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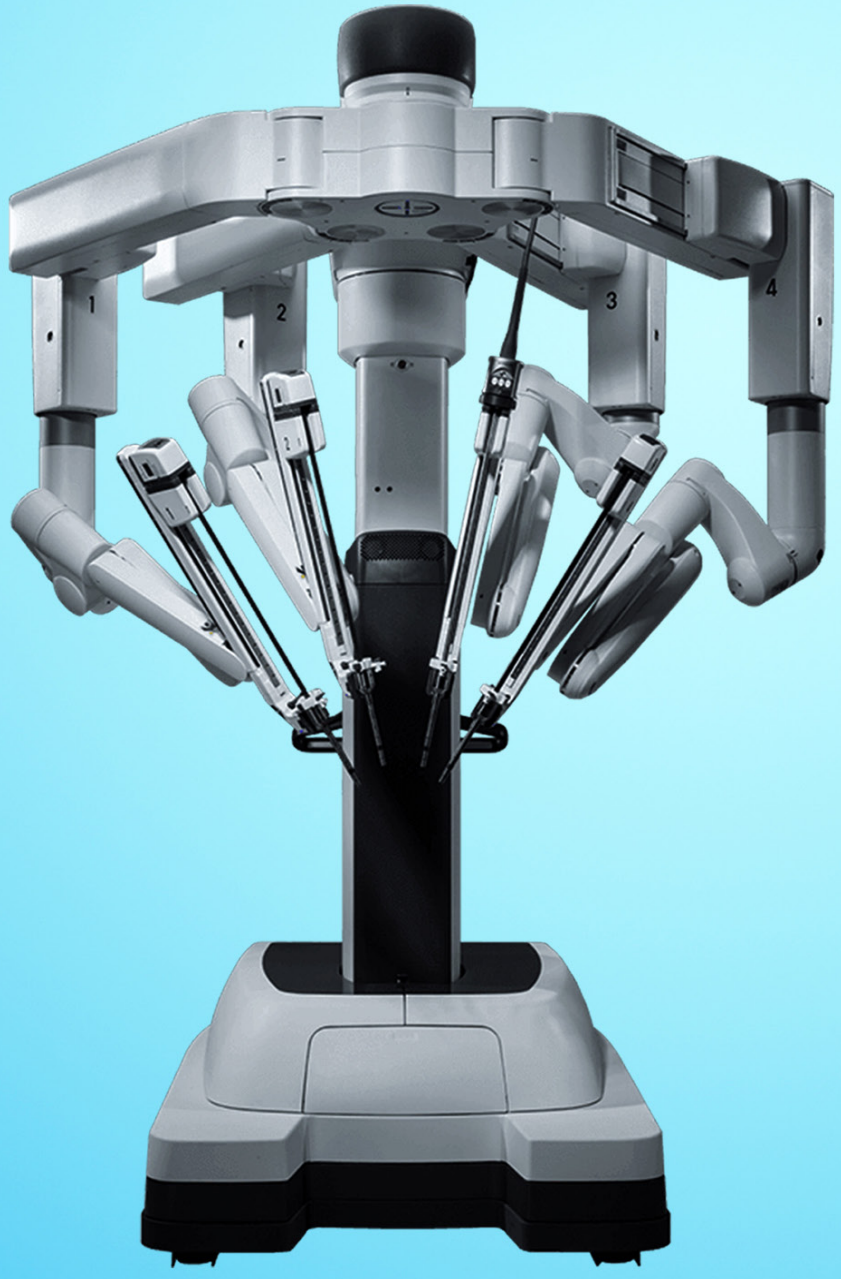
ADVANCES IN ROBOTIC HEART VALVE SURGERY



Penn Medicine
Heart and Vascular Center

Featured Speakers

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Please note: A complimentary video playback of this eBook is now available on YouTube at this link.

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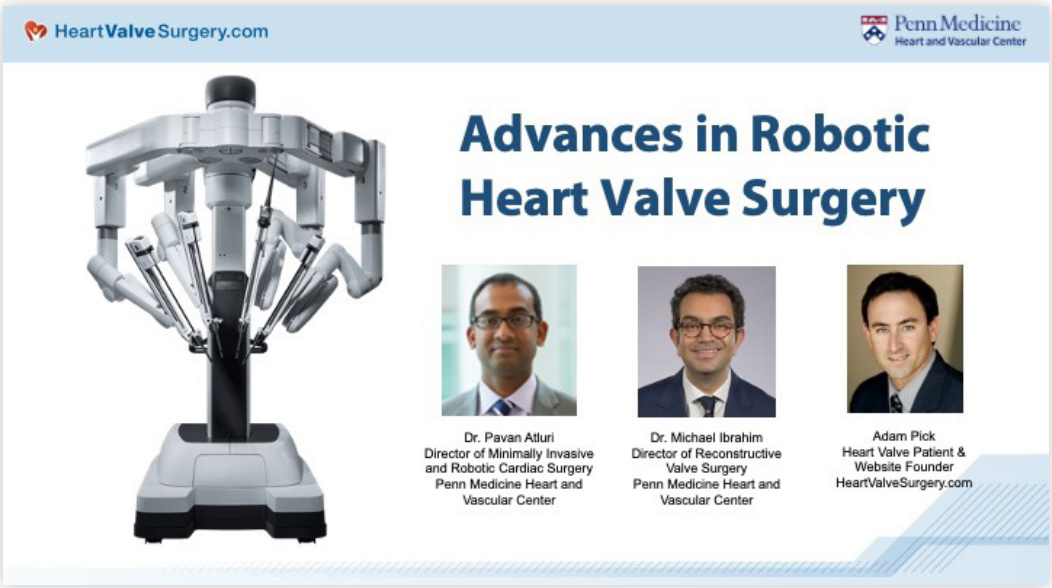
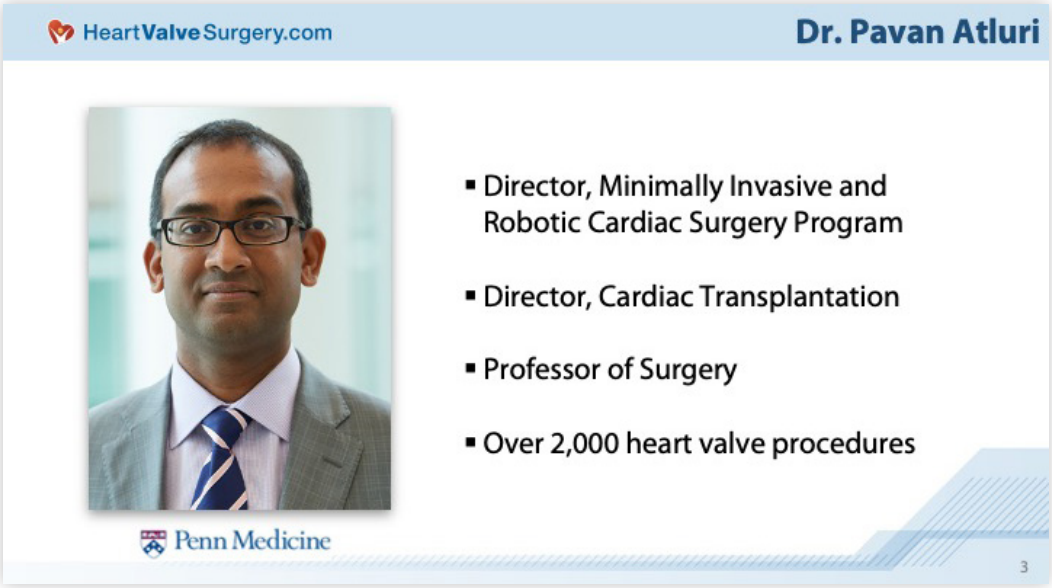


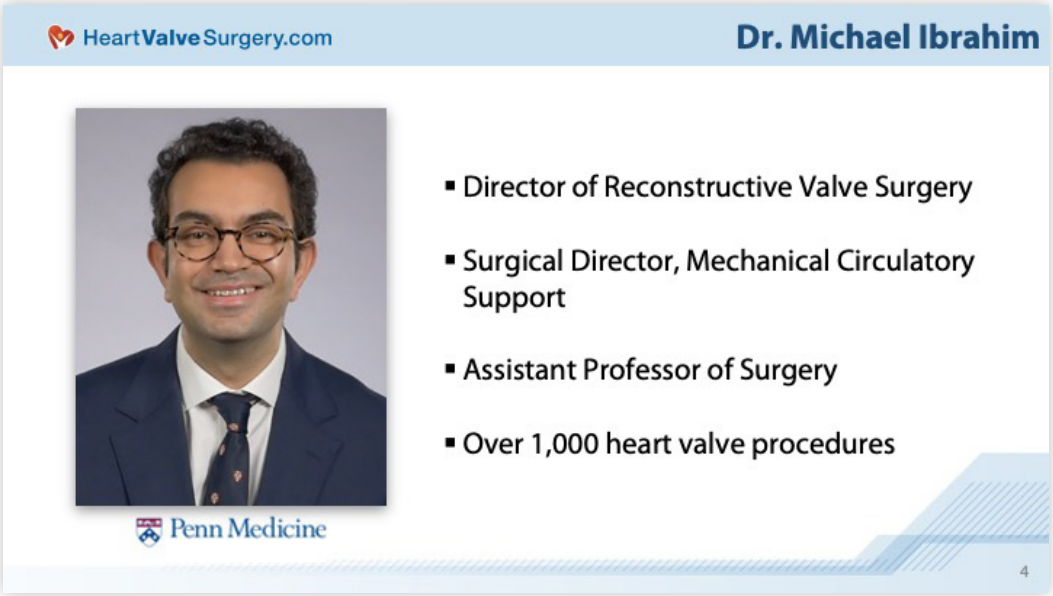
Adam Pick: Hi, everybody. My name is Adam Pick, and I'd like to welcome you to the webinar titled Advances in Robotic Heart Valve Surgery. If I have yet to meet you, I'm the patient who started HeartValveSurgery.com all the way back in 2006. The mission of our website is simple: we want to educate and empower patients just like you. This webinar, which has had over 500 registrations from patients in countries all over the world, was designed to support that very important mission.

Now, throughout the webinar, you're going to be in what's known as "listen-only" mode. I encourage you to submit your questions in the control panel on your screen. As we look at the agenda, I'll explain why. I'm going to introduce the featured speakers. We're going to look at the unique applications of robotic technology and techniques for heart surgery, then spend some time evaluating advantages and patient outcomes for this technique. We're going to answer your questions which you have submitted in your control panel, and we're going to conclude. I'm going to ask you to complete a very quick five-question survey.

When it comes to the featured speakers of today, I am honored and I am humbled that they are taking time away from their very busy practices at Penn Medicine Heart and Vascular Center in Philadelphia, Pennsylvania. So who are they? Well, Dr. Pavan Atluri is the director of minimally invasive and robotic cardiac surgery. He's also the director of cardiac transplantation and he is a professor of surgery. During his incredible career, which extends over two decades, he has performed over 2,000 heart valve procedures. Dr. Atluri, you and I have known each other for a long time. It is great to see you, and thanks so much for being with us today.



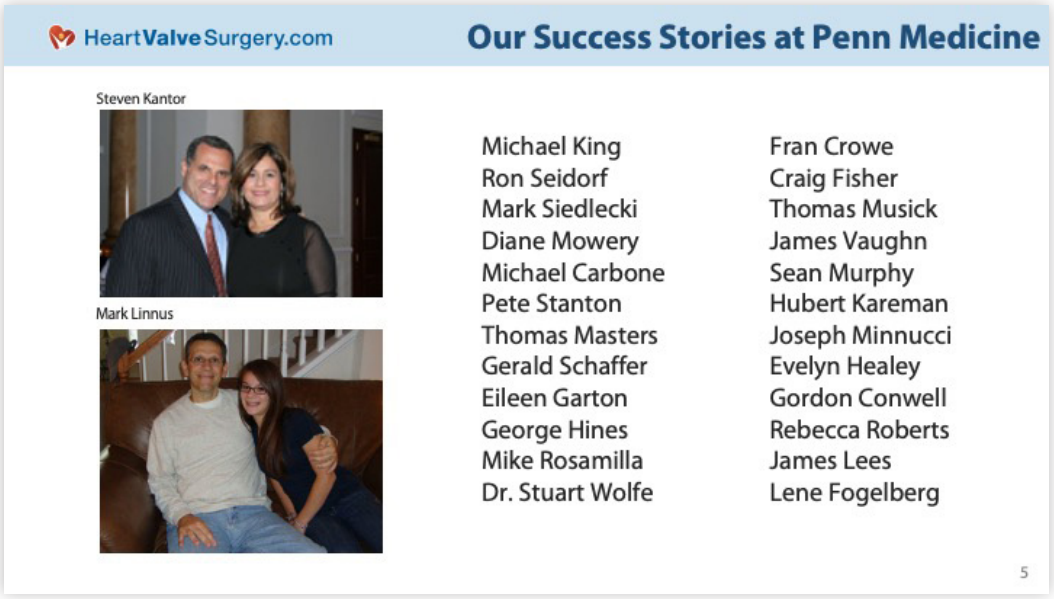
Dr. Pavan Atluri: Thank you, Adam, and I look forward to talking really to this wonderful audience that has made time on the East Coast on this Thursday evening. If you're on the West Coast, it's late Thursday afternoon, so thank you again.



