WHY DO WE INNOVATE?

At Boston Children’s Hospital, we’ve been the leaders in pediatric innovation since the hospital opened its doors nearly 150 years ago. Innovation is in our hearts and in our heads. It’s our history and our future.

We are scientists and researchers. We are doctors and nurses. We are administrators and teachers. First and foremost, we are caregivers. Whether we are delivering care at the bedside or supporting those who do, at Boston Children’s we are all focused on the same mission — providing the highest quality care to the children and families who put their trust in us, whether they come from just down the street or the farthest reaches of the globe.

But in order to deliver the life-changing care that Boston Children’s is known for, there’s one more role we must play:

*We are all innovators.*

This book highlights just a handful of the best and brightest from our innovation community, their groundbreaking ideas and the children who inspired them. On the pages within, you will read about children whose lives were changed by Boston Children’s scientists, doctors, administrators and more — all of them caregivers, all of them innovators.

So why do we innovate? Because when it comes to the families who come through our doors, *good enough is never enough*. When others say it can’t be done, Boston Children’s embraces the challenge. Together, with the children and families who put their trust in us, we make innovation happen. Together, we strive to do more, to do better and to make the impossible possible, until every child is well.

Thank you for joining us in *Taking on Tomorrow*.

Sandra L. Fenwick, Chief Operating Officer, Boston Children’s Hospital
IMPACT: WHO DO WE INNOVATE FOR?

ELI D.
EMIR
RYAN
PLUCK
VIOLET
NINA
KALEB
MILANA
ELI M.
AUGUSTIN
GALI
DILLON
NINA
Eli, now 3, had a tracheostomy and was placed on a ventilator after birth. He went into respiratory distress at home in New Hampshire. Even a minor condition can be extremely challenging for a home-ventilated patient like Eli.

The child’s complex medical needs often require ICU admission for conditions like a simple urinary tract or viral respiratory infection.

Drs. Robert Graham and David Casavant suspected remote teleconferencing technology could help keep patients at home to maintain quality of life while also minimizing costs for families and payers. They applied for and received an Innovation Grant from Boston Children’s Innovation Acceleration Program and installed encrypted, HIPAA-compliant software (Vidyo) to enable voice and visual connections between clinicians and their patients at home.

A pilot project of 14 families documented 27 remote TeleCAPE encounters and showed they prevented the need for 23 clinic visits, three emergency department visits and likely one hospital admission.

Eli was one of the patients treated via telemedicine. He has done well since the incident and was decannulated before his third birthday.

“What the data showed is that the sicker you are, the more valuable the image of the patient becomes. The image may reveal things like fatigue or difficulty breathing that may not be easily conveyed by telephone alone,” explains Casavant.
AUGUSTÍN AND EMIR

Agustín from Argentina and Emir from Turkey live worlds apart but share a common bond. Both have rare genetic disorders.

Agustín was born with the rare immune-deficiency disorder SCID-X1 (“bubble-boy disease”). He was defenseless against infections, unable to make enough T-cells to fight them off. Agustín’s infancy was spent in isolation with his mother.

Emir was born with Wiskott-Aldrich syndrome (WAS), another genetic immunodeficiency. WAS starts with an error in or loss of a single gene. Without a working WAS gene, maturing immune cells can’t react to infection, and platelets can’t develop properly. Emir’s first years of life were spent in and out of hospitals, where he battled infections, severe eczema and heavy bleeding.

Both boys’ lives changed when their parents brought them to Dana-Farber/Boston Children’s Cancer and Blood Disorders Center. The center uses advanced gene transfer methodologies to cure some of the most devastating genetic diseases in children.

Agustín received gene therapy at 5 ½ months as the first U.S. participant in an international gene therapy trial, led by Dr. David A. Williams.

At 2, Emir was the first patient to take part in an international trial of a new gene therapy treatment for WAS.

The protocols for SCID-X and WAS are similar. Physicians collect stem cells from the patient’s blood, mix them with a vector — a virus carrying a working copy of the defective gene — and then inject the corrected stem cells back into the child.

Both boys are leading healthy lives. Agustín goes to the playground with no fear of infection. Eight of the nine boys in the SCID-X trial are alive and well, with functioning immune systems and no sign of SCID-associated infections.

