrand Cambou.

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## **5 Questions for a Scientist: Bioengineer Z. Maria Oden** **(<http://sciencenetlinks.com/blog/snl-educator/5-questions-scientist-bioengineer-z-maria-oden/>)**

Learn what it's like to work in science with this Science NetLinks blog series of interviews with STEM professionals. Today's subject: Biomedical engineer and inventor Z. Maria Oden.

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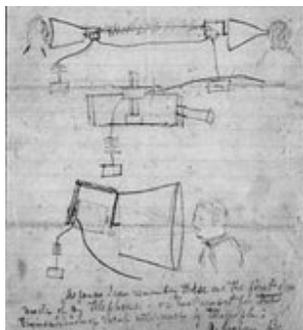
## **5 Questions for a Scientist: Inventor and Engineer Eric Fossum** **(<http://sciencenetlinks.com/blog/snl-educator/5-questions-scientist-inventor-engineer-eric-fossum/>)**

Learn what it's like to work in science with this Science NetLinks blog

series of interviews with STEM professionals. Today's subject: camera chip image sensor inventor Eric Fossum.

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## COLLECTIONS



### Inventors and Inventions

K-12

Learn about groundbreaking creations and the inventors and innovators who helped to shape the world as we know it.

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## FUNDER INFO

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## FOR IMMEDIATE RELEASE

*News from the AVS 60th Annual Symposium & Exhibition, Oct 27-Nov 1, 2013*

*Media Contact: Catherine Meyers | [cmeyers@aip.org](mailto:cmeyers@aip.org)*

### **The Science of Sliding: Understanding Friction May Lead to Healthier Hips and More Energy Efficient Cars**

**LONGBEACH, Calif.** – The way Laurence Marks of Northwestern University sees it, friction needs a fan club to really understand it.

The ubiquitous phenomenon of resistance to sliding surfaces impacts nearly every human endeavor, but still defies complete explanation. Scientists, who like Marks are devoted to untangling the complex mechanism of friction and finding ways to reduce it, call themselves tribologists after the Greek word “tribein,” meaning “to rub.” Marks, one of the foremost practitioners of tribology, will present some of his latest research on the topic at the AVS 60<sup>th</sup> annual meeting, held Oct. 27 – Nov. 1 here.

"Friction is one of the most under-appreciated issues in energy," says Marks, a professor of materials science and engineering at Northwestern University in Evanston, Ill. "Consider cars for example. By some estimates, about one third of the fuel energy in automobiles goes to overcoming frictional losses. If we could reduce friction substantially, a lot of the energy problems we face in the world would go away."

#### **Visualizing Friction-free Possibilities**

And the possibilities in a nearly friction-free world would go far beyond transportation. For example, Marks and his collaborators envision one day manipulating natural biological lubricants in the hip to produce a regenerative medicine fix for arthritis – a thin film of self-healing, self-renewing lubricant so bones of aging joints slide pain-free.

The Marks' team uses a novel imaging technique based on an extremely high-powered microscope first developed after World War II, but later shelved for more economical technology. The team revived and refined the technology to produce images that reveal the mechanisms of solid lubricants. This approach brings new insights into what is happening at the triboactive layer of materials, which is buried and hidden from traditional observational means due to its extremely small size.

"The imaging technology we are using is able to look directly at the interactions at the atomic level," explains Marks. This means the lab visualizes and seeks to manipulate materials measured in mere nanometers. A piece of matter 10 nanometers in size is 1,000 times smaller than a human hair.

continued

Innovative, interesting things happen at the nanoscale. Nanotechnology is increasingly a focus of advanced research because of the novel properties and possibilities that emerge when tiny players interact.

This is particularly true for biological systems because proteins that controls cellular functions are around 1-20 nanometers in size. If researchers can successfully manipulate proteins, they can control function and processes in the body – such as getting old hip joints to slide smoothly again.

### **Fixing Hips with Varnish**

A novel extension of the Marks' lab hip work is their investigation into the formation of varnish – a sticky, shiny residue well known in industry as a trouble-maker for machines because it accelerates friction and wear in metal parts, thus reducing performance. Yet varnish also spontaneously forms in biological systems, such as on metal-on-metal (MoM) hip replacements, where a graphitic tribolayer develops between moving surfaces of the implant during normal use.

The hip tribolayer is interesting because it is not composed of biological proteins, as one might expect. It chemically changes to become a solid lubricant of graphitized carbon. Strangely, where varnish formation is a problem for machines, in the hip it appears to have the opposite effect by improving performance.

