[MUSIC PLAYING]

CARL SNYDERMAN: Dr. Gardner and I are going to take you for an odyssey through the nose. Thank you for joining us today. I do want to warn you that there are some graphic images in this presentation. So I hope that not too upsetting for you. But it's a very exciting area of surgery, and I think you'll enjoy this presentation.

So first question always is what is skull base surgery? It's really in a difficult to reach area. It used to be a no man's land, sort of between the brain, the domain of the neurosurgeon, and the facial structures, the domain of the otolaryngologist or head/neck surgeon. So this is an example from the Bodies Exhibit showing a plastinated specimen, but show you that it's a very difficult to reach place, a lot of critical structures that are in the way, and a lot of the work has been on trying to find the least morbid ways to get there.

As this graphic shows, skull based surgery is at the nexus of the disciplines of neurosurgery and otolaryngology. And that's always a most exciting place to be. That's where the innovation takes place. That's where we're always pushing the boundaries. And so we really learn from each other. We, together, we can do things that neither specialty could do alone.

There's been an evolution of skull based surgery over the years. Back in the beginning, we had the early pioneers that were back in the 60s and 70s that were just trying, doing the first open skull based surgeries. And then, sort of the birth of modern open skull based surgery occurred in the 1980s when I was finishing my training. And I was very fortunate to be graduating at the time that we started the Skull Base Center at the University of Pittsburgh.

And Pittsburgh had the first skull base center in all of North America, established back in 1987. We're almost ready to celebrate our 35th anniversary. And over the years, I'm the only constant factor of all these people, but there I am during my fellowship, and then here I am, a recreation of the picture in more recent years. After this era of open skull base surgery, there was the introduction of advanced radiation therapy techniques called radiosurgery.

And then there was another paradigm shift where we introduced endoscopes and started doing minimally invasive or minimal access surgical approaches to the skull base. And now in this most modern era, we've adopted a multi-port approach where we may combine both open and endoscopic approaches to devise the best approach for the patient.

I think we're very grateful to the visionaries that recognize the potential here. Going back to Eugene Myers, emeritus chair of the Department of Otolaryngology, and Joe Maroon, a renowned neurosurgeon. And the two of them partnered, and based on what they were reading about in the literature, decided to perform the first skull base surgery at the University of Pittsburgh Medical Center.

And this is an actual photograph of that patient with a recurrent cancer involving the tissues of the nose and the skull base. And here is a model or moulage showing the defect that they created. So this is how they took this tumor out. And then they had Mr. [INAUDIBLE] create a plastic replacement for those superficial structures. And this patient lived for many years, with good function, with this surgery.

By today's standards, this is certainly a very crude surgery, but it gives you an idea of how far we've actually come. There have been a number of people over the years who have made contributions. Most notably, Victor Schramm from otolaryngology, Ivo Janecka here from otolaryngology and Laligam Sekhar from neurosurgery. But from the beginning, this has been a team enterprise with the involvement of lots of different specialties including radiology, pathology and other surgical specialties.

Just to give you an idea of what it was like when we got started doing open skull base surgery, we did not have MRI scans yet. We had very crude first-generation CT scans, and you can see that they don't provide much detail regarding the soft tissues. We didn't have navigation systems. Our magnification consisted of the microscope. And in order to take bone out to cut off the skull, we had to make a little burr holes and use what's called a Gigli saw. And this is basically a piece of barbed wire that you sort of slide back and forth across the bone to make your bone cut. So very crude, but that was state of the art in the 1980s.

Some of the big advances at that time were doing the open approaches from above. Traditionally, to gain access to the skull base here, you have to pull back on the brain. And so that's bad for the brain. And we devised techniques where we could take off more bone and minimize the amount of brain retraction, as shown here. The other major advance was what's called a craniofacial disassembly. We can take off not only cranial bone, but the bones of the facial skeleton. And this shows you how much bone we could take off, and that gives us direct access to the area of the pathology without manipulating key structures, such as the brain, major vessels and nerves.

