**VS SURGICAL MORTALITY**

**COLD OPEN**

**Hannah**: In 2014, Karen Lefave is at Mount Sinai hospital, pregnant with twin girls. She’s beingheavily monitored because the pregnancy is complex and extremely high-risk.

At 26 weeks, a regular ultrasound spots a new, unexpected problem: a possible heart defect in one of the twins, Charlie. Karen is sent to SickKids for more conclusive fetal imaging. Karen remembers that Charlie was so, so tiny…

**Karen**: She was only 5 or 6 inches. I can’t imagine her heart must have been the size of like a thumbnail.

**Hannah**: Karen’s unborn daughter is diagnosed with a condition called Transposition of the Great Arteries, or TGA. The main valves leaving the heart are reversed in position, which means the oxygen in her blood will be dangerously low when she’s born.

It's scary news, but Karen and her husband Greg are told that TGA is common, as congenital heart defects go. (Congenital means present at birth.) SickKids surgeons do about 30 of these corrective surgeries a year.

**Karen**: Prognosis was fantastic. She would be just as active, just as mobile. And she could do everything her sister can.

**Hannah**: But several weeks later, as Charlie—and her heart—grow bigger in the womb, the diagnosis becomes more dire.

**Karen**: Charlie now gets diagnosed with a much more complex—a very complex—heart condition that she needed to be in-utero for as long as possible simply because she needed to be as big as possible for her to survive a surgery once she was born.

**Hannah**: Shortly after delivery, Charlie will have open-heart surgery. But it will be a temporary fix so that she can grow and gather strength for a second surgery. The big one. Her tiny heart will have to be dismantled, rearranged and sewn back together. It’s a rare, risky procedure, and Charlie might not survive it.

Even a world-leading paediatric centre like SickKids would only see a case like this every three to five years.The most seasoned surgeon would still be entering uncertain terrain.

But what if surgeons could see a patient’s heart *before* opening their chest -- an exact reproduction that they could hold. Better yet, what if they could practice on the model heart? What would that mean for patients like Charlie? And how could it help less-experienced surgeons in other hospitals in other parts of the world? Charlie’s surgeon and radiologist were about to find out.

[MUSIC]

**Hannah:**You’re listening to SickKids VS, where we take you to the frontlines in the fight for child health. I’m Hannah Bank. And this is SickKids VS Surgical Mortality.

**ACT ONE**

**Hannah**: Paediatric heart surgery is one of the toughest specialties in medicine. And not just because a newborn heart can be as small as a strawberry. Unlike adult heart anatomy, which is predictable, a baby’s congenital defects can be completely unique and totally wonky. Valves reversed. A whole ventricle closed off. Holes between chambers.

**Hannah**: And in cases like Charlie’s, it’s the distinct combination of defects that requires a skilled surgeon. Someone with not just technical skills, but confidence, good judgement and stamina. All of which come with experience.

**Dr. Glen Van Arsdell:** My name is Dr. Glen Van Arsdell, and I am the chief of congenital heart surgery at University of California, Los Angeles. Prior to that I worked at SickKids from 1996 through 2018, and I was chief of cardiac surgery for 17 years.

**Hannah**: Do you remember Charlie Lefave’s heart?

**Dr. Glen Van Arsdell:** I do remember Charlie’s heart. Charlie was one of those where we struggled with the diagnosis.

**Hannah**: Charlie’s diagnosis was complex. Not only were her main arteries swapped, but they both came out of one side of the heart. One of them was quite narrow. And there was a hole between the bottom chambers. It all added up to the same overall prognosis. Her blood oxygen would be too low, which would eventually cause heart failure and death. But the surgery to correct her heart went from straightforward to remarkably intricate.

**Dr. Glen Van Arsdell:** The operation we did for her was, you know, an unusual one. I’ve probably been involved in about 15 of them in my career. And that’s a career at a high-volume place.

**Hannah**: Volume is important in surgical programs. Studies have shown that the best results for complex heart patients come out of hospitals, like SickKids, that perform at least several hundred surgeries a year. Enough that surgeons would encounter the whole spectrum of disease, especially the rare ones. And if you’re a junior surgeon, you get to see these rare hearts in the OR. You might observe or help with one of the surgeries until you’ve built enough knowledge and confidence to do it yourself. This often takes years.

