VALLUVAN JEEVANANDAM: Hello. I'm Valluvan Jeevanandam. I'm the chief of cardiac and thoracic surgery and professor of surgery at the University of Chicago Medicine. So today I'm going to talk about some really exciting new developments in cardiac surgery. This is going to be a synopsis, so it's not meant to go into a lot of details, but to give you a real overview of all the exciting things that are going on in the field.

So what are the biggest challenges we're facing right now? The patients are getting sicker. So the acuity of the patients is increasing. And to deal with those patients, we need to be able to minimize trauma to be able to get the optimal patient experience. So at the University of Chicago Medicine, we have developed a comprehensive program to deal with all those complex issues and give the best possible outcome. For instance, we have brand-new physical facilities. So this is our new facility in south side of Chicago. This is University of Chicago Medicine's Center for Care and Discovery. And our unit's on the eighth floor, and operating rooms are on the sixth floor. These are state-of-the-art facilities with private rooms.

But more importantly, we can deliver really complex care because we have a hybrid and a very advanced operating suites. These suites allow full functionality for cardiac surgery, vascular surgery, electrophysiology, and interventional cardiology. That allows us to do multiple procedures on the patient at the room at the same time. This facilitates things such as endovascular repair, robotic T-CABs, plus percutaneous intervention, ECMO placement, or complex arrhythmia management in the combination between cardiology and cardiac surgery. We're all interconnected in the operating room. So there's audio and video that can be shared, stored, edited, and beamed to the internet. And all the monitors-- and we have plenty of monitors in each one of these rooms-- we can see echoes, angios, and CT scans.

So other than the physical facility, of course, you have to optimize the physicians who are using the physical facility. And for that we have really, at the University of Chicago Medicine, divided ourselves into different what we call disease-related segments. So at the Center of Cardiovascular Therapy we have, the sections of cardiology, cardiac surgery, and vascular surgery. And to be allowed us to deliver this very advanced care, we have different disease entities, such as aortic disease, valve and structural heart, advanced heart failure and transplantation, arrythmias, ischemia management, and preventive medicine. Each one of these disease entities has a set group of physicians who are responsible for delivering the optimal patient care.

So I'm going to just go through some of these disease entities. And the first we'll start off with is the most common disease process in the United States, which is coronary artery disease. So when an artery's blocked, it can cause heart attacks, and what we like to do is revascularize, or bring blood back to that area. So the most common way to do this is coronary revascularization. That involves what we call CABGs, or Coronary Artery Bypass Grafting.

Now in the recent patient populations as they evolve, the patients present to us with more comorbidities. They have much more complex disease. They require reoperations. And in the past, one of the ways we minimize trauma is not go on the heart/lung machine. However, recently, because the patients have gotten sicker, we are forced to go on the heart/lung machine. So as you can see on the slide, in 2001, where 30% of our cases were done what we would call off-pump. In 2013, it's only about 11%.

Now having said all that, there is data that clearly shows that bypass surgery superior to stenting for multi-vessel disease. And that the LIMA to the LAD, or the mammary artery to the LAD, is superior to all revascularization strategies. And that the bilateral mammary artery is the best for long-term survival. However, patients are reluctant to have their chest opened. And so that drives them to get stents, although we know that's sub-optimal therapy.

So to be able to give the patients the best therapy, a solution is robotic-assisted coronary artery bypass grafting. This is done through the da Vinci Intuitive System. And it's not like the robot does the surgery. The robot is an enabling technology. So there's a surgeon who's dedicated to running the robot, and the robot acts like the arm. So it's almost like you can put the surgeon's arm and hands and fingers inside a patient, without, obviously, putting your hands inside the patient.

So what is robot-assisted bypass surgery and what does it accomplish? Well, the vision is to be able to do the entire procedure through very small-- half an inch or one centimeter size-- ports that at the end of the operation we'd just close with Band-Aids. And without the heart/lung machine, the patient is able to be discharged within a day or two. This is a cartoon that kind of depicts what we're trying to emulate. It says "We've located the blocked artery, Coach. We'll do the bypass, close, up and have the big fella back on the field by, say, the third quarter."