Adam Pick: The other half of the dynamic duo today is Dr. Michael Ibrahim. He is the director of reconstructive valve surgery. He's the surgical director of mechanical circulatory support. He's an assistant professor of surgery and he's performed over 1,000 heart valve procedures. Dr. Ibrahim, thanks so much for being with us.

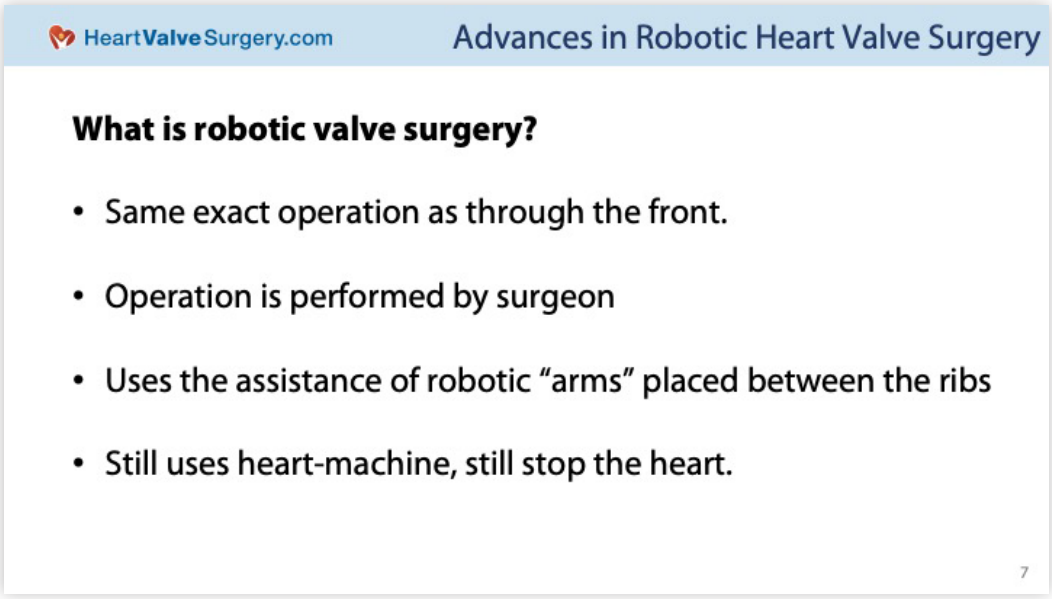
Dr. Michael Ibrahim: Thanks, Adam. It's great to be with you guys again and talk about stuff that we love doing and patients that we love taking care of.

Penn Medicine Success Stories



Adam Pick: I could go on and on, Dr. Atluri and Dr. Ibrahim, about all of your accolades, all of your achievements, but what I'd like to do for the community today is really show them this. This is one of my favorite parts is the smiling faces and the names of patients who were on heartvalvesurgery.com, members of our community, and went to Penn Medicine for very, very successful heart valve procedures. Whether it's Steven Kantor, Mark Linnus, Ron Seidorff, Gerald Schaffer, Evelyn Healey, on behalf of these patients, Dr. Ibrahim and Dr. Atluri, thank you for being with us today and we are going to get started with Dr. Michael Ibrahim.

What Is Robotic Valve Surgery?



Dr. Michael Ibrahim: Great. Thank you, Adam. The first thing I want to say just before we get onto the slides is I know many of your patients who are on the line will be thinking about surgery in the near future, and I understand. One of the things that really motivated me to become a heart surgery was a family experience with being very close to a patient. Honestly, I was a little bit disappointed about the communication from the physicians. That was something that I was very motivated to change as I went through my own career. I know that there's a lot of anxiety about waiting for one of these operations.

Valve surgery in 2024 is in general very safe, very effective, and restores people's lives back to normal. I just want to say I understand how stressful this is for the

patient community but there's a lot of hope and there's a lot of great outcomes. Hopefully you guys can partner with a surgeon you feel comfortable with and that can take you through that journey. Try not to worry too much. I think educational things like this are going to be very helpful for the community of patients that we have.

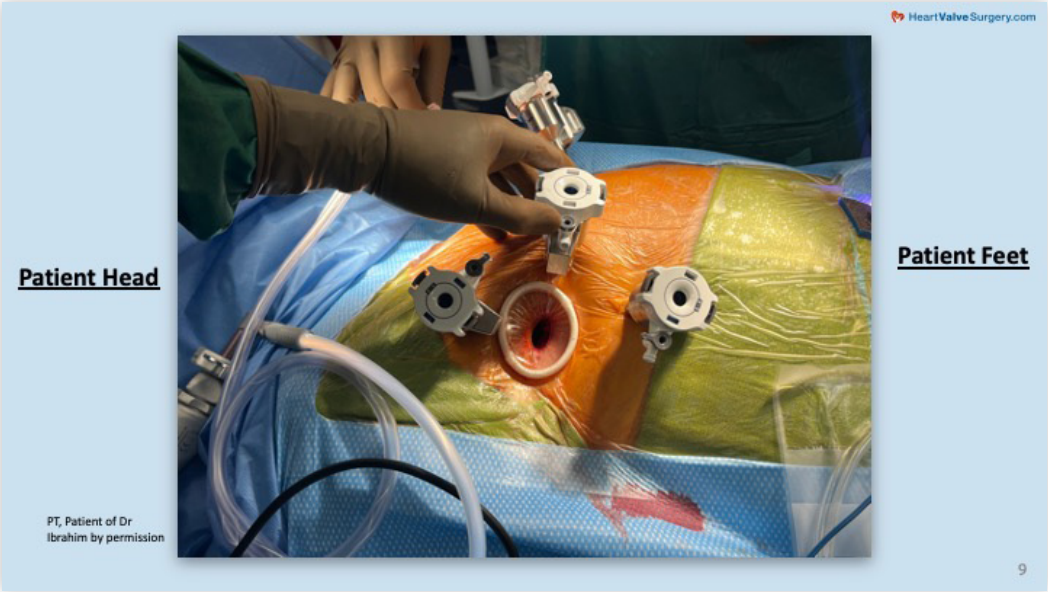
So what is robotic valve surgery? I think the most important thing to say is that when we do an operation robotically, we are doing precisely the same operation as we would be doing through conventional sternotomy incision. One of the principles that Dr. Atluri and I have is that we never compromise on the operation. We want to do it robotically; we want to do it perfectly, but it must be perfect. That's more important than any incision or any approach.

About 80% of my valve operations are robotic, and that's the focus. The operation is performed by the surgeon. There's this myth that arises sometimes; is the robot autonomously by itself doing the operation? No, the robot is a tool just like a set of forceps, just like a needle driver. The operation is done by the surgeon. We use the assistance of robotic arms that are placed between the ribs and enter the patient's chest and into the heart under very careful control by the surgeon. The surgeon is in complete control of the operation. We still use the heart-lung machine and to do these valve operations, we're still stopping the heart in exactly the same way as you would going through the front.

Evolution of Minimally Invasive Techniques

Dr. Michael Ibrahim: Here, we have this slide that shows close to home the evolution. This was a sternotomy patient, and this is a pretty conventional incision, nothing wrong with that. For many patients, we can go from this to these very small incisions. This is one of my patients that very kindly allowed me to use this picture of her, which shows this very small, about centimeter or centimeter and a half incision as the main working incision. This is something that I've developed over a period of time that 90% of my robotic patients, this will be the approach. There's a set of 8 millimeter incisions that go around a central one to one and a half centimeter incision. I don't spread the ribs; I don't make a big thoracotomy or anything like that. There's different types of minimally invasive surgery but for me, this is what robotics looks like.

Robotic Surgery: Patient Setup



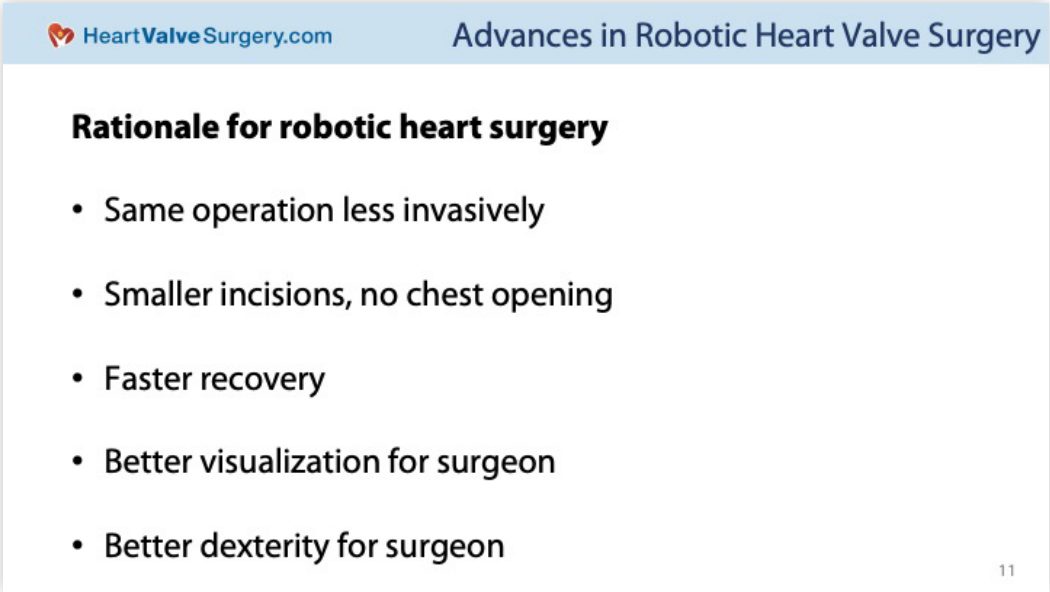
Dr. Michael Ibrahim: This is the set-up. The patient's head is up here. The patient is draped under these drapes. The patient's feet are down here. We're looking at – these are ports that are 8 millimeters. They enter between the ribs, and there are four of them that control two arms, a right and a left arm, a camera, and then this is what we use to retract inside the heart. Then, this is what we use to put things in and out the chest as we need material to repair the valve. This is another of my patients that has kindly allowed us to use this. I think one thing is this is not a tiny patient; it's not a massive patient. It's applicable for a very large number of patients.

Robotic Surgery: Surgeon Control Station

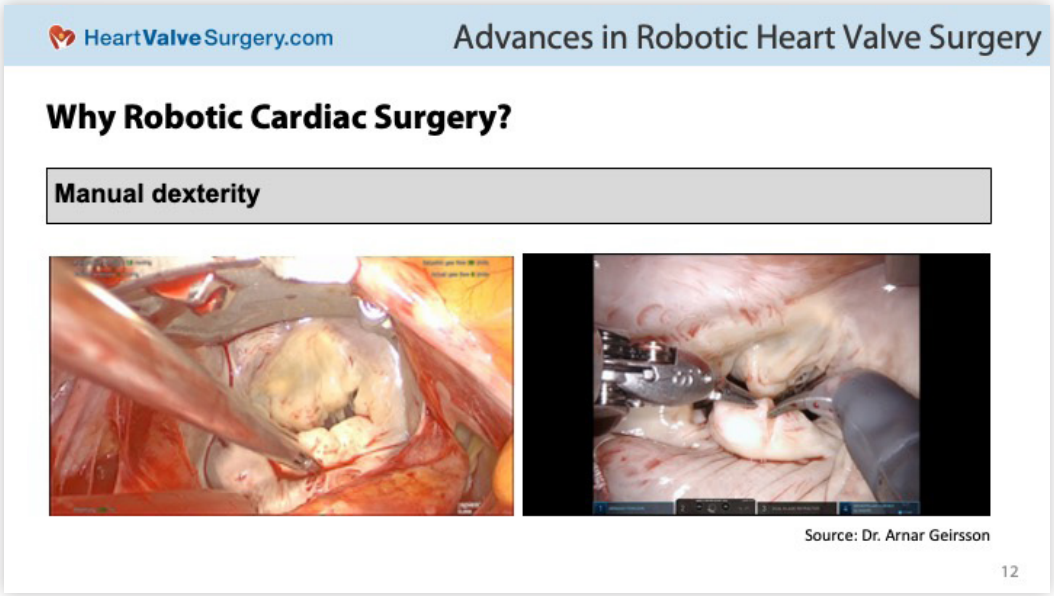
Dr. Michael Ibrahim: These are the videos that were taken by my resident of me doing a case a few weeks ago. I think it just shows, I'm sitting on the robot. I'm about a meter away from the patient. The patient's heart is currently stopped. I'm working inside the heart to introduce stitches to repair the mitral valve in this case. As you can see, I'm engrossed in this and working with my hands. You can see how the hands of the robot translate those movements into movements inside the patient. This I just think is useful to give patients the seen of what this actually looks like.

These machines are incredibly advanced. They're several million dollar machines. They're highly reliable They translate our movements with perfect precision. They do a number of things. We get some tactile feedback from them. There's different ways of controlling the camera and the right and left arm and energy tools that we may need to use during the operation but just a general sense.