And Emir’s platelet count, which was between 24,000 and 29,000 before gene therapy, has skyrocketed to 148,000, far exceeding the trial’s goal of 50,000. “His immune function is excellent, and we have no worries whatsoever from a bleeding standpoint. He’s perfectly safe to play like a normal child,” says Dr. Sung-Yun Pai.

Innovators: Luigi Notarangelo, MD, Sung-Yun Pai, MD, David A. Williams, MD

Innovation: Gene therapy

Impact: Replace defective immune systems in boys with certain rare diseases with functioning immune systems

Results: Agustín, 5, and Emir, 4, both have functioning immune systems and play with other children with no fear of infection.

David A. Williams, MD
ELI M.

Diagnosed in utero with severe aortic stenosis, Eli was highly likely to develop hypoplastic left heart syndrome (HLHS).

Babies born with HLHS, a condition in which the left side of the heart cannot pump properly, need three surgeries during infancy and toddlerhood. A revolutionary fetal intervention changed this trajectory for Eli.

In 2001, a team of pediatric cardiologists at the Boston Children’s Heart Center and obstetric providers at the Brigham and Women’s Hospital performed their first fetal aortic valve dilation, a procedure attempted at other centers with limited success.

By expanding the valve in utero, the team reset the developmental course of the fetus’ heart and salvaged enough function for the heart to pump normally after birth.

This landmark procedure led to further innovations, all developed to address the medical challenges faced by patients who had received a fetal cardiac intervention.

A subset of babies who had undergone fetal aortic valve dilation avoided HLHS, but later had other mitral valve problems, bringing an opportunity to innovate new care options. “We were the first center to place a balloon-expandable Melody valve in the mitral position in a pediatric patient with mitral valve disease,” says Dr. Audrey Marshall.

Marshall thrives on the challenge of a highly technical procedure and finds reward in working with the families she meets. “These families are extremely engaged, and they’re willing to take risks and be a part of something groundbreaking.”

Eli’s parents travelled to Boston for his fetal aortic valve intervention and returned to deliver him. Shortly after birth, Eli had a catheterization to further open his valve and then an aortic valve replacement.

Although he required additional procedures for his valve and left heart as he grew, Eli thrived. Today, he loves Legos, helicopters, fire trucks and monster trucks.

Innovator: Audrey Marshall, MD
Innovation: Fetal aortic valve dilation
Impact: Preventing hypoplastic left heart syndrome
Results: Since his last open heart surgery four years ago at age 2, Eli’s energy level has skyrocketed. He has not needed a repeat intervention.
**MILANA**

Shortly after birth, Milana was diagnosed with a severe mitral valve problem.

Her parents were informed their daughter would need surgery at some point in her young life. The family was discharged, but Milana struggled and a week later, she was readmitted to a local hospital. Doctors managed her condition with medicines, trying to postpone her surgery. Unfortunately, Milana didn’t improve.

“When the doctors realized she wasn’t able to thrive without surgery, it became clear it couldn’t be prolonged anymore,” says her mother Janelle. She needed a mechanical valve.

“Growing children often outgrow these fixed prosthetic valves within months to years after implantation, requiring multiple replacements over time,” says Dr. Sitaram Emani. And multiple replacements translate into multiple surgeries, a huge expense and a huge strain on a child’s growing body.

There was another problem. Milana needed a 12 mm valve, but there is no available valve for sizes less than 15 mm.

Milana’s parents took to the Internet, looking for the optimal treatment. The search led them to Boston Children’s where Emani and Dr. Pedro del Nido had developed a way to modify the Melody valve (designed to be used at full size), allowing it to expand as the child grows.

The family traveled to Boston, where Milana, now 2, underwent surgery to implant the Melody valve.

Milana thrived after her surgery and is even surpassing some developmental goals. “She’s healthy, active and, most importantly, happy,” says Janelle. The dilation of her valve saved her an open heart operation to replace the valve, and Emani is hopeful the valve will last until she is old enough to get an adult-size valve, limiting her reoperations.

**Innovator:** Sitaram Emani, MD, Pedro del Nido, MD

**Innovation:** Melody valve modifications

**Impact:** More durable valves with longer performance and better outcomes, fewer surgeries

**Results:** Milana is healthy, active and happy. Emani is optimistic her valve will last until she is eligible for an adult-size valve, limiting her reoperations.
Gali has severe epilepsy. His mother Leonor fears he could die in his sleep.

Dr. Tobias Loddenkemper hopes a wristband could save Gali’s life and calm Leonor’s fears.