And this is how we actually accomplish this. So this is the patient. And you can see there are marks for where the ports go in. And this is the surgeon who's actually marking the ports. That's the stabilizing port, or S port. There are two ports for actual instruments, and one port for the cameras. He's placing in the camera port right now. And then there's the machine that's coming in to dock on to the ports. And once the surgeon docks the robot, he then goes to a separate console in the corner of the room and telemanipulates the robot. And the robot will behave-- will obey the commands that his fingers do.

So there's one of the ports that's going into the chest. That has a electrocautery instrument at the end of it. Here's another port. This is going to have a grasper. And what you'll see, the first thing we're going to do is take down the mammary artery, which is done with the robot right now. And you can see the artery coming off the chest wall, to see that better. Then what we do is start preparing it for the bypass. And we do that by partially transecting it. And as we transect it, we put in the special type of sutures. They're called U-clips. And they basically allow us to do suturing without actually having to tie knots.

Now the heart is exposed and the artery is stabilized. And we put the other end of the sutures through the artery. And there you have putting all the sutures in place. And then we activate the sutures by just pinching them, which is done right there. And there's the completed anastomosis, so the procedure is then done. And as you can see, just close with some Band-Aids, and this patient went home within 48 hours. More importantly, not only going home fast, but being able to do all their daily activities, such as bicycling, obviously walking, going upstairs, lifting heavy objects. There's no limitations to activity after this procedure. And that includes driving.

This is the actual U-clip and this is how it works. You put this clip in place. It's made out of nitinol. Once it's in the artery, you just pinch it. And once you pinch it, it activates and closes, and therefore you don't actually have to physically do a knot that you would have to do without this type of instrument.

Now the next iteration of this is actually automating the entire anastomosis. So this is called the Cardica C-Port Anastomosis Device. So instead of the surgeon actually putting in a stitch, you can put it in through this machine. And just think of that as the mammary artery that you saw in the original slide. And you put it in this machine. You load it up. And remember, all this is done inside the chest using the robot. And once it's all loaded in place, you then go to the heart. You make a very small incision in the coronary artery, right there. You put a stitch to stabilize that hole. And then you insert this anastomosis device into the hole. And then you fire it. It places little staples to create the anastomosis. So it's a very, very standardized anastomosis that anybody should be able to perform.

So what are the advantages of robotic bypass? It allows us to use two internal mammary arteries, which, as I told you earlier, gives the best long-term results. There are no post-operative activity limitations. Length of stay in the hospital's about two days. Very rare to get any infection in these patients. So the indications are vessels that have very focal lesions that are non-calcified. The LAD is the easiest one to do. And then the diagonal and the ramus and the obtuse marginal vessels are little bit more difficult. If you have to do more than two vessels, then it becomes a little bit more of a challenge, because you have to do sequential mammary arteries where you t-graft off the mammary arteries.

You really cannot do right-sided lesions with this type of approach. So if somebody needs a right-sided bypass, we either have to allow the cardiologist to put stents in, or we don't do it robotically. The patient has to be able to tolerate single lung ventilation. And if the vessels are very calcified or intramyocardial, we can't find them, then obviously we can't do them robotically.

The results have been excellent out of 1,500 cases. And, of course, this is very surgeon-dependent. Our graft patency is equivalent to that of open bypass.

So what's new and great in valve replacement surgery and valve repair? Obviously, we always want to keep the native valve whenever possible, so there's a lot of focus on repair. And this is repair of the mitral valve. And the trends, again, are acuity and the comorbidity increasing in our patients. But with increasing challenges, we also have better imaging techniques.

So what you see here are pictures-- these are three-dimensional pictures from and echo-- so you can put an echo probe in, and the surgeon can get in real time what the valve is actually looking like and what's abnormal in the valve. So we know exactly what to go in and fix. And because we know what to fix, we can obviously do them through smaller incisions. So these things are less invasive. So that's called Three-Dimensional TEE, and that is again improving imaging and information for the mitral valve repair. At the current time, we're able to repair greater than 90% of all the myxomatous valves.