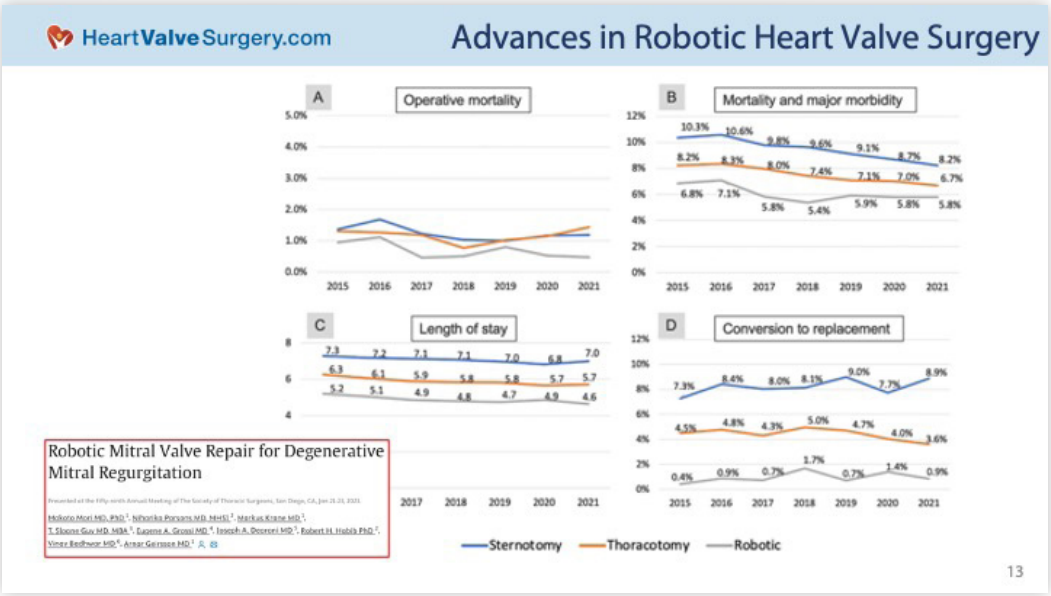
Rationale for Robotic Valve Surgery



Dr. Michael Ibrahim: So what is the rationale? As I mentioned before, it's the same operation, just less invasively. We're able to do smaller incisions without opening the chest. Patients can recover faster. I had a patient recently – a young person who was very motivated to get back on the golf course. That was his marker for himself that he was doing well, that he was back on the golf course on day four after the operation. I don't recommend that necessarily, but that's what he did.



I honestly think it's actually a better visualization for the surgeon. I think the dexterity for the surgeon is better. This is some recent data that came out, the Society for Thoracic Surgery, which is one of our largest academic institutions in North America that tracks heart surgery. These are matched patients, so they compared people having, in this case, mitral valve surgery through a sternotomy, conventional operation through a thoracotomy, and through a robotic approach.



I won't go through all of it, but basically what you can see is that the robotic patients actually did pretty well. They did best out of the three groups that were examined. They had the lowest mortality; they had the shortest lengths of stay; they had the lowest rates of conversion to replacement of the valve. There is no way in which the robotic approach compromises the quality and safety of the operation. It may enhance it but certainly does not compromise it. That's something that patients ask me a lot – are we paying a price in terms of compromising the operation for a robotic approach? The answer is absolutely not.

The caveat, of course, if you got to go to the right center, because it's not just the surgeon; it's the team. It's the anesthesiology team; it's the O.R. team; it's the post-operative team. They have to be looking at robotic patients all the time, and that's what we do here at Penn Medicine. That's an important point.

Minimally Invasive: Short Term Patient Benefits

Dr. Pavan Atluri: Mike laid it out beautifully for you what the advantages of robotics, what the advantages of a nonsternotomy approaches and I think what he said earlier is a very salient point, and that is the long-term is the ultimate goal. It's something that we're all focused on. We can do it very cleanly with these approaches and I think that's important. Unfortunately, experience matters, and there's people who may not have the same level of expertise on their team, but we're very, very fortunate that we've got this team that is highly experienced on all fronts.

I really do think that we can provide the benefits. It's really the short-term benefits in terms of recovery, in terms of incision while maintaining the long-term. The long-term, what we're talking about, mitral valve disease especially is normalize survival, normalize quality of life to an age and risk matched population.

Not to belabor this, but there's a lot of advantages to a minimally invasive operation. That is rapid recovery, so we see shorter lengths of stay, short times in the I.C.U. Often, these patients are extubated in the operating room and they're back to activity really fairly quickly. I don't know that I'd recommend four days. There's still a little bit of soreness, but certainly a lot quicker. That's been shown for – we've known that for well over a decade; in multiple different forms, it's been studied.

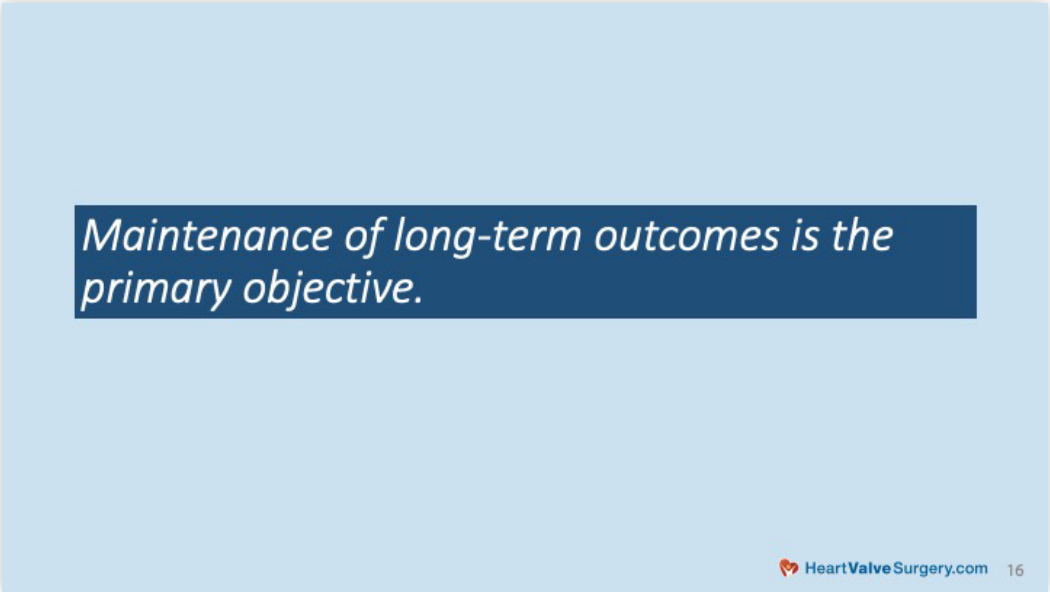
We see lower rates of blood transfusion. Now, we take all the precautions we can in order to minimize blood transfusion but, in fact, the minimally invasive approach is they bleed less; there's less places to bleed. The rates of blood transfusion in multiple series, including our own series, is showing lower rates of transfusion.

The pain is certainly better. One of the things that we are cognizant about is how we approach the chest wall, the incisions that are made, how much we spread. It's hard to do with zero pain because after all, we are making incisions in the chest, but that pain tends to subside fairly quickly.

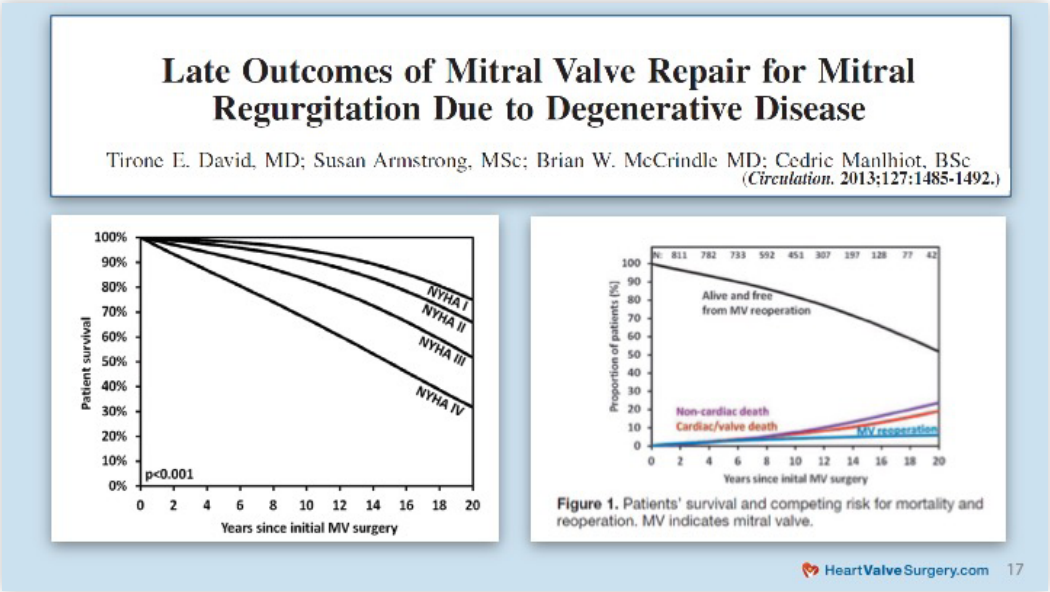
We utilize a protocol known as an ERAS protocol for more rapid recovery from pain. Importantly, in 2024, I think we've gotten very aware of the importance of minimizing narcotic pain medication and these approaches really do allow us to minimizing not having pain medication. We've seen a lot of opioid addiction over the years, and we've developed protocols in addition to procedures to help minimize the need for opioid pain medications and for the ability to recover very quickly.

There's obviously a cosmetic benefit. We've been seeing decreased rates of atrial fibrillation depending on the series that you look at with nonsternotomy approaches and robotic approaches.

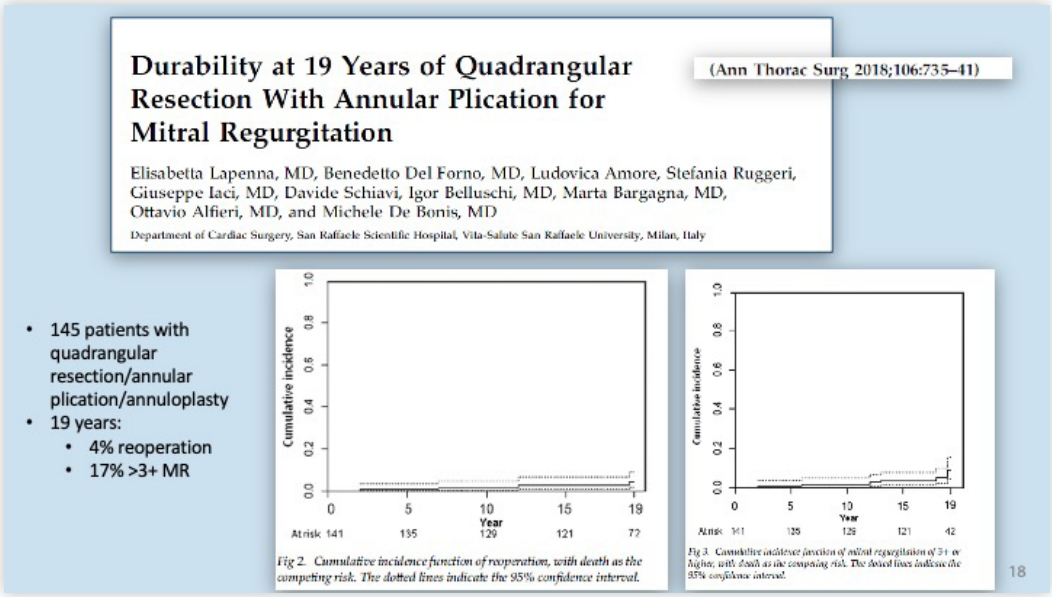
Long-Term Outcomes for Mitral Valve Repair



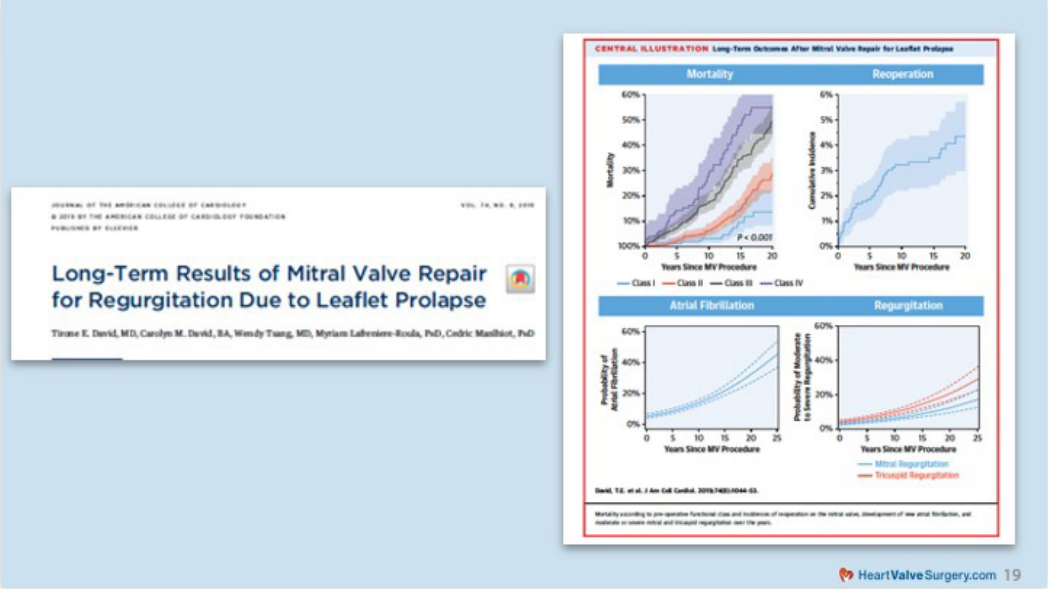
Dr. Pavan Atluri: The maintenance of long-term outcomes is the main objective. This is objective one through ten. Our focus is making sure that you have a durable valve repair long-term that will rival any data that you see out there. Right now, the data is very good. There's a lot of really good single-center data out there that demonstrates durability from valve reintervention of greater than 90% at 20 years. This has been shown in multiple series. I can show you that we do that. That is something that is our focus. We use the appropriate techniques to make sure the valve is repaired right.