And then Ivo Janecka devised a new transfacial approach. I know this looks horrendous, but once you put these flaps back in place you can hardly tell the patient had a surgery. But this gave us unparalleled access to the skull base, allowed us to take out huge tumors that previously would be considered inoperable. In the 1990s, we saw the introduction of radiosurgery. Dade Lunsford, a former chair of the Department of Neurosurgery was the first in North America to use this novel technology, and really revolutionized the non-surgical management of patients. And this is still in active use for the treatment of certain pathologies.

At the same time, a partnership between neurosurgery with Dr. Joe and Dr. Carrau and myself developed the first endoscopic pituitary surgeries of finally applying a new technology to have a less invasive approach to tumors. So this was a major paradigm shift in all of surgery, across all the surgical disciplines. This really started with urological surgery doing endoscopic surgery, but quickly progressed across the different surgical disciplines; you know, laparoscopic cholecystectomy, taking gallbladders out, and then endoscopic sinus surgery, as shown here within our specialty.

And then neurosurgery was actually the last specialty to embrace endoscopic techniques, and that revolutionized the area of cranial base surgery as well. But if you look back far enough, there's really nothing new in the world. Everything's been done before. And the Egyptians were using an endonasal approach to the skull base way back in 3,000 BC. This is an actual recreation of the technique they used to mummify people.

So we use the same approach. These bones are very thin. We have a natural corridor through the nose that gives us access to the skull base underneath the brain. Of one of the most common operations that we do is pituitary surgery. This is the most common skull base tumor. Here is an enlarged pituitary tumor that's replaced the pituitary gland or compressed it. And so we can come in through this natural corridor, through the nose, to gain access. And here's the patient early post scan showing complete removal.

With the traditional microscopic approach, you can see you don't have a very good view. You see a very small area of the skull base. This is the exposed pituitary gland. And so we're working down a long, narrow corridor. In contrast, once you put an endoscope in there, it really opens things up for you. And so now we have a huge panoramic view. We can see all these structures.

We can look around corners with angled endoscopes. And so it's really unparalleled visualization of the anatomical structures. In the 2000s, we really branched out from pituitary surgery adapting these techniques to other areas of the skull base, in both sagittal and coronal planes. So working in a midline corridor from the forehead down to the spine, and then working out across the floor of the skull base and all the different areas. That effort was led by Dr. Carrau and myself from ENT, and Dr. Amin Kassam from neurosurgery.

But this was quite upsetting to the status quo, as you can imagine. And for the first few years where we were developing our expertise, we didn't really share our results. We wanted to have enough experience that people would accept this novel approach. And it's the same in every discipline. Every time there is a paradigm shift, there are the early adopters and the late adopters, and there's a gradual acceptance of techniques until most everybody is using it.

There was a lot of resistance. I compare this to the five steps of the grieving process that the famous Swiss physician, Elizabeth Kübler-Ross developed, for patients with a fatal disease. They go through the steps of denial, anger, bargaining, depression, and acceptance. And so initially people said, you can't do that. It's impossible, or you're crazy. You shouldn't be doing it. But then they started to see that we were making it work and they asked, well can you show me how to do it? Can we come take your course? And then they realize it's not as easy as it looks, but with enough experience, everybody can get to a point where they can say, I can do it.

And just very briefly, I want to highlight some of the concepts of going through the nose to approach brain tumors. How is this different than a traditional approach? A traditional approach is like eating an ice cream cone. You start out with a very wide exposure, and as you get deeper into the head your corridor gets more narrow. And so you may end up with a very small working space once you get to the pathology.

In contrast, we're using an inside out approach with the nasal techniques. And so it's like the beam of a flashlight. It starts at a small focal point and then branches out from there. The big advantage is that we're not moving structures to get there. So it's really no brain, no touch brain surgery. We're not lifting the brain to get there. We're not moving arteries and nerves out of the way.

The way we take tissues out is also different. It's often taking it out in small pieces. We have the ability to work around corners. And the most novel thing is we really introduced a concept of simultaneous team surgery. I can't think of any other surgical discipline where two teams of surgeons work hand-in-hand throughout the majority of the surgery. And reconstruction is also different. Instead of having these big open approaches with big flaps, we developed small flaps inside the nose that we can use for reconstruction.