And what you can see here is a leaflet that's prolapsing right there. And what we do is we keep it from prolapsing, and we repair and normalize the valve. Before we go to the operating room, we can actually measure the length of the cords, so we know what is normal and what's abnormal. So even before we go to the operating room, I know exactly what length of the cord to make, to make these repairs work. And this is a video of one of those repairs. You can see we measure the length of the posterior leaflet and the anterior leaflet of this mitral valve. You can see something flipping up and down, so that is a ruptured cord. You can see all the yellow. So the yellow is blood going back into the lungs and drowning the patient. And, obviously, we want to prevent that yellow from occurring. So this is a small mini thoracotomy incision. And that's going to allow us access to the heart. As we go in, you'll see the heart.

The heart is in its covering called the pericardium. Unfortunately, you're going to see it again, just to reinforce it. So there's the heart. And once you open up that covering, there's the aorta, and there's the right atrium, and there's that thing that was flipping up and down in the echo. You can see that thing as part of the posterior leaflet of the mitral valve. And what we do is we measure the cords just to make sure that the cardiologists were correct, and how long those cords need to be. And the next thing you'll see is us actually making cords. This is made from Gore-Tex material. You probably all know Gore-Tex. It's what you wear for waterproofing with jackets. Well, in a very interesting way, it also works great to create cords for the mitral valve. So that's a Gore-Tex suture. The quality and the durability of Gore-Tex is actually very, very good. So we create these cords.

And then once we create the cords, we then connect them to the heart. And then we create these loops. And we put the loops onto the posterior leaflet of the mitral valve. And then once that is done, we now have a restricted leaflets, so it doesn't slip up into the atrium. We then go ahead and put sutures in for a ring. You can see here, we now have no flipping of this leaflet. This is our ring that we put on. And this is the test. And we actually have a very, very good test. And this is the echo afterwards. And yes, you can see we don't have anything flipping up into the left atrium. And once we put color, absolutely no yellow going up, so this is 100%-perfect repair of this mitral valve.

So we could do this through less invasive approaches. We can either do a half sternotomy. We can do it through a mini thoracotomy. We now have the ability to do this robotically. So again, we just-- very, very small, Band-Aid-sized ports.

And we are also investigating this latest technology. This is called the NeoChord technology. And so what this does is, instead of actually doing surgery at all, we can just access the heart. We access the apex of the heart. And then we put this instrument-- remember this, is with the heart beating, and not on the heart/lung machine. We actually stabilize that posterior leaflet. When we stabilize the leaflet, we know that we have good contact by the colors that come up in the monitoring device. And from the outside, we actually put these cords in place. And then we pull the cord through the patient, and it comes outside the heart right there. And once it comes outside the heart, we then go back on the echo. And we can adjust the length of this cord to make sure that the regurgitation is gone. So, again, a very nice investigative, but a minimally invasive, way to be able to do this in patients.

So that's the mitral valve. So what's exciting about the aortic valve? So we do a lot of aortic valve surgery. We can very easily replace the aortic valve. But, again, as the patient population changes and becomes more acute, we have patients who have very high surgical risk. And so these are patients who have porcelain aortas, which are really calcified aortas. They have hostile chest. They have other problems-- like liver problems, lung problems, neurological dysfunction, or just very, very frail-- that make classic surgical procedures very, very risky.

So these are some examples. As you can see here, all of that white is calcium on the aorta. So this is an aorta that would probably crack if you had to open it up conventionally. This is a patient who has a very, very deep chest. And you can see here, this is a very fragile patient who's in a wheelchair, who if we had to go ahead and do cardiac surgery on would probably never really recover. And these are some other reasons for patients who have tough disease. This is a radiated chest, and you can see the heart is right up against the chest wall. And this is a patient that's had previous CABG. And you can see this artery is adherent to the sternum. So if we ever have to open up the sternum, we would get into that artery right away.

So for those patients, we do what's called transcatheter valve implantation. So this, again, is an animation of the Edwards SAPIEN valve. And what we do is make a very small incision on the left side of the chest. Sorry-- the left side's over here. I showed the right side. And we put a wire through the apex of the heart. And you'll see that right now. You put a wire through. We put some stabilizing stitches. Then you put a wire through the aortic valve. And in the previous portion of that animation, you saw how that aortic valve did not open properly. That's called aortic stenosis.