In children with severe epilepsy, the risk of death from seizures can be as high as 1 in 100. Gali, 13, has weekly seizures, even though he’s taking multiple medications. Worse, the seizures are usually at night when no one is watching.

Gali was among some 200 patients who have tested Loddenkemper’s wristband, developed in partnership with Empatica — a company spun out of the MIT Media Lab. The device senses increased sweat production, blood flow changes and rapid arm movements which could signal a seizure.

“Every parent asks, ‘What can I do to prevent my child from harm?’” Loddenkemper says.

So far, the wristband has proven to pick up almost all generalized tonic clonic seizures — aka grand mal seizures. Loddenkemper hopes it will also be able to pick up more subtle seizures through its sweat detectors.

Loddenkemper’s work is driven by wrenching phone calls he has received from parents, telling him their child died in their sleep from seizures. Those are calls he dreads — and hopes the device will prevent.

Gali tested the wristband for several weeks. Leonor found peace of mind during the trial, knowing the device would alert her if her son suffered a seizure overnight.

The wristband is also helping Loddenkemper better establish a child’s overall pattern of seizures, so he can time medications to hours of the most epileptic activity. In this way, he’s been able to make drug treatment more effective. Currently, physicians largely rely on patients’ seizure diaries, but these can be inaccurate, especially when seizures occur at night. “We need an independent detector that can send a warning or potentially allow seizure rescue efforts,” says Loddenkemper.

Innovator: Tobias Loddenkemper, MD
Innovation: Seizure tracking via wristband
Impact: Avoiding seizure deaths, better medication timing
Results: Gali underwent surgery to control his seizures after participating in the wristband trial. He loves the Patriots and hopes to get a wristband when it goes to market.
RYAN

Ryan was born with a 4-inch gap between the upper and lower parts of his esophagus.

The standard treatments for esophageal atresia can result in lifelong complications — chronic aspiration and chronic lung disease — and require children to have multiple operations throughout life.

His parents wanted better and found what they were looking for with the Foker process.

Dr. John Foker had perfected a novel treatment for esophageal atresia that gradually grew an infant’s tissue. After the baby is put into a drug-induced coma, the surgeon places stitches on each end of the esophagus. These are threaded onto buttons that are turned regularly to increase tension and stimulate tissue growth until the two ends pass each other and can be attached surgically. Minneapolis-based Foker was the only surgeon performing the procedure.

Ryan was at Boston Children’s.

Dr. Russell Jennings worked with Ryan’s parents to make the surgery possible — with one request. “If you go to Minnesota, can I go with you?” he asked.

“I wanted to absorb as much as I could from him [Dr. John Foker] and bring the procedure to Boston.” So Jennings traveled with the family and immersed himself in the Foker process.

Ryan was successfully treated and is completely unaffected by his atresia.

Jennings mastered the surgery and now treats four to six babies with long-gap esophageal atresia every year. Foker collaborates with Jennings to train surgeons at Boston Children’s and apply the techniques to other areas.
When Philip ‘Puck’ Wheaton started walking in 1979, he seemed to wobble a bit. Dr. Lyle Micheli determined the toddler was missing his right anterior cruciate ligament (ACL). Micheli did what the world’s best surgeons do. He improvised and innovated. He threaded Puck’s iliotibial band in and around his knee to devise a makeshift ACL.

Puck was released from Boston Children’s with his leg in a cast, but he never slowed down. Nearly 40 years after his surgery, he maintains an active lifestyle and is an avid skier and cyclist.

The surgery inspired Micheli to innovate a game-changing surgical procedure that provides a way to reconstruct a child’s torn ACL, so she can return to healthy activity and sports without risking an injury to the growth plates.

This “experimental” surgery done on Puck is now being performed by surgeons worldwide for ACL injury in younger patients.

**Innovators:** Lyle Micheli, MD  
**Innovation:** Growth-plate sparing ACL reconstruction  
**Impact:** ACL reconstruction without harm to growth plates  
**Results:** Puck skied 1.7 million vertical feet in five years. He has not needed additional ACL surgery.
COREY

Corey was an active graduate student when he tore his ACL.

Research led him to Dr. Martha Murray, who had spent decades devising a better way to treat ACL injuries. Murray was a graduate student in engineering when a chance encounter with a friend who had torn his ACL changed the path of her career.