And that certainly has been one of the biggest challenges of this surgery, but It's a challenge that we have solved. Within endoscopic surgery, there's been a similar evolution of techniques. We started out with the most basic endoscopic surgery, starting with pituitaries, and then we expanded out to the area around the pituitary gland, and then worked up and down this corridor in the middle of the skull base, and then started working out laterally across those corridors.

Over the last decade, I think we've really pushed endonasal surgery to the limits using a multiport surgery, combining approaches. Juan Fernandez-Miranda was another addition to our group in neurosurgery. And now our current group includes the addition, not only of Dr. Eric Wang, but George Zenonos from neurosurgery. There are several stages of development that we've gone through. Initially we had to show that this was feasible. We had to relearn the anatomy, develop new instruments and techniques.

The second stage was to show that this can be done safely, and we've done that. But in the final stage, which is an ongoing stage, we continue to demonstrate the benefits of the surgery, showing that the outcomes are at least equivalent, if not superior, to what we can achieve with traditional open approaches.

PAUL GARDNER: So as Dr. Snyderman mentioned, one of the, there are many tumors that we're able to actually improve our outcomes with by this new approach, which allowed us to access tumors from a whole different corridor because of the visualization of the endoscope and because of working with two surgical teams side-by-side. Here's the example of a tumor called a meningiomas, which is a benign growth, but can cause severe vision loss, even blindness.

A traditional craniotomy would come from above, lift up the brain, and then work around the nerves trying to visualize the tumor. Whereas coming from below, we land through the sinus, directly on the tumor, and you can see here, we have direct access on the tumor so that we don't have to move the nerves, we don't have to move the brain or the arteries, and because of that, all we touch is tumor. So the only thing that is removed or manipulated is the tumor itself.

In addition, you can see here, based on this visualization how beautifully we can see all of the important structures. We can see the pituitary gland here at the bottom of the screen. And this ability to see these structures lets us preserve them better. So if you see it, you can do the same kind of dissection, because we're working with two hands side-by-side, and I can preserve all of these important structures.

In addition, working through the nose with an expert head and neck surgeon like Dr. Snyderman or Dr. Wang, this allows us to preserve the nasal structures and the sinus function. This combination, I think, is critical for doing the surgery in the least invasive way possible. And this concept has really provided this corridor. You see how all we've done here is break this tumor up into pieces, do what we call debulking, and then gently take it away from all of the critical structures, in this case, the optic nerves, the arteries that feed the front part of the brain.

Here we can see the right side and optic nerve and how the tumor is just taken away from it, rather than having to lift the nerve away or blindly peel it off. Here every single maneuver we do is completely visualized. There's nothing blind, and not only that, the roots of this tumor actually come down to the sinus. So by removing the roots of the tumor, we actually get a more complete removal, and so it's less likely to come back.

Here we see a beautiful view at the end where you see the optic nerves coming back to where they meet the brain. You can see the arteries feeding the front part of the brain, and we can see the pituitary stalk, all of it perfectly preserved, in addition to all these tiny blood vessels that feed these structures, which also have to be preserved. This is just showing some of that reconstruction that Dr. Snyderman discussed, that he was one of the key people in developing and implementing.

One of, just one of the advances that we've had. It turns out that over the years, by studying outcomes of all our surgeries, studying the patients before and after surgery, very carefully looking at every aspect of it from vision to how nerves function to any risks around the time of surgery, we found that it's better for a whole variety of different tumors that come to the skull base. And this has allowed us to revolutionize the field.

And this has been through two things. Both from the innovation of actually developing these surgeries, which requires research of its own, but then also studying our outcomes. That helps us be better surgeons. It also helps us understand where these surgeries are good and where they're better than other surgeries and where they maybe aren't. I think one of the real questions that we are trying to constantly understand and expand is what really are the limits of endoscopic, endonasal surgery.

And one example is, in the past this would have been considered an inoperable or unremovable chordoma, certainly from an endonasal approach, just because of the size of the tumor. In here, you can see in the bottom corner, this is showing our own learning curve that we studied very carefully, showing that how over time, we got better and better at getting the most complete resection, to now being at the point where about 90% of the time, we get a complete resection of chordomas, which is really probably incomparable.