This is one of those sets of data. This was data that came out in 2013. This is data out of Toronto. It really shows a really optimal survival following mitral valve surgery. Now, this via sternotomy approaches that Tirone David presented, but look at our data and it will largely parallel this.

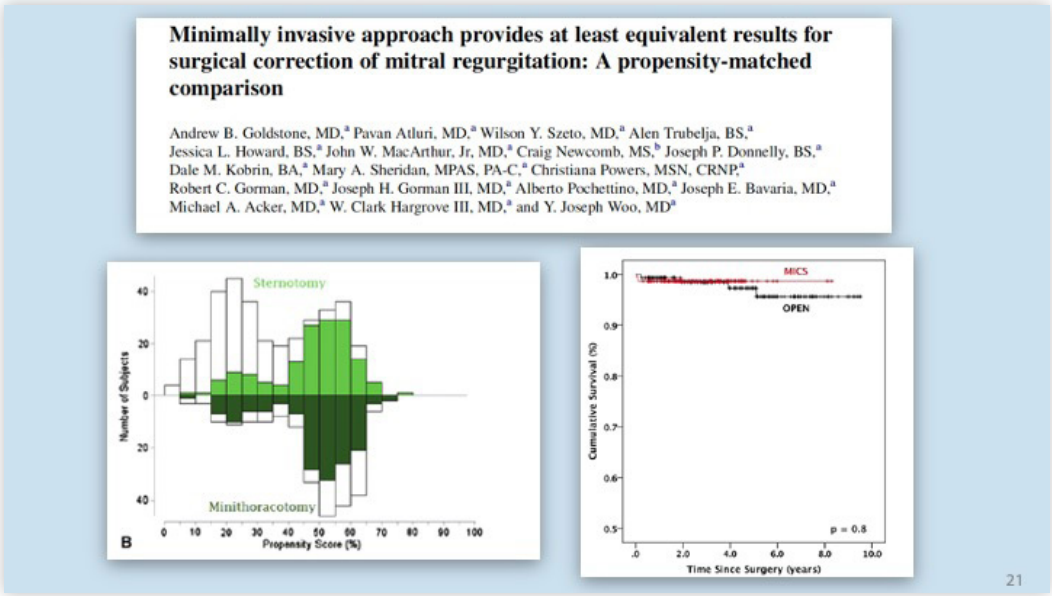


Same thing has been shown out of Italy and the Italians who are also very, very good mitral valve surgeons. This particular is a group out of San Rafael Hospital in Milan. I know many of these surgeons; they're excellent surgeons and they've got really good data, data that, again, demonstrates very low reoperative rates, less than 5%. Think we got a 4% reoperation rate, which is the same numbers that we have, and that's at 19 years. Mitral valve repair can be done very well and hold up long-term, and that's the key.



Dr. Tirone David republished his data and again shows just really excellent long-term outcomes, very low mortality from surgery, very low reoperative rate, very low rates of atrial fibrillation or recurrent mitral regurgitation. This is why we're pushing to do mitral valve surgery at an earlier stage. We also know that if we wait too long, heart damage can set in and can impact long-term survival. When you're talking about operative risk well below 1% with really, really durable repair, we can really make a very big impact on people's lives, both quality of life as well as maintaining survival with these operations.

That can be done minimally invasively in the majority of our patients. The main message, repair the valve.



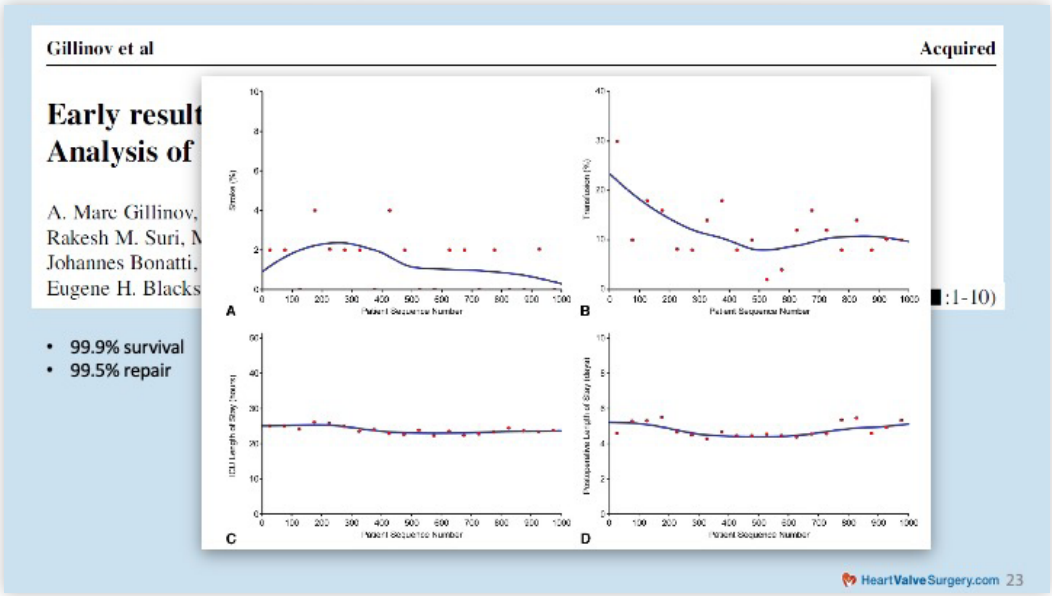
That being said we've looked out our own data. We've seen that you can have nearly 100% repair rates for patients that do very well when you compare minimally invasive groups with our sternotomy patients. This is data out to ten years. This is Penn Medicine data.

TABLE 3. Operative and echocardiographic data stratified by operative approach: Propensity-matched cohorts

Variable	Any cause			Degenerative only		
	Median sternotomy (n = 201)	Minimally invasive (n = 201)	*P* value	Median sternotomy (n = 153)	Minimally invasive (n = 153)	*P* value
Crossclamp time (min)	82.3 ± 38.5	101.3 ± 32.4	<.001	81.9 ± 30.7	103.7 ± 31.6	<.001
Bypass time (min)	108.1 ± 48.3	136.8 ± 42.0	<.001	106.8 ± 36.8	138.1 ± 41.2	<.001
Repeat bypass run	9 (4.5%)	6 (3.0%)	.4	6 (3.9%)	5 (3.3%)	.8
Significant SAM	2 (1.0%)	0 (0%)	.3	2 (1.3%)	0 (0%)	.5
Ring type						
Flexible	14 (7.0%)	105 (52.2%)	<.001	9 (5.9%)	90 (58.8%)	<.001
Semirigid/rigid	187 (93.0%)	96 (47.8%)		144 (94.1%)	63 (41.2%)	
Incomplete	5 (2.5%)	1 (0.5%)	.1	0 (0%)	1 (0.7%)	1.0
Complete	196 (97.5%)	200 (99.5%)		153 (100%)	152 (99.3%)	
Repair strategy			<.001			<.001
Leaflet resection	136 (67.7%)	105 (52.2%)		121 (79.1%)	98 (64.1%)	
Neochordae	16 (8.0%)	37 (18.4%)		15 (9.8%)	29 (19.0%)	
Leaflet remodeling	15 (7.5%)	32 (15.9%)		4 (2.6%)	19 (12.4%)	
Annuloplasty alone	29 (14.4%)	19 (9.5%)		10 (6.5%)	5 (3.3%)	
Post-repair MR			.04			.04
None	181 (90.0%)	192 (95.5%)		140 (92.1%)	148 (97.4%)	
Trace/mild	20 (10.0%)	9 (4.5%)		12 (7.9%)	4 (2.6%)	
Moderate	0 (0%)	0 (0%)		0 (0%)	0 (0%)	
Post-repair EF (%)	57.8 ± 14.2	56.6 ± 10.7	.3	58.4 ± 12.0	57.5 ± 9.5	.5

Continuous variables are expressed as means ± standard deviation. *SAM*, Systolic anterior motion; *MR*, mitral regurgitation; *EF*, ejection fraction.

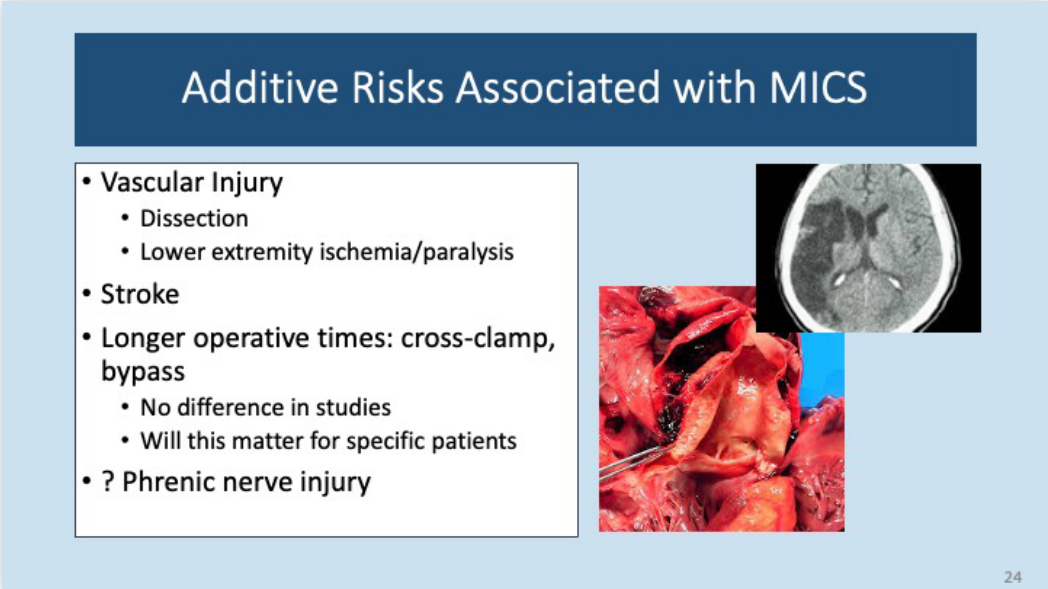
And again, long-term outcomes, very low rates of occurrence of mitral regurgitation. We're talking single-digit rates with really good long-term outcomes.



This data and a very good paper that came out – this paper is almost eight, seven years old now, and this came out of Cleveland Clinic. Their techniques are very similar to ours. I know all the surgeons very well, talk to them all the time. We all share best practices.

With these practices, they've achieved nearly 100% survival rate with a nearly 100% repair rate, which is really quite remarkable.

Risks Associated with Minimally Invasive Surgery



Dr. Pavan Atluri: It is important to know that there can be a risk associated with minimally invasive approaches, and we've seen some of them, the vascular injury, potential for strokes; the operative times can be longer. There are other nerve structures that we could potentially interact with along the way. One in particular is the phrenic nerve. We think about your risk factors, think about how we can avoid these because none of these problems will maintain a normal survival for you. As we think about how best to approach each individual patient, I assure we, we think about all these issues and how we're going to minimize any complications.

When we've looked at our own data, we've seen very low rates of complications. Now, I'm going to be honest with you. In the early days, back in the late '90s, we saw higher rates of vascular complications, and now we've done a lot of work. We've looked at very good screening techniques, and our current aortic dissection rates and vascular complication rates are extremely, extremely low.

That's important to recognize that there is a learning curve with this, and there is a lot that can be learned over time, and so experience does matter. We've learned this; I've learned this from my mentor. We've passed this on to Dr. Ibrahim. An experienced center will be able to provide that for you. At Penn Medicine, I'd like to think that we're able to use our experience to continue to improve our outcomes and get nearly optimal outcomes for our patients.

Finding An Experienced Cardiac Center

Adam Pick: Dr. Atluri, I imagine some patients are hearing you talk, and they are getting these really important points, which is the learning that you and your team have experienced over the years. Then, at the same time, the importance of the team, the people who come together to perform these wonderful procedures. They might be wondering, "How do I know if the cardiac center that I'm going to has these types of outcomes? Are there certain questions that you would encourage them to ask? Or, is there a reference out there? How can they know that they're going to the right place?"

Dr. Pavan Atluri: Honestly, word of mouth. Talk to your cardiologist and ask your surgeon. I know very few people out there that will lie to you, but just ask them the hard questions. How long you been doing this for? How many have you done? The question's critical. It's astonishing, but if you look at the Society of Thoracic Surgeons data, an average number of mitral valves that are done has gone up over the years. It was three in the past. Now, it's up to six. Then you're also looking at many of us who are doing several hundred of these a year and you're averaging that out to everybody else out there. When you look at the median, the number the majority are doing, it's close to three. I can assure you, anything I do three times a year, I am not going to be an expert at. Do something 200 times a year, you'll certainly be an expert at it. I think that's important.