Murray was appalled when the man explained the ACL couldn’t be fixed — it had to be removed and replaced with a tendon graft.

Unable to get the problem off her mind, she switched from engineering to medicine and embarked on a 30-year quest to find a way to repair a torn ACL.

Murray wound up at Boston Children’s — working with Dr. Lyle Micheli — and primed to continue the history of surgical innovation. She learned about other downsides to ACL reconstruction. Although most patients are able to return to sports, the re-tear rate hovers near 20 percent. Up to 80 percent of patients develop arthritis 15 to 20 years after surgery.

Ultimately, Murray devised Bridge-Enhanced ACL repair (BEAR). The procedure uses stitches and a bridging scaffold to stimulate healing of the torn ACL.

Animal studies yielded positive results and indicate reduced risk of arthritis with BEAR.

The FDA approved a first-in-human safety trial of the technique in early 2015. Corey was the first to undergo the new procedure. Six months after his surgery, MRI results suggested his ACL was healing.

Martha Murray, MD

Innovator: Martha Murray, MD
Innovation: Bridge-enhanced ACL repair
Impact: Less invasive ACL surgery with potentially reduced incidence of arthritis
Results: Corey’s MRI results suggest his ACL is healing. He runs, bikes and dreams of running the Boston Marathon.
When Dillon was 13, he received a very special gift from his stepfather Nicholas Gula — a new kidney.

But Gula didn’t donate his kidney to Dillon. Instead, he gave it to a stranger, an Atlanta man who needed a kidney. And in return, the man’s wife gave her kidney to Dillon.

The carefully choreographed “operation” involved two selfless donors, two flights, two states, three hospitals and four surgeries — more than one thousand miles apart.

When Dillon was diagnosed, Gula was eager to donate his kidney to his stepson. But their blood types were incompatible.

Courtney Loper, MSN, RN, CPNP, Boston Children’s Renal Transplant Coordinator, asked the family if they would be interested in participating in a United Network for Organ Sharing (UNOS) program that matches incompatible donor-recipient pairs through a nationwide pool. Gula said, “Sign me up.” Within a week after the necessary donor testing was complete, a four-way match was identified.

“Without a living donor, our pediatric patients often have to wait months or even years on the waiting list,” says Loper. “The kidney-pairing program significantly increases our patients’ options and the likelihood of receiving a living donor transplant.”

One year after the transplant, Dillon’s life is relatively normal, and it will likely be a long time before he will need another transplant — living donor kidney transplants typically last 15 to 20 years.

“You can tell the difference from the child with kidney disease and the child now,” says Gula. “There was a weight upon him. He knew he might die. He is my hero.”

**Innovator:** Courtney Loper, MSN, RN, CPNP

**Innovation:** Living donor kidney swap

**Impact:** Improved outcomes, longer transplantation duration

**Results:** Dillon is a healthy, active teenager who likes to play football. As a living donor recipient, Dillon can expect his kidney to last up to 20 years.
VIOLET

Violet was diagnosed with a Tessier cleft, an extremely rare and serious craniofacial anomaly before birth.

Her parents Alicia and Matt contacted Dr. John Meara before Violet was born.

“Dr. Meara reassured us that Violet’s situation wasn’t as dire as we were being told by our doctors in Oregon,” recalls Alicia.

Over the next year and a half, the couple shared Violet’s MRI and CT images and digital photos with Meara and the rest of her Boston Children’s care team, including Drs. Mark Proctor and Peter Weinstock.

Weinstock and his team created 3-D models to help plan the nine-hour surgery — a facial bipartition and nasal reconstruction — to reshape Violet’s skull.

“The 3-D models are exact reproductions of children’s anatomy that allow surgeons to do the surgery before the actual surgery,” explains Weinstock.

“I can see on the model better than in the operating room. I can see the trajectory of where I will have to make certain cuts, and that’s never been possible before,” says Meara.

One year after her life-changing surgery, Violet’s life is like that of many toddlers. She and her twin sister Cora are inseparable co-conspirators and have developed their own sign language. Their favorite words are “candy,” “more” and “beautiful.”

Innovators: John Meara, MD, DMD, MBA, Mark Proctor, MD, Peter Weinstock, MD, PhD

Innovation: 3-D printing

Impact: Improved surgical planning and preparation

Results: Violet is a happy and mischievous toddler who loves playing with her twin sister. She’ll see Meara three years after her surgery for additional cosmetic repairs.
As Nina battled a life-threatening bloodstream infection, specialists hovered by her bedside in Guatemala City.