Here's another case that many people probably rightly would not approach endonasally, but because of our experience and our work in understanding the anatomy, we're able to treat this very large aneurysm. This was actually a physician who had his eye closed from pressure and a palsy of the nerve that opens and moves his left eye. So here we're opening the lining of the brain.

So this is really the most extreme kind of thing because we're dealing with blood vessels, which is everyone's greatest fear during surgery, is not having control over blood vessels. And certainly working at a depth, there's concern for people that this is not something that can be done safely. But I can do all of the same things that I can do with an open surgery because of this team approach, because of techniques and instruments we've developed, and again, we're constantly trying to advance this surgery, working with companies to come up with clips that can be used in the nose and can work safely.

But here you can see this very large aneurysm. These are normal blood vessels feeding the brain that we have to preserve. Here's the nerve being absolutely crushed by this aneurysm, right there. And this is the normal brain stem. So here we're doing what's called trapping the aneurysm where we very briefly put the person into a chemical coma for literally only 10 or 15 minutes. We block off blood flow for less than five minutes by placing these clips across the blood flow into the aneurysm, and that allows us to soften this giant aneurysm, which otherwise may be too strong to even put a clip across.

And then we can put a clip across it, and you can see how immediately this nerve is decompressed. So there's the first clip, and I'll fast forward this in the interest of time, but we place other clips across it, and then eventually we have a complete control of the aneurysm. And there are many aspects that lead to limitations, but we've always believed very strongly in surgical innovation. And the saying that we go by is that, if you always do what you always did, you'll always get what you always got. And that's a famous quote from Albert Einstein, but it really fits here.

And there are two schools in surgery a lot of times where people try to just do the same thing and make sure they always do it the same way for their entire career, but the truth is that's not how surgery advances and that's not how we improve ourselves. One of the approaches that we recently came up with through the ingenuity of Dr. Snyderman is the contralateral transmaxillary approach. Paul?

CARL SNYDERMAN: Yeah, so this is applying sort of old approaches in a new way. [ECHO] So this is applying an old approach in a new way. We just figured out that by coming through the cheek sinus on the opposite side, coming in through the mouth and making a window through that sinus, it gave us an angle of approach that allowed us to get to areas that we simply couldn't get to before, and also to perform a safer surgery.

So the area that we're talking about is behind the main artery that goes to the brain, the internal carotid artery. And so if there's a tumor in this area, it's very difficult to dissect around the artery to get to that area. And this picture shows how coming through the nose, we only have this much access. By coming through the cheek sinus, we can expand our access all the way out to here, and this gives us not only a better angle for approach to the artery, but also we can reach further along the skull base. So it allows us to work back into areas that we simply couldn't get to safely in the past.

[VIDEO PLAYING]

- This is a case of a combined endoscopic/ endonasal and endoscopic in the posterior septal mucosa onto the--

[END VIDEO]

CARL SNYDERMAN: So I'm just going to skip forward just to show you a highlight of this approach, how we can get all the way back behind the carotid artery, taking this tumor out, and now we're dissecting right on that artery.

[SIDE CONVERSATION]

OK. I'm sorry. I'm going to back this up a second, just because I-- there's something good to show you here. So this is going to demonstrate how we apply this approach in a patient with a large tumor. So on the scan now you can start to see the tumor. Here we've done a graphic representation of where the tumor's located. And you can see it's tucked behind that artery. And then coming in through the front wall of that cheek sinus, through the mouth, it puts us in perfect alignment with that tumor.

So let me just, once again, skip ahead just to show the last parts of the operation taking that tumor out. This shows you where we're actually able to reach. So this is a navigation system showing us, and so we're right along those arteries. And then the reconstruction at the end.

PAUL GARDNER: One of the more recent things that we have been very fortunate to be able to work on is a new treatment, actually, for intractable seizures. There's a treatment where we remove the innermost part of the temporal lobe, which is the part of the brain which is just deep to your temple here. And a standard surgery does a craniotomy to open that and removes the outer parts of the temporal lobe, which are not affected and actually don't need to be removed.