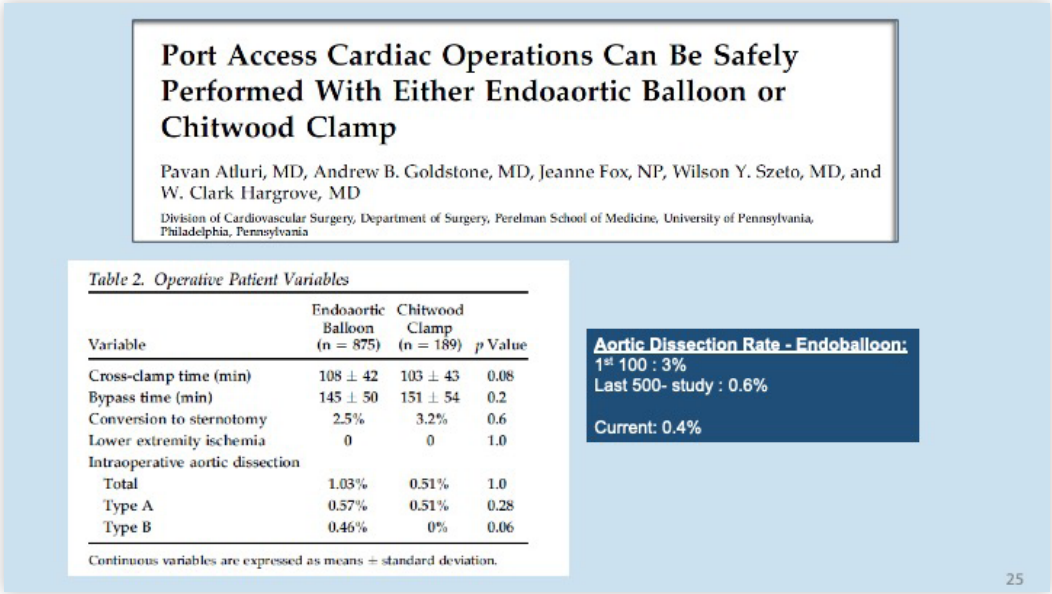
Ask them their outcomes; ask them – any good mitral valve surgeon will follow their patients long-term, so ask them what the recurrence rates of mitral regurgitation are and how many patients are having to reoperate on for recurrent mitral regurgitation. These are really important questions. We'll get down to the meat and potatoes. Is this going to be a good, durable operation for

me long-term?

Then, get a feel for them. I get a lot of patients who come see me for second opinions, and I never undersell; I never oversell. It's important to just be honest with people and find that rapport with your surgeon. If you trust them, you're comfortable with what they're telling you, then make the decision. At some point, unfortunately, you do have to make that leap and trust that they will do what's right for you. Those questions I told you have repeatedly been mentioned in multiple different forums as being important questions, and I'll agree with that.

Dr. Michael Ibrahim: I completely agree. I think it's very important. Every operation is different. A sternotomy mitral valve repair is not a robotic mitral valve repair, is not a thoracotomy mitral valve repair. I think it's very important to really get a handle on how many have you done; how many have you done per year; what are the results? I have a slide deck that I show my patients that is very open and up-front about that. I'm very proud of our results; our results are excellent. The result of not only the experience but selection, care, the ability to rescue when there is a problem, and so on. It's often the basic stuff that goes wrong that we hear about from other centers or whatever that leads to complications. I completely agree that it is really important. It's shocking the number of mitral valve repairs, and I just did a robotic mitral valve repair today; I've got another one tomorrow. There are some surgeons, that's their whole experience for the entire year. That is not good. You do not want that person repairing your mitral valve.

Blood Control During Surgery



Port Access Cardiac Operations Can Be Safely Performed With Either Endoaortic Balloon or Chitwood Clamp

Pavan Atluri, MD, Andrew B. Goldstone, MD, Jeanne Fox, NP, Wilson Y. Szeto, MD, and W. Clark Hargrove, MD

Division of Cardiovascular Surgery, Department of Surgery, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania

Table 2. Operative Patient Variables

Variable	Endoaortic Balloon (n = 875)	Chitwood Clamp (n = 189)	p Value
Cross-clamp time (min)	108 ± 42	103 ± 43	0.08
Bypass time (min)	145 ± 50	151 ± 54	0.2
Conversion to sternotomy	2.5%	3.2%	0.6
Lower extremity ischemia	0	0	1.0
Intraoperative aortic dissection			
Total	1.03%	0.51%	1.0
Type A	0.57%	0.51%	0.28
Type B	0.46%	0%	0.06

Continuous variables are expressed as means ± standard deviation.

Aortic Dissection Rate - Endoballoon:
1st 100 : 3%
Last 500- study : 0.6%

Current: 0.4%

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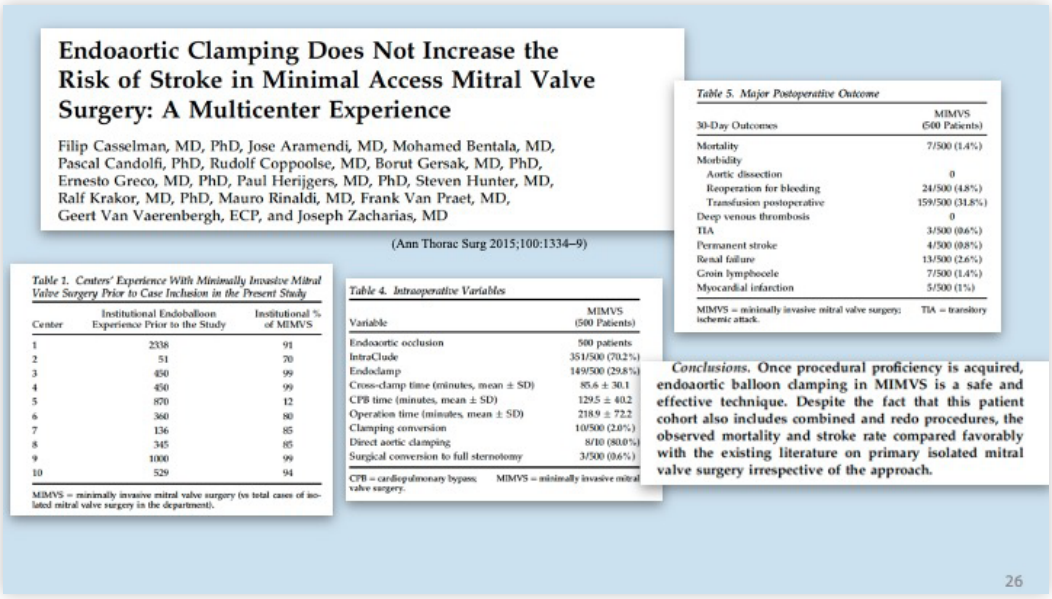
Dr. Pavan Atluri: We use some fancy techniques to control the blood in the heart. Some of this takes experience, and this data I'm showing you is from very experienced centers. For instance, if someone's going to try using this balloon that we put up to try and controlling the heart, if you don't have experience, it will be an issue.

Contraindications for Robotic Heart Valve Surgery



Endoaortic Clamping Does Not Increase the Risk of Stroke in Minimal Access Mitral Valve Surgery: A Multicenter Experience

Filip Casselman, MD, PhD, Jose Aramendi, MD, Mohamed Bentala, MD, Pascal Candolfi, PhD, Rudolf Coppoolse, MD, Borut Gersak, MD, PhD, Ernesto Greco, MD, PhD, Paul Herijgers, MD, PhD, Steven Hunter, MD, Ralf Krakor, MD, PhD, Mauro Rinaldi, MD, Frank Van Praet, MD, Geert Van Vaerenbergh, ECP, and Joseph Zacharias, MD

(Ann Thorac Surg 2015;100:1334–9)

Table 1. Centers' Experience With Minimally Invasive Mitral Valve Surgery Prior to Case Inclusion in the Present Study

Center	Institutional Endoballoon Experience Prior to the Study	Institutional % of MIMVS
1	2338	91
2	51	70
3	450	99
4	450	99
5	870	12
6	360	80
7	136	85
8	345	85
9	1000	99
10	529	94

MIMVS = minimally invasive mitral valve surgery (vs total cases of isolated mitral valve surgery in the department).

Table 4. Intraoperative Variables

Variable	MIMVS (500 Patients)
Endoaortic occlusion	500 patients
IntraClude	351/500 (70.2%)
Endoclamp	149/500 (29.8%)
Cross-clamp time (minutes, mean ± SD)	85.6 ± 30.1
CPB time (minutes, mean ± SD)	129.5 ± 40.2
Operation time (minutes, mean ± SD)	218.9 ± 72.2
Clamping conversion	10/500 (2.0%)
Direct aortic clamping	8/10 (80.0%)
Surgical conversion to full sternotomy	3/500 (0.6%)

CPB = cardiopulmonary bypass; MIMVS = minimally invasive mitral valve surgery.

Table 5. Major Postoperative Outcome

30-Day Outcomes	MIMVS (500 Patients)
Mortality	7/500 (1.4%)
Morbidity	
Aortic dissection	0
Reoperation for bleeding	24/500 (4.8%)
Transfusion postoperative	159/500 (31.8%)
Deep venous thrombosis	0
TIA	3/500 (0.6%)
Permanent stroke	4/500 (0.8%)
Renal failure	13/500 (2.6%)
Groin lymphocele	7/500 (1.4%)
Myocardial infarction	5/500 (1%)

MIMVS = minimally invasive mitral valve surgery; TIA = transitory ischemic attack.

Conclusions. **Once procedural proficiency is acquired, endoaortic balloon clamping in MIMVS is a safe and effective technique. Despite the fact that this patient cohort also includes combined and redo procedures, the observed mortality and stroke rate compared favorably with the existing literature on primary isolated mitral valve surgery irrespective of the approach.**

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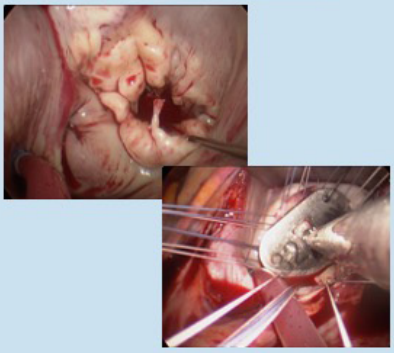
Dr. Pavan Atluri What are the contraindications? When you look at the data sets, some of the early data sets have shown increased rates of stroke, increased rates of vascular complications. It's important that we screen for that and make sure we minimize those complications, and what are those? I think the really big complication is really bulky, bad vascular disease, big chunks of calcium in the aorta. Those are the ones that do really pose issues. They tend to cause problems in terms of potential for tearing the aorta. They can increase rates of stroke. That's really the big contraindication.

Contraindications

- Aorto-Iliac disease
- Ascending aortic dilatation >4.4cm
- Moderate to severe aortic insufficiency
- Acute Endocarditis
- Severe MAC
- Concomitant CAD
  - Consider hybrid
- Systemic disease: pulmonary hypertension, RV failure, hepatic dysfunction
- Pectus excavatum
- Radiation heart disease



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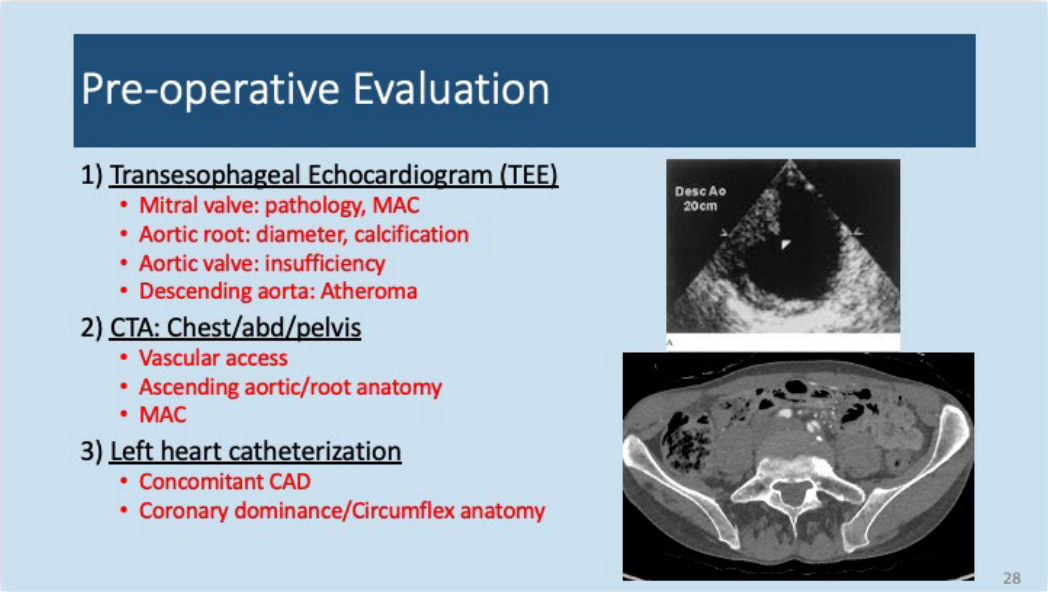
The rest of it all is – that we're going to talk about are relative. Ascending aorta that's big, after a certain size, we don't want to ignore other heart disease, so aortic aneurysms. After a certain size, we need to start thinking about do we treat this? I've got a patient coming up that I've got to take care of the aorta at the same time. He's got an aneurysm, so fix your heart valve, leave you with an aneurysm, that can be a risk down the line for rupture; I'm not doing you a favor.