And here you can see that we will place a balloon through the valve. And then we blow up the balloon. So we now have made that space a lot bigger. And then we will go ahead and deploy a valve that is wrapped around a stent. And we will deploy that right there. And basically have replaced that valve with a valve that now freely opens. Now, this is not a substitute for patients who are low risk for surgery, but this is a fantastic alternative for people who are either inoperable, or have a prohibitively high risk. And as you can see the animation, we now have about that opens much wider than it was before this valve was implanted.

And this is a fluoro-- this is what we actually see in the operating room. You can see that valve being deployed and we have a very good result.

This is what it looks like in the lab. This is a patient with aortic stenosis. And after you deploy the valve, you can see that there's a stainless steel stent that opens up with a valve inside. So this is the partner trial. And with the partner trial, it's a very simple trial that compared conventional aortic valves to this Edwards SAPIEN valve. And you can see that the results are very similar. That the mortality is similar, whether we do this with a surgical AVR or TAVR. And so I think there's compelling evidence that you could do it either way. But only, again, for very high risk or inoperable patients.

Another component of what we do that's exciting is arrhythmia surgery. So what we have done is really try to combine our robotic expertise with our electrophysiologist. And so, for instance, a lot of patients need epicardial-- or outside the heart-- ventricular tachycardia ablation. And normally what the cardiologist does is makes a small incision, and then just blindly puts the probe over the heart and then ablates. So we've combined that with robotics. So with the robotics, we can make a very small incision, completely expose the heart for the electrophysiologist, who would then go in and actually oblate under direct vision.

And the other thing that we have done is atrial fibrillation surgery that is a combination of both robotic surgery and the electrophysiologist. Remember I told you earlier that we have these fantastic new hybrid ORs. And this is really a great reason to use them. So this is a patient who-- this the mitral valve. And we're doing a cryoablation. So there's the cryo probe that goes in. And we can do a complete cryoablation procedure with the robot. And then the cardiologists come in and check our work. And if there's any spot-up work that they need to do, they can. And our success rates-- even with very, very chronic atrial fibrillation-- is absolutely excellent.

So another disease entity that we deal with that is actually increasing in frequency is advanced heart failure. And what the two surgical therapies that we use for that are either mechanical assist devices or transplantation. So on your left you see a heart that is enlarged. And on the echo you can see it's really not beating very well. On the right side is a heart that is more normal in size. And you can see that's beating. So I would say that the heart on the left has an ejection fraction or efficiency of about 10% to 15%, and the efficiency of the one on the right is more normal, at about 55% to 60%. So what you do for somebody who has a heart like the one on the left?

Well, you could do a transplant. So you can get rid of the heart and give him a new heart. And what I'm going to show you here on the screen is a quickie transplant. So this is in 30 seconds what usually takes us about six to seven hours to perform.

What we do here is we open up the chest of this patient. You can see that this heart is very, very enlarged. It's kind of boggy and really not a very happy heart. So we put it on the heart/lung machine. We clamp the aorta, and there's the heart that's coming out. You can see that we have to do six connections to the heart. There's the aorta, the pulmonary artery, and the inferior and superior vena cava, and the two pulmonary veins. So at this point, we're waiting for the heart that arrives in a pickle jar on ice. And as you can, see the heart is much smaller, and it's nice and doesn't have that much fat. We sew it in place.

We say it comes in a pickle jar, but that just means that another surgeon's gone out, procured it, and put it on ice. So after we're done, we got to wake it up. So we give it a little coochie-coochie action and we tickle it. And eventually, it'll come back, and there's the new heart beating in the chest. And you can see how much more vigorous it is, and how much happier it is. The blood pressure is great. This patient is fantastic.

So what are the issues with transplantation? Our one-year survival is absolutely excellent at 90%. Even our 10-year survival is 60% to 70%. And that's actually excellent, because if you do age-match comparisons, that's about how much you would expect a 60- or 70-year-old person to survive if they have heart disease. If the patients have worked before surgery, 90% of them return to work. The biggest limitation with heart transplant is that in the United States we only do 2,000 to 2,500 per year because of donor limitations.

The other problems, of course, are rejection and heart dysfunction. Remember this heart is foreign to the body, to the body tries to reject the heart. And by rejecting the heart, we have to give it medication to suppress its reaction to the heart. And by suppressing that reaction, we actually increase the exposure to infection. So one of the ways to decrease the rejection is to have better preservation or drugs to decrease rejection. And, obviously, the best way is to expand the pool of unused organs.