**Dr. Glen Van Arsdell:** So most people who want to become children’s heart surgeons are going to spend 8 to 10 years in clinical training after medical school to get there. And that’s just the start. It takes 4 to 7 years to become a full-service heart surgeon. I went through that process early on in my staff years. You start out doing more straightforward cases, and as your circle of confidence expands then you do more complex cases and it’s a bit-by-bit addition of complexity.

**Hannah**: The complexity of Charlie’s heart demanded an experienced surgeon like Glen at a world-class hospital like SickKids. But even Glen would need all the help he could get. So he asked Charlie’s radiologist to 3D-print a replica of her heart. To really know what he was getting into, Glen would need to hold it in his hands.

**ACT TWO**

**Dr. Shi-Joon Yoo:** My name is Shi-Joon Yoo, cardiac radiologist. I’ve been working for the last 21 years at SickKids.

**Hannah**: A radiologist uses imaging to diagnose disorders. Shi-Joon specializes in heart disease. He interprets pictures and data from cardiac ultrasound, CT and MRI to detail a patient’s disease. But it’s not as straightforward as it sounds, especially for congenital heart defects.

**Dr. Shi-Joon Yoo:** Actually, inside, detailed anatomy varies tremendously. So, it is not easy to really recognize all of this just by studying. So, all of this is really the complicated puzzle.

**Hannah**: A congenital heart disease diagnosis often requires *thousands* of images of different segments of the heart at various angles. And that’s just the pictures. There’s also data, like how much space is inside a valve or how quickly blood can flow through it.

**Dr. Shi-Joon Yoo:** To me as the imager, I understand what’s going on, but the problem is, I need to explain this complexity of the anatomy. Really good images can save a thousand words. That is true. But that does not mean that surgeons will be able to understand them very quickly.

The images and words can confuse some people or mislead, what if you have a real, physical model in your hands?

**Hannah**: Shi-Joon is talking about 3D-printed models. SickKids got its first 3D printer in 2009. But even before then, Shi-Joon had already recognized the enormous potential for 3D models to explain complex heart diseases in a way that 2D images can't.

**Dr. Glen Van Arsdell:** There are times that I’m thinking, mmm, when I go into the operating room I’ll figure it out. Because it’s just too hard to compute that in your mind. And you put the model in your hand and there’s this a-ha moment. This is what it is. There’s no question trying to turn two dimensions into three.

**Hannah**: With a user’s manual and help from a colleague, Shi-Joon learned how to print hearts in his spare time. The early models were rigid, ceramic-like. They didn’t look like what you or I would imagine. But to surgeons, they were a gleaming roadmap.

**Dr. Glen Van Arsdell:** Getting it in your hands is as close at it gets to what you’re doing as a surgeon. All you have to do is hold it and look where the holes are and where the routing are that you need to do. All these kinds of things that we think about—do I need to make the hole bigger to route blood through it—those things become obvious to you.

**Hannah**: When preparing for Charlie’s surgeries, Glen asked her parents if Shi-Joon could print her heart.

**Karen**: Of course we agreed to it. I was thinking how amazing is this that they can at least get something, you know, tangible, without physically getting into her chest.

**Hannah**: Between May and August 2014, Charlie had survived birth, months of intubation, and her first open-heart surgery. It worked beautifully. Her blood-oxygen levels climbed, boosting her health for the next several months, when she and Glen would be ready for her big surgery.

**Karen**: They had planned the second surgery for March 5, 2015. She was 9 months old and still only 10 pounds.

**Hannah**: That morning, after squeezing in every last cuddle and kiss, Karen and Greg turned Charlie over to the surgical team.

**Karen**: She was just the happiest, just kind of rolling around. And I remember taking her hand and I was sobbing at this point. I had no idea if we were going to see her again.

**Hannah**: After more than 10 hours in surgery, Charlie not only survived, but she had a fully functioning heart. Everything had been *rearranged*, *patched* and *reassembled* in one of the most complicated congenital heart procedures.

**Dr. Glen Van Arsdell:** The 3D modelling and planning was really helpful. I walked in knowing what I was dealing with, knowing what my options were, confirming what we found, and then doing what we had hoped to. When I started my career for those really complex hearts, I used to have to go in with an algorithm and say, ok, if I find this, I’m going to do this. If I find that, I’m going to do that.