Along that same lines, an aortic valve that's leaking very badly may be hard to arrest at the time of – to protect the heart appropriately at the time of mitral valve surgery. At some point, we do need to start thinking about is it time to address that aortic valve. Acute endocarditis is a relative contraindication. Early on, we would say no to it. I think it really depends on where the disease is and how much you need to do. Endocarditis could potentially be a contraindication depending on extent of disease. Very severe mitral annular calcification (MAC) is one that I'm careful with. I've been very – it's very humbling when you have a lot of mitral annular calcification, and I deal with it a lot. I have other surgeons send me these cases, but it's still very humbling, even if you do a lot of it. Calcium can be very delicate, and it's something you have to handle very carefully.

Other heart disease, coronary artery disease is something that we need to tackle. It's not something that we want to leave behind, so if you have a blockage in one of your heart arteries, it's something that we'd do a bypass with at the same time. Then, really bad disease of your lungs, or radiation heart that can potentially compromise the heart where every minute on bypass matters.

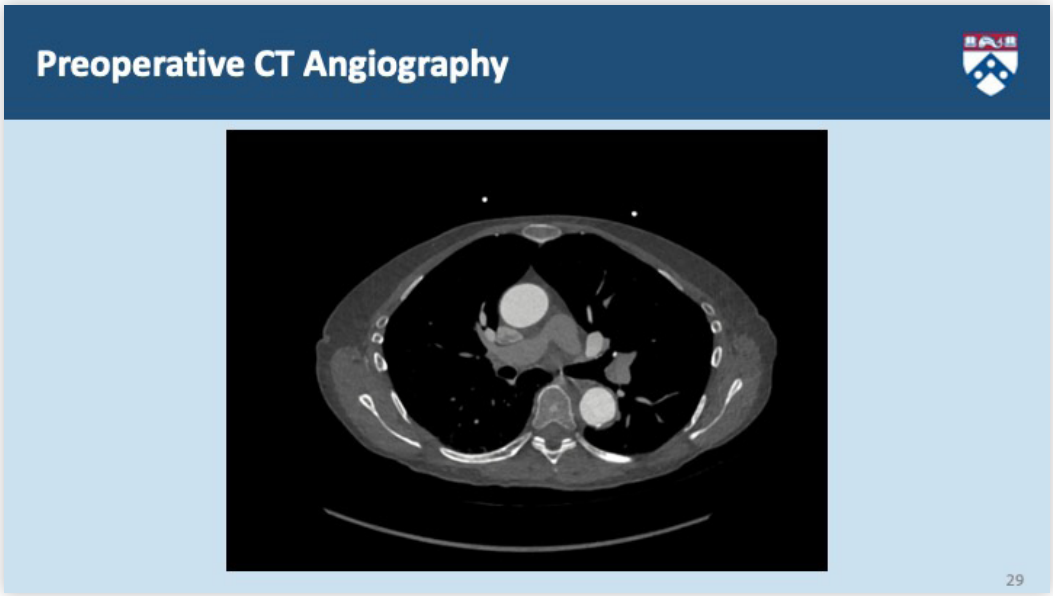
Those patients, I try to really minimize any operative time at all possible. Over the last decade and a half, I've learned some of these patients really struggle if you don't minimize some of the amount of time that the heart is stopped. Pectus excavatum, depending on the extent of the disease.

Pre-Operative Evaluation



Dr. Pavan Atluri: What do we do to help the public evaluate for this? Really, three major tests; transesophageal echocardiogram, which is really important not only to look at the mitral valve disease but it also gives us a sense of what the aorta looks like, what the aortic valve looks like, and it's also a really good way of looking at any calcium burn in the aorta itself.

A CAT scan, every once in a while, I'm really surprised that I pick up disease, and this is one of my patients from years ago at the bottom, that surprisingly picked up a dissection in his groin vessel, and if that's the case, you don't want to be using that for bypass because that tear could propagate all the way up to the heart.

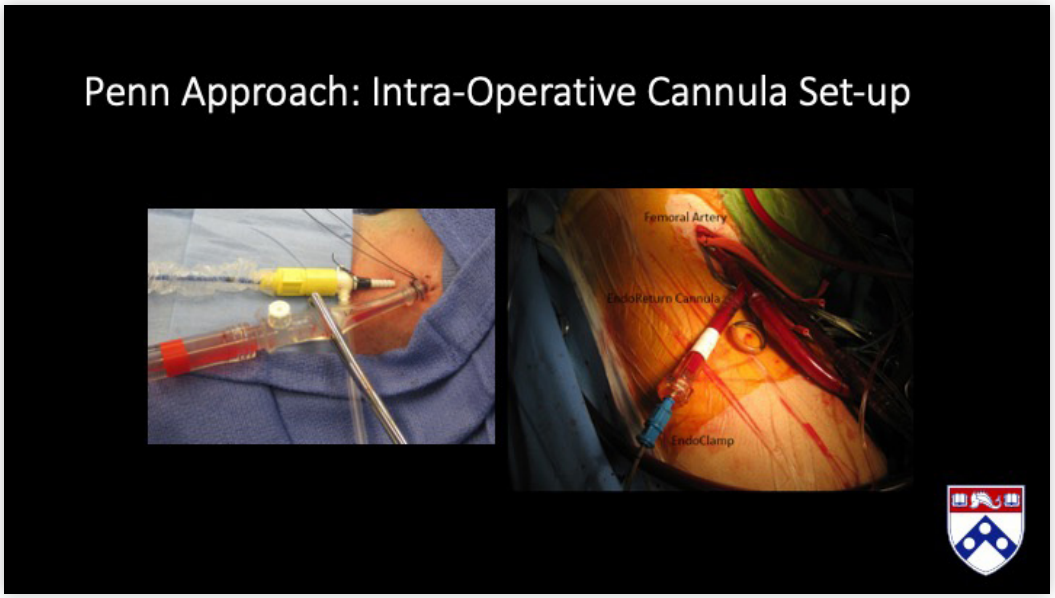


Then a heart catheterization, and it gives us really to pieces of information when you get the heart catheterization. One is really knowing where the coronary arteries are relative to the valve and then the second is to make sure that there's no heart disease.

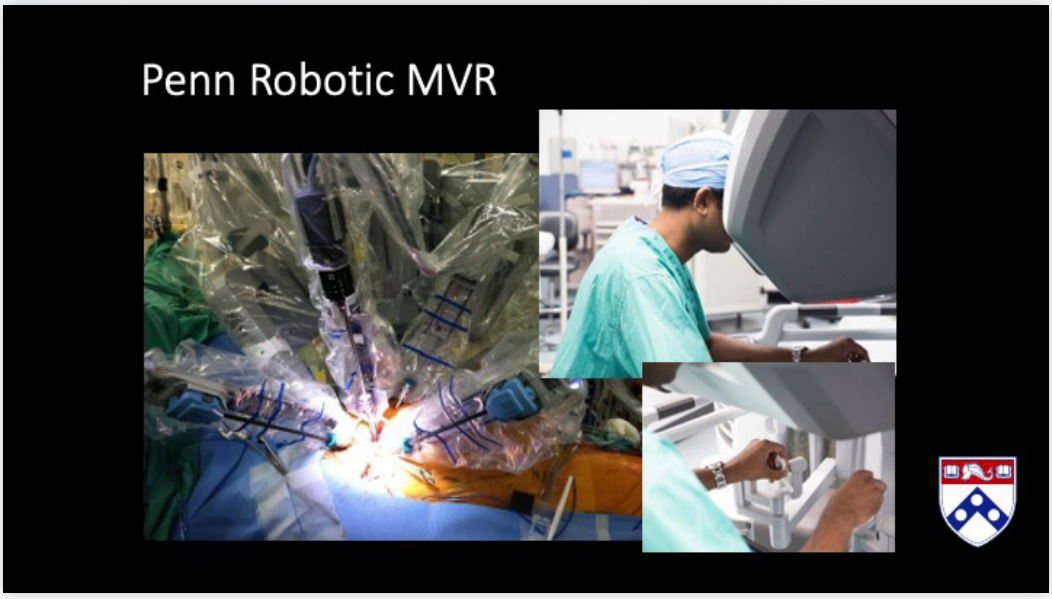
This is just an example of the CAT scan. You can see the aorta is the bright white blood vessel. This is the blood vessel that we utilize in minimally invasive approaches to make sure that the blood flows to the body and that we're able to safely keep the body with good blood flow during the operation. The CAT scan gives us a lot of information to make sure that when we reserve the blood flow going up to the heart, that we're able to do this very safely and protect the patient and all their organs.

This is a pectus patient. Depending on how bad this is, this can sometimes pose an issue. Some of these patients, we've even had to repair the pectus where the heart is basically touching the left chest on the other side. In those situations, sometimes we've had thoracic surgeons come in and actually repair the pectus, restore the chest anatomy. A lot of that is cosmetic, but sometimes something that they want to do, but a really bad pectus can pose visualization issues.

Penn Medicine Robotic Approach



Dr. Pavan Atluri: This is my approach. I think Mike's approach is very similar. We put two I.V.s in the neck. One is to measure pressures from the heart. The other is for the heart lung machine. Then we put cannula in the groin. One is to drain the blood, the vena cannula. One is to return blood, that's the arterial cannula. The majority of our patients, we use an endo-aortic balloon which allows us to further keep incisions small, keep the field clean.

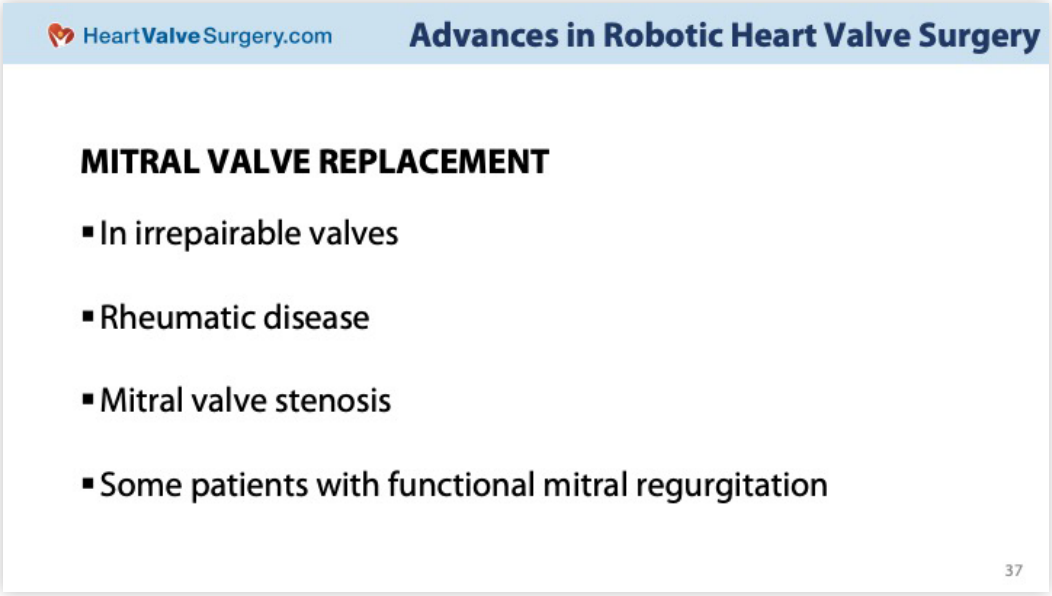


That balloon goes in and it basically blows up inside the heart and separates blood flow from the heart to the body. This is a patient who's been docked for robot. You see pictures of me at the console there. This is pretty standard robotics set up.

Patient Incision Healing

Dr. Pavan Atluri: These are several of my patients that have recovered through the years. You see that they heal pretty nicely.