### **Extending An Ancient Inquiry**

Dr. Marks is now working to understand this chemical transformation and other curiosities of varnish tribolayers, ever mindful that in so doing, he is extending an ancient inquiry. He cites images from 1880 B.C. found on the tomb of Tehut-Hetep in which a man pours lubricant to help people haul a stone statues. Says Dr. Marks:

"This tells us the problem of friction has been a big issue for a very long time – worthy of tomb art 2000 years before Christ and showing the world's first documented tribologist."

###





MENU

## Best of Both Worlds

SHARE THIS      

### Ferromagnetism + Semiconductor = Spintronics: New Opportunities for Improving Electronics

From the Journal: *Applied Physics Letters*

By AIP News Staff

WASHINGTON, D.C., May 9, 2016 – More, faster, better, cheaper. These are the demands of our device-happy and data-centered world. Meeting these demands requires technologies for processing and storing information. Now, a significant obstacle to the development of next-generation device technologies appears to have been overcome, according to researchers from the University of Tokyo (Japan), Tokyo Institute of Technology (Japan) and Ho Chi Minh University of Pedagogy (Vietnam).

Specializing in the emerging field of semiconductor spintronics, the team has become the first to report growing iron-doped ferromagnetic semiconductors working at room temperature — a longstanding physical constraint. Doping is the practice of adding atoms of impurities to a semiconductor lattice to modify electrical structure and properties. Ferromagnetic semiconductors are valued for their potential to enhance device functionality by utilizing the spin degrees of freedom of electrons in semiconductor devices.

“Bridging semiconductor and magnetism is desirable because it would provide new opportunities of utilizing spin degrees of freedom in semiconductor devices,” explained research leader Masaaki Tanaka, Ph.D., of the Department of Electrical Engineering & Information Systems, and Center for Spintronics Research Network, University of Tokyo. “Our approach is, in fact, against the traditional views of material design for ferromagnetic semiconductors. In our work, we have made a breakthrough by growing an iron-doped semiconductor which shows ferromagnetism up to room temperature for the first time in semiconductors that have good compatibility with modern electronics. Our results open a way to realize semiconductor spintronic devices operating at room temperature.”

The researchers discuss their findings this week in *Applied Physics Letters*, from AIP Publishing. The researchers’ maverick move challenged the prevailing theory that predicted a type of semiconductor known as “wide band gap” would be strongly ferromagnetic. Most research focuses on the wide band gap approach. “We instead chose narrow-gap semiconductors, such as indium arsenide, or gallium antimonide, as the host semiconductors,” Tanaka said. This choice enabled them to obtain ferromagnetism and conserve it at room temperature by adjusting doping concentrations.

Investigators have long envisioned bridging semiconductors and magnetism to create new opportunities of utilizing spin degrees of freedom and harnessing electron spin in semiconductors. But until now, ferromagnetic semiconductors have only worked under experimental conditions at extremely low, cold temperatures, typically lower than 200 K

(-73°C), which is much colder than the freezing point of water, 273.15 K. Here, K (Kelvin) is a temperature scale which, like the Celsius (°C) scale, has 100 degrees between boiling (373.15 K = 100°C) and freezing (273.15 K = 0°C) of water.

## Ferromagnetism and Semiconductor Spintronics Offer New Opportunities for Improving Electronics

The texture of the background is the experimental data expressed as a lattice image observed by scanning transmission electron microscopy of the investigators' (Ga,Fe)Sb thin film. One white dot corresponds to one atom.

When all spin magnetic moments are aligned in one direction, the material is ferromagnetic. Maintaining such ferromagnetic state, even at high temperature, is a key issue both for fundamental studies and for practical applications. In such ferromagnetic state, the magnetization properties show hysteresis, as shown in the lime green curves taken from a (Ga,Fe)Sb sample with an Fe content of 25%.

In the crystal lattice of the ferromagnetic semiconductor (Ga,Fe)Sb studied in this work, the purple, blue, and black spheres represent Ga (gallium), Sb (antimony), and Fe (iron) atoms, respectively.

Credit: Based on work and data of the Masaaki Tanaki research group; infographic by The Story Laboratory, LLC, for the American Institute of Physics, 2016.

Potential applications of ferromagnetic-semiconductors include designing new and improved devices, such as spin transistors.

"Spin transistors are expected to be used as the basic element of low-power-consumption, non-volatile and reconfigurable logic circuits," Tanaka explained.

In 2012, the team postulated that using iron as magnetic doping agents in semiconductors would produce performance advantages not seen in the more frequently studied manganese class of dopants.

Skeptics doubted this approach, but the team continued and successfully created a ferromagnetic semiconductor known as "n-type."

"This was thought impossible by almost all leading theorists," Tanaka noted. "They predicted that such n-type ferromagnetic semiconductors cannot retain ferromagnetism at temperatures higher than 0.1 K. We demonstrated, however, many new functionalities, such as the quantum size effect and the ability to tune ferromagnetism by wave function manipulation."