Ultimately, a critical care specialist thousands of miles away saved her life.

A few months later, Nina walked into the Boston Children’s lobby with her parents and asked for Dr. Jeff Burns. Nina smiled and high-fived Burns.

Burns was puzzled.

Within minutes, he realized the unfamiliar face belonged to Nina from Guatemala City.

A few months earlier, Burns had been videoconferencing and advising the team of specialists caring for Nina as she battled a life-threatening bloodstream infection.

Nina survived.

When Burns met her, he realized there were thousands of children across the globe whose caregivers couldn’t access the critical care expertise he had shared with his Guatemalan colleagues.

He established a partnership with IBM and the World Federation of Pediatric Intensive and Critical Care Societies to build OPENPediatrics. The platform provides an online community of clinicians sharing best practices from resource settings around the world.

**Innovator:** Jeff Burns, MD, MPH  
**Innovation:** OPENPediatrics  
**Impact:** Best practices in pediatric critical care shared globally  
**Results:** Nina survived. OPENPediatrics grew into a global resource and is used in 981 hospitals in 127 countries.
When Kaleb was 1, he started having bouts of diarrhea that continued with greater frequency and intensity as time passed.

“He was not eating and was having up to 14 loose stools per day,” recalls his mother Christine.

Stool cultures confirmed Kaleb had the debilitating infectious disease Clostridium difficile, also known as C-diff.

Following months of unsuccessful antibiotic treatment, Kaleb underwent a fecal microbiota transplant (FMT) performed by Dr. George H. Russell.

Kaleb has been free of infection ever since.

FMT delivers pre-screened, healthy human donor stool to a patient via colonoscopy or by nasogastric tube and serves as an effective alternative to long-term antibiotic use for the treatment of C-diff.

Research published in the Journal of the American Medical Association says there is a third, less invasive, less expensive option to treat C-diff: frozen poop in a pill.

“This paper shows that with encapsulated, frozen donor stool, fecal transplantation can be used to successfully treat recurring C-diff infection in 90 percent of cases,” says Russell, co-author of the Massachusetts General Hospital-sponsored study.

“The FMT study provides proof of concept that invasive means do not need to be used to deliver the fecal transplant.” Patients in the study had fewer daily bowel movements and no relapses of diarrhea for eight weeks following treatment.

Though the poop pill is still in the experimental therapy stage, Russell says this cutting-edge technology is spurring further clinical research at Boston Children’s, specifically for use in other disease states, such as inflammatory bowel disease (IBD).

Innovators: George Russell, MD
Innovation: Frozen poop pill
Impact: Effective, less invasive treatment for C-diff
Results: Kaleb, 6, is a charismatic little boy. He loves playing sports with his big brother and blowing bubbles, and he never shies away from music and dancing. Kaleb no longer suffers from C-diff.
WHY DO WE INNOVATE? WHERE WILL IT TAKE US?

We innovate for the future — for the children and families we care for, the ones whose faces we know and for the many more whom we don’t yet know.

Many of them will travel to Boston Children’s Hospital seeking the best care in the world. And they’ll find it here. They’ll find it in the innovations detailed in this book, the hundreds of others that are part of our daily work at Boston Children’s and those that are yet to be developed.

Every child around the world — regardless of where they live or where they seek care — we’re innovating for them as well. We strive to disseminate innovations far and wide — sharing them with providers, parents and caregivers everywhere.

As innovators and caregivers, we work to impact the patient journey at every stage — from disease awareness and prevention, to detection and diagnosis, to care and recovery. And we focus on the entire process — from equipping scientists and clinicians with the resources to support and nurture their ideas to growing them into solutions that can be used at Boston Children’s and beyond.

Understanding what patients need is the first step.

Just as we aim to expand our pipeline of innovations, we aim to expand our pool of innovators. We see and support future innovators everywhere — in our nurses, parents and teachers — everyone we interact with. We see it in the faces of the children we care for.

Our legacy brings us together, and it drives us toward the future. We’ve cultivated a focus on innovation that is both razor-sharp and exceedingly broad. It’s the Boston Children’s model. And it’s designed to be shared.

John Brownstein, PhD, Chief Innovation Officer, Boston Children’s Hospital