Mitral Valve Replacement



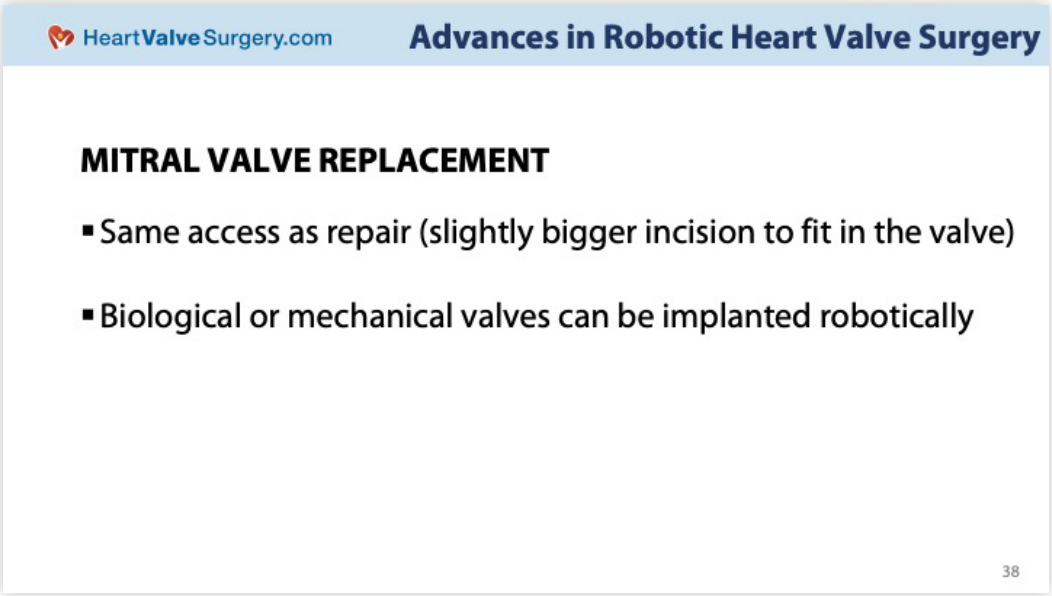
Dr. Michael Ibrahim: I think Pavan hit a lot of the different important points about the way that we approach this. For almost all patients with degenerative mitral valve disease, we are looking to repair the valve. I think for most patients, that's going to be the case with a 90% chance, but there are also patients who need a mitral valve replacement. We can also do that robotically. Just to hit a couple of little things that I've seen crop up in the questions, if you have a previous mitral valve repair that's failing, it can either be re-repaired or replaced robotically.

Repeat operations are not a problem. I do that routinely. We've pushed the limits on what we think is safe and suitable for a robotic candidate based on the development of techniques. Our results are outstanding. In terms of strokes and things like that, very, very low rates of stroke.

Anyway, who do we think about mitral valve replacement before we think about valves that cannot be repaired, either there's not enough tissue, there are lesions that are not repairable, there is extensive damage, infection, other things that can't be repaired.

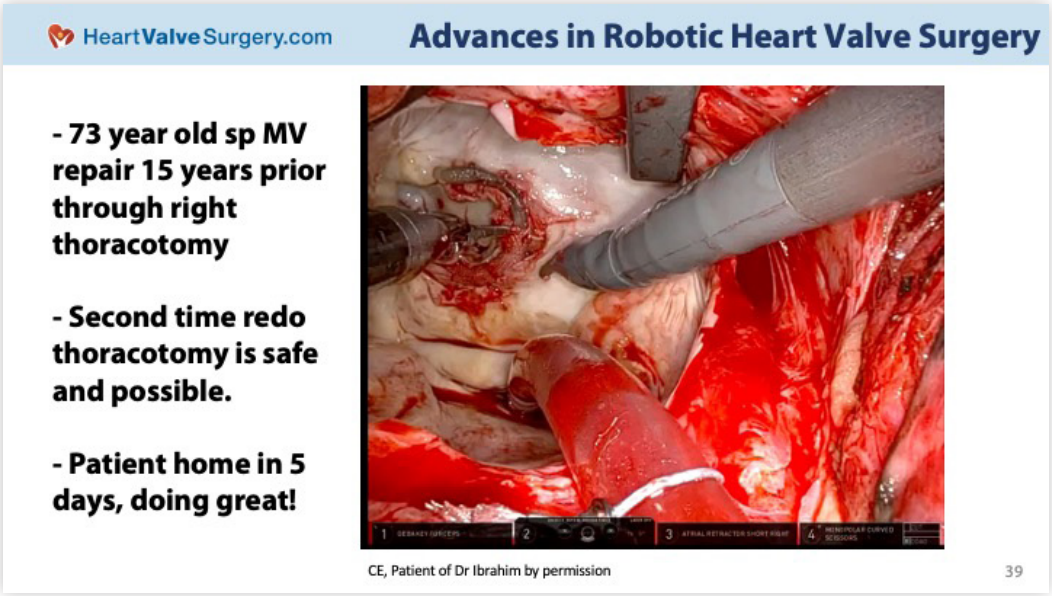
Rheumatic disease where the valve is very scarred down, often those are very difficult to repair. Often they have additional mitral valve stenosis where the problem is not just that the valve is leaking but it's also not opening very well. That is a situation where we would consider mitral valve replacement.

Then, some patients who have functional mitral regurgitation who either have failed medical therapy or have other therapies like mitral clips and other things that are now looking into any mitral valve replacement.

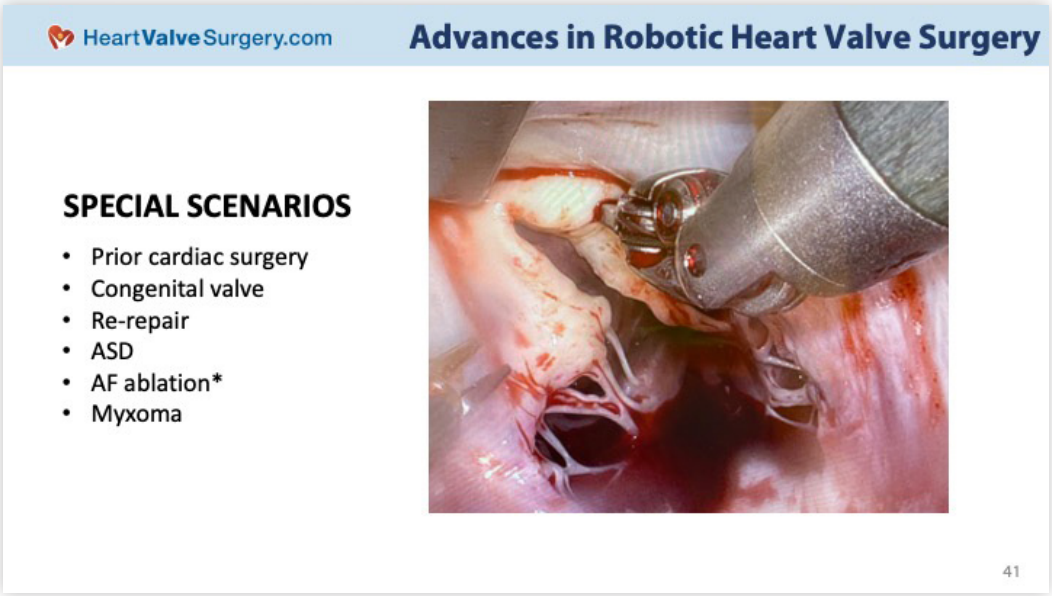


Mitral valve replacement is the same basic setup as myself and Pavan showed you. Slightly bigger incision because you have to fit an actual valve in there. We can do mechanical or biological valves. I've done these robotically, both of these.

Robotic Special Scenarios



Dr. Michael Ibrahim: We can re-repair valves, something that I've also done robotically. We've fixed other cardiac problems, holes in the heart like atrial septal defect, or ASDs. I've also done ventricular septal defects, VSDs, robotically when they are appropriate.

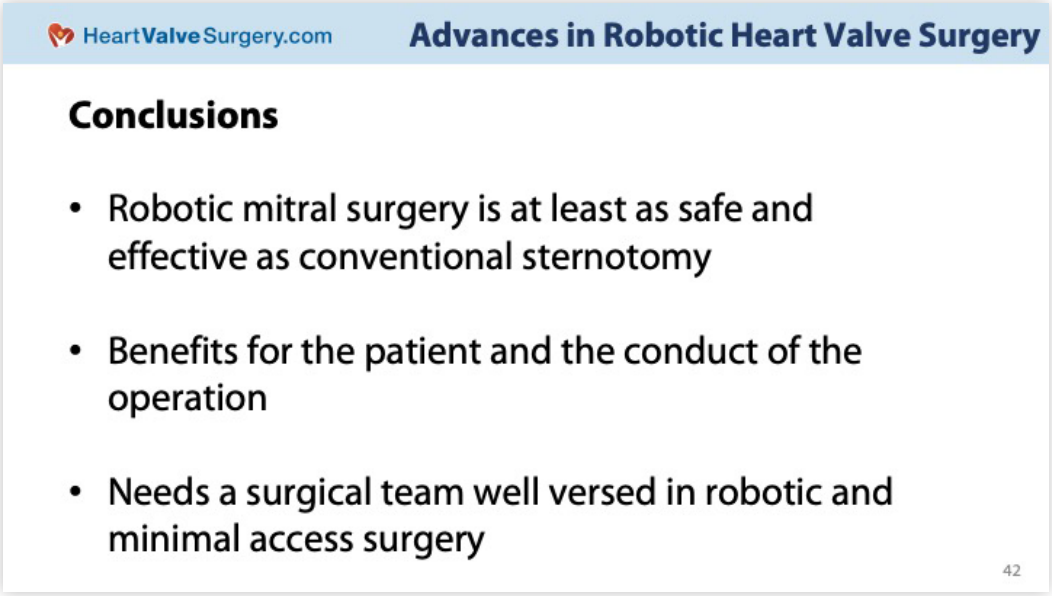


One of the most important things is that a lot of the patients who have mitral valve disease also have atrial fibrillation.

A commitment that we make here at Penn Medicine is that no patient is going to be under-treated by a robotic approach. We do full atrial fibrillation ablations, mazes, and closure of the left atrial appendage to reduce the stroke risk after surgery robotically. That's something that is very important. Also myxomas and tumors of the heart can be approached robotically also and other valve operations.

Aortic valve operations are something that we're starting to do robotically, but that's a little bit less developed than mitral valve surgery for sure.

Conclusions



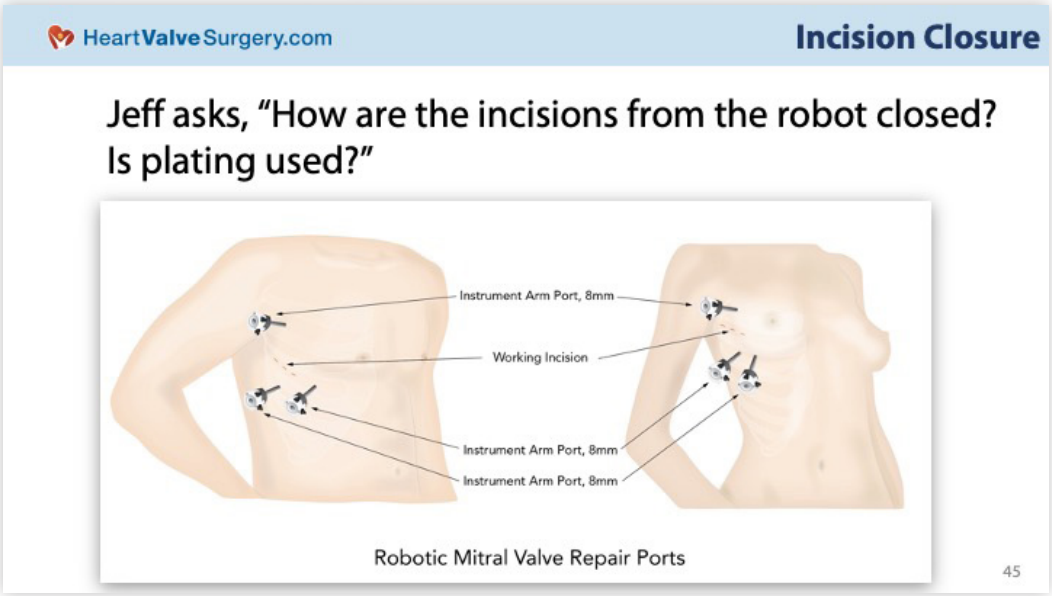
Dr. Michael Ibrahim: I think we just wanted to wrap up here and open up for questions. I think with time we're a little bit behind but not too bad. Robotic mitral and cardiac surgery is at least as safe and effective as conventional surgery for the right patient. There are benefits for the patient and for the conduct of the operation getting excellent valve result. You need a surgical team that is well versed in robotic and minimal access surgery and mitral valve surgery in general. As we mentioned, the median number of – average number of mitral valves done by most heart surgeons in the country is three, three to five. That's what I'm doing in a week sometimes. That is the most important thing. Also, very specifically what is the experience with robotics, what is the development of the program, what are the results.

Questions & Answers

Adam Pick: Thank you so much, Dr. Ibrahim and Dr. Atluri, for the prepared remarks. That was fascinating. I know I learned a lot. I'm sure your presentation has caused many patients on the line to think and question some of what we've learned today. So, let's get to some of the questions here.

Adam Pick: Kelly asks, "I've heard that robotics require longer times on the heart lung machine. Is that true? Can that lead to pumphead?"

Dr. Michael Ibrahim: It's a good question. I think it depends. For a straightforward mitral valve repair, my time on the heart lung machine is not very different between a sternotomy and a robotic approach. That part was not true in the earlier experience but I think it's gotten substantially the same, to be honest. I think that we're so safe and meticulous with the use of the heart lung machine and the degree of monitoring that it really is not a big deal for most patients.