So, again, this is an investigational procedure that we're doing at the University of Chicago Medicine. And what it is we call it the organ care system. And what it does is instead of taking a heart, which you saw before, that you just put on ice in a pickle jar and you keep it quiescent for within four hours, and then we have to sew it in in four hours, this machine actually takes the heart and keeps it beating. And by keeping it beating, you can actually keep it being for 48 hours-- a much longer period of time. You can assess how well it works, and then the transplant it into the patient. And by keeping it away from the cold injury, actually there's much less injury to this heart, so you have less rejection. You have better performance of the heart.

So this is a video depicting us doing this procedure. You can see-- we call it heart in a box. It's a heart that's in a box. There it is. It's beating. It's all sterile, of course. And we use the blood of the donor itself to keep this heart moving. It's like a ICU because we monitor the blood pressure, which you'll see pretty soon on the next frame. We can monitor the blood pressure. We can monitor the oxygen content. We can monitor the temperature, the lactate, and et cetera.

And when we're ready for transplant, we just pop open the hood. You can see the heart is beating. We disconnect the heart from the machine. And we infuse a little potassium, which is done right there. And once the potassium goes in, the heart stops. We take it out of the preservation device. And we go ahead and do our transplant. So real improvements and advances that are coming with transplantation to make patients live even longer than they are right now.

Of course, everyone wants an actual heart. That's the idea behind transplantation. You have to remember that the natural heart is very reliable. I don't think most of us worry about when our next beat is going to come. It beats 3.4 million times per month. That calculates out to almost 50 million beats per year. By the time you're at 20 years, you're on your billionth beat. The heart is great. It grows from an infant size all the way to an adult. It fights infection. It's self-powered-- I don't think most of us need to recharge our own hearts. It adjusts output as necessary. So when you're sleeping, the cardiac output is only about two liters, and when you're exercising, go up to 20 liters. It's non-thrombogenic, in that it doesn't form clot. It's filled with love. Unfortunately, if it's filled with love, it can be broken. And so the question is can mankind actually make a replacement?

And so this project started in the '60s, and we've been working on this for over 50 years, trying to make a real good replacement for the heart. And what we find is that we really can't beat nature, because if you try to completely replace the heart, you need to have four chambers, four valves, and have mechanical reliability that even with all the things that we do right now is just physically impossible. And so all of the mechanical hearts that we have designed have been very short-term hearts that have usually degenerated within about a two-year period of time.

So instead of giving up, we did a lot of research. We found out that instead of replacing the entire heart, it's best to assist the heart. So what we have developed is things called left ventricular assist devices, that are machines that decrease the workload of the native heart. Instead of asking the native heart to work 100%, we ask the native heart to work 10% to 20%, with the machine doing the rest of the work. And the device that's really revolutionized this field is called the HeartMate II. You can see it here. It's a continuous axial flow pump, and I'll show you a schematic of it shortly. It's very small. It's the size of a D-cell battery. It's very durable. There's only one part. There are no valves. It does need blood thinning. And it is a partial assist device.

And this is how it works. It takes blood from the left ventricular apex, it straightens it out with some fins. It then has a turbine that then ejects the blood up into the aorta through this flow graft. And by doing that, it dramatically decreases how much the actual heart has to work. And what are the results? So this study is a combination of two studies, so it's a composite graph.

But what you can see in this graph at 12 months, is that if you do OMM-- that means Optimal Medical Management-- only 25% of these patients are alive. But if you put in the HeartMate II LVAD, 68% are alive. So that's almost a three-fold increase in survival, which is very dramatic for these patients. At 24 months, you can see that with optimal medical management only 8% are alive. With LVAD therapy, 58%. So that's almost eight times improvement in survival.

And it's not only the survival. It's the fact that these patients have a much more normal quality of life. They can do almost anything other than swim. We've had patients who have done bungee jumping or parachuting, or we've had people do contract work, et cetera. So you have a very good quality of life with a lot of energy. And these, of course, were the initial trials. And you can see our results at the University of Chicago Medicine are more of a 80% to 85% 12-month survival.