On a practical level, the team continues its research with the goal of applying iron-doped ferromagnetic semiconductors to the field of spintronic device innovation. On a theoretical level, the team is interested in re-evaluating conventional theories of magnetism in semiconductors. "Based on the results of many experimental tests, we have proven that ferromagnetism in our iron-doped semiconductor is intrinsic," Tanaka said.

###

## For More Information:

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[media@aip.org](mailto:media@aip.org)

301-209-3090

**Article title:** [High-temperature ferromagnetism in heavily Fe-doped ferromagnetic semiconductor \(Ga,Fe\)Sb](#)**Authors:**

Nguyen Thanh Tu, Pham Nam Hai, Le Duc Anh and Masaaki Tanaka

**Author affiliations:**

University of Tokyo, Ho Chi Minh City University of Pedagogy and Tokyo Institute of Technology

**About the journal:****Applied Physics Letters**

*Applied Physics Letters* features concise, rapid reports on significant new findings in applied physics. The journal covers new experimental and theoretical research on applications of physics phenomena related to all branches of science, engineering, and modern technology.

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## Quantum Computing Advances with University of Tokyo Researchers' Control of Entanglement

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**University of Tokyo University researchers have set a world record by entangling more than one million physics systems.**

**From the Journal:** [APL Photonics](#)

By AIP News Staff

WASHINGTON, D.C., September 27, 2016 -- When the quantum computer was imagined 30 years ago, it was revered for its potential to quickly and accurately complete practical tasks often considered impossible for mere humans and for conventional computers. But, there was one big catch: Tiny-scale quantum effects fall apart too easily to be practical for reliably powering computers.

Now, a team of scientists in Japan may have overcome this obstacle. Using laser light, they have developed a precise, continuous control technology giving 60 times more success than previous efforts in sustaining the lifetime of "qubits," the unit that quantum computers encode. In particular, the researchers have shown that they can continue to create a quantum behavior known as the entangled state -- entangling more than one million different physical systems, a world record that was only limited in their investigation by data storage space.

This feat is important because entangled quantum particles, such as atoms, electrons and photons, are a resource of quantum information processing created by the behaviors that emerge at the tiny quantum scale. Harnessing them ushers in a new era of information technology. From such behaviors as superposition and entanglement, quantum particles can perform enormous calculations simultaneously. The report of their investigation appears this week in the journal *APL Photonics*, from AIP Publishing.

"There is a problem of the lifetime of qubits for quantum information processing. We have solved the problem, and we can continue to do quantum information processing for any time period we want," explained Akira Furusawa, of the Department of Applied Physics, School of Engineering at the University of Tokyo and lead researcher on the study. "The most difficult aspect of this achievement was continuous phase locking between squeezed light beams, but we have solved the problem."

Quantum computers are considered a next generation of computing after the integrated circuit, silicon-chip based computers that now dominate information processing technology. Current computers use long strings of zeros and ones -- called bits -- to process information. By contrast, quantum computers process information by harnessing the remarkable power of quantum mechanics that encodes 0s and 1s in quantum states called qubits. Qubits configure in two unusual ways: "superposition" and "entanglement."

Brace yourself -- quantum behaviors are unusual. Einstein himself characterized entanglement as "spooky action at a distance."

Start with the fact that quantum systems can be in several states simultaneously -- the up and down of superposition, for example. Particles also exhibit the quantum behavior of entanglement. It is a deeply intimate property between quantum particles that unites them perfectly in a shared existence, even at immense distance. In other words, spooky.

And it is this spooky action -- entanglement -- that the University of Tokyo team discovered how to manage so it can be applied to run quantum computers.

For the next steps on this promising path toward making quantum computing practical, Furusawa envisions creating 2-D and 3-D lattices of the entangled state. "This will enable us to make topological quantum computing, which is very robust quantum computing," he said.

###

For More Information:

AIP Media Line

[media@aip.org](mailto:media@aip.org)

301-209-3090

**Article title:** [Generation of one-million-mode continuous-variable cluster state by unlimited time-domain multiplexing](#)

**Authors:**

Jun-ichi Yoshikawa, Shota Yokoyama, Tishiyuki Kaji, Chanond Sornphiphatphong, Yu Shiozawa, Kenzo Makino and Akira Furusawa

**Author affiliations:**

University of Tokyo and University of New South Wales

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**About the journal:**

**APL Photonics**

APL Photonics is the dedicated home for open access multidisciplinary research from and for the photonics community. The journal publishes fundamental and applied results that significantly advance the knowledge in photonics across physics, chemistry, biology and materials science.

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