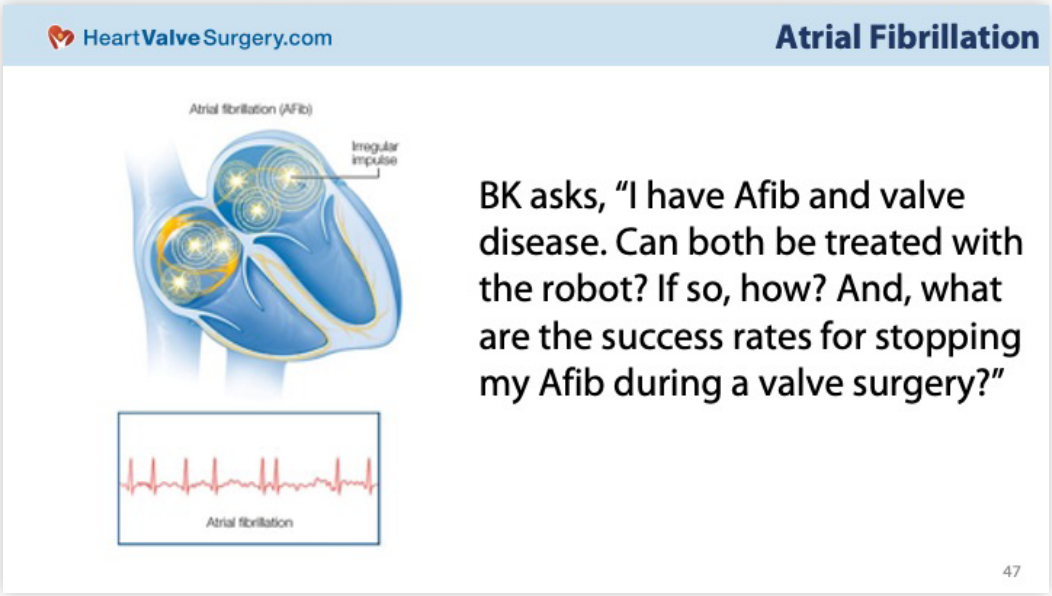


Adam Pick: Jeff asks, "How are the incisions from the robot closed? Is plating used?"

Dr. Pavan Atluri: No, it's sutured, very easy to close. They're very small incisions. Plating is really just for bone and we're not bringing the rib back again. We want to leave them in the orientation.

Adam Pick: Great, let's move over to Shirley's question. I think I heard you, Dr. Atluri, talk about ERAS protocols. She asked, "Do patients that have robotic valve surgery follow the ERAS protocol?"

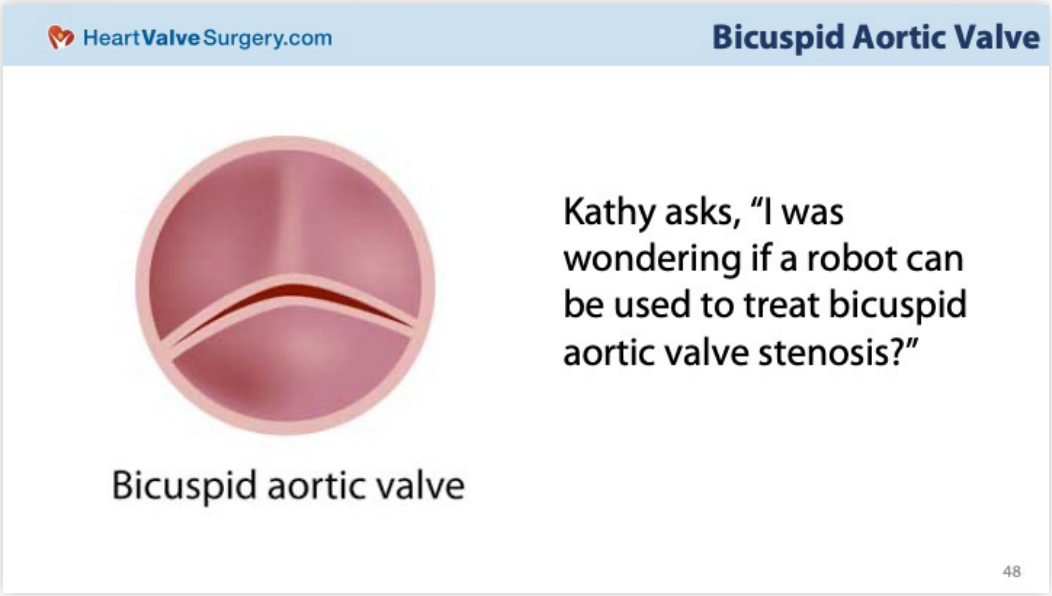
Dr. Pavan Atluri: The protocol is utilized – it's got multiple facets including how they're hydrated, not a whole cocktail of non-narcotic medications that are utilized and then we do nerve blocks in addition to provide temporary relief on top of that. It's really a protocol to help minimize pain as well as minimize or eliminate narcotic use.



Adam Pick: Let's move on to BK who I think you just referenced this, Dr. Ibrahim. BK says, "I have afib and valve disease. Can both be treated. If so, how? What are the success rates for stopping my afib during a valve surgery?"

Dr. Michael Ibrahim: Great question. Absolutely, in fact, just earlier today, I did a mitral valve repair with an ablation. I did exactly the same ablation as I would've done through a sternotomy. I closed the appendage of the heart, which is very important because it's a little sac that sits there. In atrial fibrillation, the top chamber of the heart is no longer beating and moving blood through but fibrillating it and so it allows blood to sit there and settles in this basket that can form clots and they can lead to strokes. We know that closure of that sac substantially reduces the stroke. We're able to do that robotically at the time of mitral valve surgery with absolutely the same results as you would through a conventional sternotomy.

Dr. Pavan Atluri: There's data out there that's very strong. The closure of that appendage may actually be one of the most important things that we do. It's critical that that is managed.



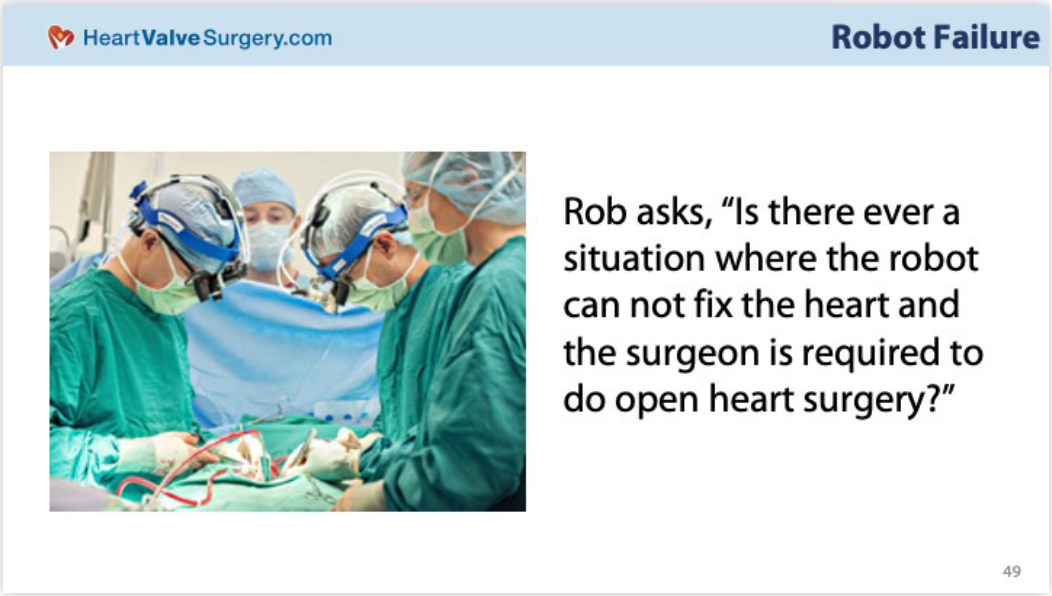
Adam Pick: Kathy asks, "I was wondering if a robot can be used to treat bicuspid aortic valve stenosis?"

Dr. Michael Ibrahim: Yeah, so it is being used for that. It is something that is in development right now. It depends. Again, I think with things like this, and it's interesting that the patient is specifically asking about bicuspid and most of the bicuspid patients, as you know, are young. The incision is secondary to the operation. I get patients who come and see me with bicuspid valves at 40 years old. I always tell them, listen, you should think about Ross because the valve disease management, whether that's a mitral valve repair, whether it's a Ross versus a mechanical valve, whether it's – it's really much more important than the approach that we use for it.

I think that's the discussion that needs to be had around that. Is it possible? Yeah, a lot of the things that are technically possible, but it doesn't necessarily mean that's the best thing for you, just as if you're 30 or 40 years old, sure, you could have a TAVR valve. That would work, but it may not be the best thing for you in the sense that it may not restore your life survival and your life

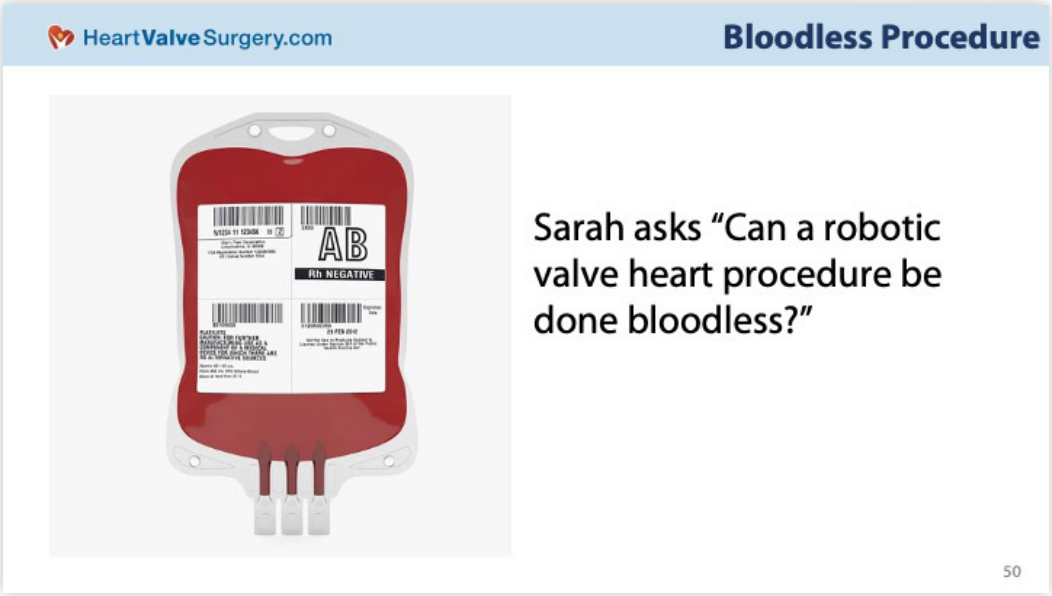
expectancy to normal.

Dr. Pavan Atluri: I think that's very much in debate, Adam. It's something in development, but what Mike said is critical, which is to consider alternate strategies, which is the Ross has been huge. I would just leave it at in development, but make sure, again, that you think about all options when you meet with your surgeon that all options are discussed.



Adam Pick: I think you have already addressed this question, Dr. Ibrahim, in terms of converting if there's an issue with the robot, there's an issue with the procedure, we're going to skip this one unless I missed what you said. You can convert over to an open-heart procedure.

Dr. Michael Ibrahim: Yeah, absolutely, if needed. Those rates are very low, but if needed, absolutely.



Adam Pick: I think you also said for patients who might be Jehovah's Witness, cannot have blood products, this can be done using a bloodless procedure, correct?

Dr. Michael Ibrahim: Yes.

Adam Pick: We've got several questions about recovery timelines. The big three were, "When can I exercise? When can I drive? When can I go back to work?"

Dr. Michael Ibrahim: Yeah, so I actually just looked this up for my – we're writing up a series that compares different approaches because I think this – I get asked this a lot. Within two weeks, 85% of the robotics patients are driving, which means that they're no longer taking opioids. They're able to safely operate their care. They feel like they're able to get up and about. That is more like four weeks for some of the other approaches, conventional surgical approaches. I think there is a benefit there in terms of getting people back up. I think this is really one of the big selling points for minimally invasive surgery.

Dr. Pavan Atluri: Yeah, I think two weeks is the magic number. I just tell my patients two weeks just to be on the safe side.

Adam Pick: On behalf of our entire community, I want to take a minute and thank Dr. Ibrahim and Dr. Atluri from Penn Medicine Heart and Vascular Center for taking the time to put together this wonderful educational presentation, participate in the Q&A and just be wonderful members of our community.

Thank you so much, Dr. Atluri and Dr. Ibrahim!

HeartValveSurgery.com Resources for Patients

Since 2006, HeartValveSurgery.com has developed several resources to help you better understand your diagnosis, your treatment options and your recovery.

Listed below, please find resources created exclusively for patients and caregivers. We hope they educate and empower you.

- Adam's Free Patient eBooks - Download 10+ free eBooks about heart valve disease and treatment options for aortic, mitral, pulmonary and tricuspid valves.
- Heart Valve Learning Center - Visit the Heart Valve Learning Center to access over 1,000 pages of educational information about valvular disorders.
- Patient Community - Meet people just like you in our patient community. There's nothing better than connecting and learning from patients who are sharing their stories in our community.
- Surgeon Finder - Find and research patient-recommended heart surgeons that specialize in heart valve repair and heart valve replacement procedures.
- Heart Hospitals - Learn about medical centers that have dedicated teams and resources that specialize in heart valve therapy.
- Adam's Heart Valve Blog - Get the latest medical news and patient updates from our award-winning blog.
- Educational Videos - Watch over 100 educational videos filmed by the HeartValveSurgery.com film crew about heart valve surgery.