And I've always thought that if we go under the lip and use these same kind of techniques, we could possibly remove that area. But how do you do that safely? How do you start to use a new technique? So, once again we combined expertise that we have here at UPMC. And working with Dr. Gonzales-Martinez, who is an epilepsy expert, one of the experts really in the world of epilepsy surgery. We went to the cadaver lab and working in our anatomy lab, we dissected different ways to try to get to that area in the least invasive, most direct way possible, that involved not touching any part of the brain that wasn't involved.

We then took that technique and brought it into the operating room. You can see here, our team, which has now added Dr. Martinez, and we're working all together side-by-side. Dr. Snyderman and I worked through the skull base, Dr. Martinez takes out the area that's causing the seizure, and when we're done we've virtually left the area untouched. Here's an example of the very first surgery done this way, what's called the Pittsburgh Seizure Surgery or Sublabial Pittsburgh Endoscopic Temporal Lobectomy.

And here, you can see and this particular patient, they were ideal, because actually they had two problems. They were leaking spinal fluid from the base of the skull from an abnormal defect, and they had seizures in the area close to it. So using that, we thought this was a perfect person to be able to combine our techniques and be able to treat two problems at once. And here you can see that area in the back where there's actually a little bit of brain and spinal fluid that's coming through.

And then this is Dr. Snyderman doing the initial exposure. And here is that small opening under the lip. A completely hidden incision, and really a very small opening that's made there. And just working through that opening and working partially through the nose allows us to have complete access to this part of the brain that is the most common location in the brain to cause seizures. I think for any of us who have dealt with family members or loved ones who have seizures, we understand the impact of not only the seizures, but the medications.

At the same time, we don't want our surgery to affect brain that's not affected by the seizures. And this is, in my opinion, the most selective way that we can do this, because it's a direct approach right onto that area of the base of the skull. Now I'm going to skip right ahead. And here you can see some of the nerves that we have to be aware of and work around in order to get to this area. And then finally, here we are working, removing the part of the brain that's causing the seizures. This is Dr. Martinez now doing this portion.

And this is an area called the hippocampus, which is the critical part that causes seizures. We follow this area called the hippocampus all the way back into the brain, removing only that part that is the only part that's affected and the only part that's causing the seizures. And when we're done, we've been able to completely remove that without affecting any other areas of the brain. And then once we're done, we then place some grafts in place, maybe a little bit of fat from the belly, and one of these flaps that Dr. Snyderman helped develop, which is a living flap from inside the nose.

And when we're done, it's almost as though we hadn't been there once it's all healed up. So this is one of our most recent innovations. And here you see another patient who didn't have a defect at the base of the skull. And now we've started to use this routinely, something we'll be reporting in the literature soon. Again, I'm sure this will also be controversial.

Education and training is also a very important part of what we do. Dr. Snyderman, would you like to talk a little more about our skull base course and other educational efforts?

CARL SNYDERMAN: Well one of the first things we did was establish a standardized training program for surgeons learning how to operate through the nose. And so that's been accepted in the literature and has been widely adopted. We regularly teach courses on site here in Pittsburgh, except for this last year where we took a vacation from that. But we typically will get people from at least 20 to 30 countries around the world, and have trained probably 1,500 or more surgeons over the years in doing these techniques.

We also established a global, free educational website that really addresses all aspects of this surgery. And we have over 1,200 members on that website currently. Another innovative technique we've done, and really it's been a model for other surgeons, is surgical tele-mentoring. And that's where we work remotely. Here we are working with a team from Maribor, Slovenia, and while they are doing their surgery, we are watching it on a big screen.

And we can give them advice on how to do things better, things to avoid, different techniques to use. We're not doing this surgery, but we're consultants. It's like we're standing behind their shoulder giving them advice during a surgery.

PAUL GARDNER: Yeah, our goal is to spread the surgery, and one of the questions I saw in the Q&A is how prevalent has this become. And I would say there probably are very few countries now in the world that aren't doing this surgery, and it's become really the standard of care for many tumors, and I would like to think this is in large part because of a lot of our efforts. So this has become, Dr. Snyderman, I think you might agree, probably one of the standards of care for skull base surgery, and any skull base center should be using these techniques.