So this is the next generation of pumps. This is an investigational device. But you can see that pumps have gotten even smaller than a D-cell battery. Now these are centrifugal pumps, in that the blood comes in and gets ejected out at a right angle. This pump happens to be what we call a wearless pump. So there's no metal-to-metal contact. It's completely magnetically levitated. And therefore we expect extreme longevity of over 10 to 15 years.

Although it's very small, it can pump upwards of 10 liters of blood flow. And because it attaches directly to the heart, as shown on this video clip, there's much less surgical trauma, therefore less bleeding, and a shorter length of stay. So that's a sewing ring that we have attached to the apex of the heart. And we've popped the device in place. The outflow graft gets connected to the ascending aorta. As you can see, blood comes into the device, gets spun around, and then gets ejected at a right angle to the patient.

And this is an implant of that device. You can see a incision just exposing the heart. Again, a heart that isn't very, very happy. We mark out where we're going to do the outflow graft. Then we rotate the heart up out of the chest. And you can see this heart's had multiple heart attacks, which is why its whitish in discoloration. We then go ahead and put on the sewing cuff, as you can see, in place. And then we do a cruciate incision. This is a coring knife, like you saw the schematic. Once we put the coring knife in place, we can visualize the inside of the heart. We make sure there's no clots. And there's the device in my hand. And we go ahead and we snap it in place.

And once we snap it in place, as you can see there, we go ahead and sew in our outflow graft to that ascending aorta, which is done there. Then we take the drive line out of the patient. And then we activate the device. And you can see how much happier the heart is. There's the device all the way up in the pericardial space. I often say the heart's happy because it's not doing any work. It's only doing 10% of the work, as opposed to the 100% before. So I think I'm that happy when I'm on vacation. I'm not doing work either.

So what's life like on a VAD? These are the many things that patients can do. We have people who are in the mountains, are in their cabins in the mountain on a VAD shooting deer. We have people in the gym. This gentleman was on dialysis and on a VAD. And he was on that way for three years. This gentleman almost died, but he saw the birth of his two children on a VAD. And this gentleman is an ophthalmologist who's actually on a VAD, and did over 1,000 opthamological procedures while on a VAD. And he eventually got transplanted.

So here you can see the focus of our program that in the beginning, in 2005 and 2006, our LVAD program was very small, in the single digits. But with exciting new therapies at each inflection point, we've seen growth of this therapy from six implants to over 80 implants last year. And that, combined with our 26 heart transplants, and combined with some of our other procedures we've done for advanced heart failure, gives us an advanced heart failure program that's in triple digits.

So, obviously, these are very, very complex patients. And we understood that to get them through the hospital, get them home, and give them a great quality of life, we need a postoperative management team. So you can see here our complexity, our case mix. 47% of our patients are valve cases. 26% are our advanced heart failure cases. And only 9% are straightforward bypass cases. And just to put this in perspective, most other hospitals, the bypass procedure will be about 70% of the work they do. So clearly we've moved beyond just bypass surgery into very, very advanced therapies.

And how do we take care of these very complex patients? Well, we have an ICU that's managed by intensivists. We have a dedicated CT surgeon who is also critical care boarded to manage all the post-cardiac surgical patients, including those in the ICU. We have 24/7 in-house PA and advance nurse practitioner coverage. And by dedicating those people at the University of Chicago Medicine, we've been able to have a 90% reduction in our cardiac arrest and our codes. We've improved our survival and length of stay. And we have 100% compliance with most of our quality measures as mandated by Medicare.

So in summary, it's taken many years to establish the basis of the current technology that's able to take care of the acuity of our patients, because the acuity of our patients is clearly increasing. We need to be able to take very, very sick patients with a high acuity, and in the current health care environment and funding pattern, be able to take care of them cost-efficiently with very good results. And we feel that the best way to do that is to have less patient trauma, whether it's robotics or catheter-based therapy, or our less-invasive VADs.

I think the two real main points of this talk are less patient trauma in one hand, and in the other hand, how to take care of the very large increasing group of patients with advanced heart failure. And that's where we talk about cardiovascular replacement therapy. I think that's a real exciting therapy-- that includes heart transplantation and mechanical assist devices-- that is really evolving towards the goal of emulating the human heart.

Thank you very much.