**Hannah**: For Glen, all credit goes to Shi-Joon.

**Dr. Glen Van Arsdell:** Dr. Yoo was probably one of the first to practically print hearts for surgeons. He was really early in recognizing that the technology existed and figuring out how to do it. It’s becoming much more common today. But in 2015, it would have been quite unusual for people to print hearts.

**Hannah**: That year, Shi-Joon’s models have been used strictly for visualizing and planning. But 3D-printing technology is improving quickly. The materials are better. And printer prices are dropping. Shi-Joon is desperate for the hospital to get a new printer. But funding could take years, and he wants to stay on top of this fast-moving technology.

**Dr. Shi-Joon Yoo:** So that’s why at a certain point, by my wife’s advice, actually: ‘Instead of waiting too long, Joon, why don’t you use your money to explore what you like?’

**Hannah**: So you decided to use your own money. Your wife convinced you.

**Dr. Shi-Joon Yoo:** Yes. That’s right. (chuckling)

**Hannah**: Shi-Joon set up the printer in a rented office space across the street from SickKids. His new hearts are a huge improvement. They’re softer and more pliable. It doesn’t take long for Shi-Joon and Glen to ask themselves, what if surgeons could not only hold these models, but *practice*on them, too?

**ACT THREE**

**Hannah**: Seven weeks after Charlie’s surgery, Shi-Joon and Glen are in Seattle. Word had got out about Shi-Joon’s hearts. He’d been asked to print 60 models for an annual meeting of American heart surgeons. Organizers wanted to run a pilot training session. For the first time, Shi-Joon’s hearts would be operated on.

**Dr. Glen Van Arsdell:** We learned quite a few things in that training session. One is it’s not easy to sew on these models.

**Hannah**: The materials lack the delicacy of human tissue and still have a ways to go to feel lifelike. But that would come. And it doesn’t matter. Surgeons are simply thrilled to be able to lay hands on infant hearts with anatomically precise diseases. Shi-Joon is certain this is the first time in history 3D hearts are used for surgical practice. He and Glen return from Seattle with the same striking idea. With Shi-Joon’s hearts and Glen’s expertise, they could develop and run their *own* surgical training course at SickKids.

**Dr. Shi-Joon Yoo:** There wasn’t any question about the feasibility of such a course and the impact of such a course on surgical training.

**Hannah**: About nine months later, in January 2016, they launched Hands-On Surgical Training. HOST for short. Ten junior and mid-career surgeons arrived at SickKids from around the world to practice on rubbery hearts with complex defects.

**Hannah**: There were lectures and demonstrations. But mostly, trainees were bent over their models, cutting and suturing. It was a relaxed environment where mistakes were *possible*—and not catastrophic.

**Dr. Glen Van Arsdell:** For a long time there was this kind of accepted concept that there was a surgeon learning curve.

**Hannah**: But now with advanced imaging and surgical technology, that’s changed.

**Dr. Glen Van Arsdell:** In North America and the western world, that would not be acceptable for a surgeon to have a learning curve. In the developing world, that’s a reality. And so of course we want to make the learning curve as minimal as possible.

**Hannah**: If, for example, Charlie had lived in a different part of the world, in a region far from a capable hospital, her odds would be a lot worse. She might not survive.

**Dr. Gustavo Orellena**: I could hold the 3D model in my hand, watch it, poke it. I understood it. You learn more than if you have read ten books or listened to ten talks.

**Hannah**: That’s Dr. Gustavo Orellena, a surgeon from Guayaquil, Ecuador. He’s done HOST a few times.

**Dr. Gustavo Orellena**: In my HOST, I made a mistake. I closed the wrong hole. And if it was a real surgery, I would have killed the kid. But because I was in training, I could learn my mistake, see how to correct it, and then never do it again.

**Hannah**: Gustavo has been doing paediatric heart surgery for about a year. He trained in Sao Paulo, Brazil, because Ecuador doesn’t have a teaching hospital. He is now a junior staff surgeon at Roberto Gilbert Children’s Hospital. It’s one of six paediatric hospitals in Ecuador.