CARL SNYDERMAN: We've also established fellowships for training in both specialties. We also have a very active international program where surgeons from around the world come to spend several months watching us operate. And we also have international fellows that go into the laboratory and do anatomical research for a year, not only learning the anatomy, but developing new surgical approaches.

One of the things that's key here is spending a lot of time in the lab training and developing these skills. And so we're in the process of developing a state of the art surgical simulation lab, because techniques, training techniques have changed over the years. We have developed these mobile dissection carts so we can have a most versatile working space. We're currently redesigning the lab.

Not only will we have anatomical dissection using human cadavers, but we have task trainers, or sort of black box exercises, to teach specific skills. We can permanently preserve specimens for teaching anatomy. We can do 3D printing, where we create models of patients, such as you see here. And these are useful not only for planning of surgery but for practicing. We have team simulation exercises. Here we are teaching surgeons how to manage a carotid artery injury.

And then we're also doing some scientific investigations of surgical cognition. Really trying to understand how do surgeons learn, are there improved methods for teaching that we can develop based on those learnings? We're involved in a number of research activities. Just a short list of them here, and I'm going to have Dr. Gardner talk some more about those.

PAUL GARDNER: So these are many of the areas that we are currently have ongoing and active research and-- [ECHO] these are many areas that we have ongoing and active research in, and I'll talk a little more in detail about just a handful of them. But I think what you'll see here is that we really try to constantly work in every aspect of care. One of the new and upcoming, exciting areas within all of tumor surgery that has not yet been applied to skull base surgery, except for by ourselves and one or two other centers in the world, is the use of molecular science and genetics to understand skull base tumors better.

We are very fortunate to have a very busy practice here where we see a lot of rare tumors, and we feel an obligation to understand that disease better. And so, for example, this is something called the Pittsburgh Panel, which is something that Dr. Zenonos, who works with me, came up with, which has revolutionized chordoma treatment. And essentially what we've done is, everyone thought all chordomas were the same. They're all extremely aggressive, they all need the most aggressive treatments, including radiation, but we didn't really know when did they need the most aggressive treatment? When did they even need chemotherapy?

And by looking at the genetics, the molecular portion of the tumor, looking at how many mutations it have. So tumors with very few mutations would fall in this group A and have a very good prognosis. With a complete removal, that's probably all they need. And then a small group would also fall in the worst prognosis, because they had a lot of mutations, and we would know we need to do other treatments even beyond surgery and radiation for these. So this has allowed us to really revolutionize. And you can see here these three groups between the blue, green, and orange are really dramatically different in their prognosis

We've also expanded this, not just to looking at the specimen that we can with the pathologist, but actually looking at the entire genetic profile. And this is actually using messenger RNA, which many people now may be familiar with because a lot of the COVID vaccines also use messenger RNA. But this is one of the things your body uses, and tumors also use that make them unique. And so by studying this, we're able to understand the mutations that make chordoma different from the person who has them, and also helps us understand how do those mutations make these tumors act differently.

That can then allow us to not only separate the tumors and treat each person individually differently, but also target each tumor with mutations. So this is some of the most exciting and upcoming work that we're working on. Other clinical research in the last couple of years, or last year rather, we came up with this clinical grading system for another tumor like chordoma, but called chondrosarcoma. If you look at all of these combined again, this is sort of what happens to them over time, the prognosis. But using this grading system that one of our fellows Dr. Venteicher who now is out practicing, came up with along with us, we can break this into dramatically different groups.

Again, deciding how aggressive to be with treatments, including things like radiation. There's a new way that we brought to the US for differentiating tumor from normal using fluorescence endoscopy. Here you can see the normal arteries lighting up very brightly. You couldn't even tell what was tumor and what was normal without this, but with it, we can see very clearly that which part is tumor and which part is artery. And this helps us remove the tumor more completely and avoid any injury to these critical arteries that feed the brain stem.

So these kind of new research that we're doing and new developments, allow us to dramatically improve the quality of our surgery. Dr. Snyderman recently came up with a new way to detect a rare cancer that we treat.

CARL SNYDERMAN: So for patients with certain types of cancers, traditional scanning techniques don't differentiate normal tissues from tumor very well. And so using some new markers that are very specific for these tumor types, we can now detect areas of tumor that we couldn't visualize in the past. And not only does this improve our ability to detect the cancers, but it offers a new modality for treatment. We can now provide targeted radiation therapy just to the areas of the tumor.

PAUL GARDNER: Other areas of clinical research include pediatrics tumors. We are one of the few, if not the only pediatric skull base centers in the country. And a lot of our research involves pediatric skull base tumor outcomes to try to understand how they are different, because they're very different than adult tumors, and how we can treat them better. Some other research that is even ongoing is, and looking forward to, is skull base healing. How do we help patients heal better? There's constant quality of life research that our entire team is working on, and even more recently, of course, making sure that we do safe surgery during COVID, knowing that sometimes this virus resides in the nose. And we've proven this could be done safely, and develop methods to ensure everyone's safety.

There are medical devices that we've worked to develop. Everything from working in our CREATES lab to improve robotics, which is very early stage. One of the things that we're constantly facing when we're bringing in new devices, and especially things like robotics, is the cost of doing this. So to be able to have the device and develop a new technique with it has a tremendous cost. You have to have the space to do it in, you have to have the specimens to work on, you have to have the instruments and be able to purchase the robot. So all of these things are extraordinarily expensive, but they have a huge payoff on the other end, not just for one or two patients, but for many patients, even beyond our own center. Dr. Snyderman, do you want to comment on that?

CARL SNYDERMAN: Just to know, this could be a separate lunchtime lecture in the future perhaps, just talking about how we work with industry and with the engineers as a partnership to develop the technologies that we need. One of the exciting things I hope to talk to you again in the future is about biomimetics, where we learn from nature, and adopt solutions that nature has already developed. And that's a collaboration with the Carnegie Natural History Museum and the engineering schools at both Pitt and CMU.

PAUL GARDNER: There are, of course, costs to research, and this is one of the things that we constantly struggle with. Just simply doing clinical research to show you some of the outcomes that we found and some of the things that we've done to improve patient care by studying our outcomes require collecting data, having database management, which is a never ending task, making sure we have research supplies to both study anatomy as well as new surgical techniques.

We need a space, research facilities to carry this ongoing, statistical analysis. And a research coordinator. Here's a picture of a lovely Benita Valappil who works with us every single day. She makes sure that we track all of our research. She makes sure it's done in a safe fashion. She makes sure that we're compliant with all of patient Information protection, but at the same time collect this valuable information, collect valuable tumor, so that we can learn as much, not only for ourselves and for our patients, but for future patients.

CARL SNYDERMAN: Well it's said that every act of creation is first an act of destruction, and that's basically what we've had to do several times. Really sort of abandon our old ways of thinking and discover new ways of accomplishing things. And that's one of the joys of working in this area, is constant innovation, always looking for a new way of doing things and not getting too fixed in our ideas. There have been a lot of Pittsburgh firsts over the years. Just some of them noted here.

Another first is that we have commissioned some original skull base art. And you see these two lovely paintings by Penny Oliver. She's the wife of one of our former residents, and she has a wonderful website called Diagnosis Art, where she does artwork related to human anatomy. Well what's the next paradigm shift going to be? Where are we headed? Certainly robotics is going to grow and play a bigger role. Virtual reality where we will perhaps be operating using a virtual image rather than looking directly at the patient. And increased functional mapping of the key structures, such as the neural pathways in the brain, so that we can take a circuitous path around these structures and have maximal preservation of function.

Whatever it is, I know it's exciting, and we hope to continue to be on the leading edge of innovation. If you've enjoyed this presentation, I hope that you will subscribe to our skull base newsletter, which comes out quarterly. Our contact information is here, but if you contact the Eye and Ear Foundation, I'm sure they can add to the mailing list in addition to the Eye and Ear Foundation Newsletter. So I hope we haven't overwhelmed you today with all of this work, and we'd be happy to entertain any questions at this time.