**Dr. Gustavo Orellena:** But only two can do cardiac surgery. And only one can do the complex cases.

**Hannah**: Wow, and so how many paediatric heart surgeons are there?

**Dr. Gustavo Orellena**: Three.

**Hannah**: There’s three.

**Dr. Gustavo Orellena**: And we have a 17-million population.

**Hannah**: So if a baby had a complex congenital heart disease and they needed surgery, they could only go to one place?

**Dr. Gustavo Orellena**: Yes yes. From all Ecuador, they are referred to our centre. All Ecuador.

**Hannah**: A hospital like SickKids treats a high volume of complex cases because it’s a referral centre for the province, and even nationally. At Gustavo’s hospital, the complex cases arrive for different reasons.

**Dr. Gustavo Orellena:** In Ecuador our main problem is that we don’t diagnose prenatally. Kids come to our centre when they are very late in the timeline of the disease. So it represents a bigger case, a more complex case.

**Hannah**: So, if a patient like Charlie was born in Ecuador, doctors wouldn’t know that her heart was severely malformed until she was born, blue and gasping. And by then, time and options are thin. At Gustavo’s centre, there’s just one surgeon who could attempt that procedure. Gustavo, of course, would need several more years under his belt.

**Dr. Gustavo Orellena:**  Right now, I’m doing the easy cases, the straightforward cases. In the next year I want to do neonatal surgery. That’s like my favourite thing in the world. But right now I don’t feel comfortable doing that because I can expose the kid to a high risk doing it myself than my colleague that does it all day, all the time. So you really have to have the maturity to accept your limitations and grow. And when I feel ready, I’ll do it. I know probably this year I won’t be able to do that surgery, but when the day comes, I will remember the steps I did to do it great.

**Hannah**: This is the nut of HOST: giving surgeons like Gustavo access to hearts that would take them *years* to observe in the OR. It will drastically fast-track their abilities.

**Dr. Gustavo Orellena:** I want to grow as a surgeon. And then want to help my colleagues to grow and my service to grow here. We do have a good service. We do have a good hospital, but I want to be part of making it better.

**Hannah**: HOST’s ultimate vision is to help decrease cardiac surgical mortality rates around the world.

**Dr. Gustavo Orellena:** That’s the only way to flatten the mortality rates. That’s the only way, I think, because having to learn in a 3D model makes a big difference. The confidence you get as a surgeon to work with a complex pathology. That’s amazing. That’s a powerful tool. That’s priceless.

**CODA**

**Hannah**: Since its first run in 2016, HOST has become an annual event. With each year, there are tweaks and improvements. Recently, the hospital’s lead 3D-printing engineer designed an infant chest cavity to simulate the resistance a surgeon would feel during a procedure.

Last December, during COVID-19 travel restrictions, HOST went virtual for the first time. Hearts were printed, boxed and mailed to 34 surgeons on nearly every continent. It was the highest turnout yet, opening the possibility of a regular online course to make HOST more accessible.

The course is expensive to attend. Models alone are between $300 and $500 each.

**Dr. Shi-Joon Yoo:** So that is already expensive. But these people need to fly to Toronto, get accommodation.

**Hannah**: HOST is also expensive *to run*. But key donor support has kept HOST going—and even expanding. In 2019, HOST launched a new monthly course for surgical residents at SickKids – surgeons with little experience. One evening a month, they learn congenital heart disease anatomy and then practice different procedures.

In the past few years, the HOST team has published several papers validating the use of 3D models in surgical training. They found that after practicing a procedure just once, at least 80%-87% of attendees had better surgical results and almost all of them were faster the second time around.

As HOST gains legitimacy and clout, it’s not hard to envision the curriculum being packaged and delivered by any hospital in any country. It could become a standard part of surgical training.

HOST’s architects are hoping it will.

**Dr. Glen Van Arsdell:** There’s room for progress. We still have major problems. We don’t cure every child. And this is one facet of helping make the world flat, helping make every child across the world have a better chance.

**END/OUTRO**

**HANNAH:** From SickKids Foundation, this is SickKids VS. Thanks for listening. If you want to support work like this, visit sickkidsfoundation.com/podcast to donate. And if you like this podcast, please subscribe and rate us on Apple podcasts, Spotify, or wherever you listen to SickKids VS.

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