Future of Health Technology Symposium

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Salil Patel:
For all of you in the audience this is going to be a low intellectual burden talk so just sit back and enjoy the next few minutes. There's not too much in the way of heavy lifting. So this certainly can be an interactive session, feel free to add any insights, comments, questions, as we go on.

I'd like to begin by asking…I'm sure we have many bright young consumers in the audience, but can anyone tell me what this actually is? It is actually the most successful commercially deployed robotic device in the history of the field, and it is a robot. Anyone have an idea? Exactly, it's a vacuum cleaner. It's the Roomba created by a robot. This has served to introduce robotics to the vast majority of Americans although as we'll soon see robotics have really pervaded an astounding array of applications, not only in industry but also in healthcare and medicine particular.

So if we are going to talk about robots it's going to be helpful to really understand the field that we are going to be traversing. Historically, the term has been very loosely used. One can conceive of a robot as any sort of machine that has some sort of programmable aspect. Today we tend to consider a robot to be any device that has both electrical and mechanical components. Today, I think we tend to think of robots as having not only effectors and sensors, but some degree of autonomy, as well. To give you a bird's eye view of how we can conceive of robots, we can think of robots in ways that are controlled, that is, whether or not they have some degree of independence or whether they are completely directed by some external control whether that be automated or human as well as the ways in which they can function. We'll see a variety of robots that have a human shape and form. That was certainly the first foray into robotics in very ancient times and even today. But I think increasingly we are moving towards a more utilitarian effector-based model of how we conceive of robots, and then in terms of applications and we'll see a variety of those.

If we think of robots autonomized as being a very broad-based field, really the underpinnings of autonoma developed from a dependence on a single programming language to help control these devices. One can reach all the way back to 500 B.C. when Panini, who was a famous grammarian actually developed some very simple rules that really are the precursor to almost every modern programming language.

And through the intervening years there were several attempts at the creation of devices that might be considered robots. We had the first wooden pigeon, there were numerous case reports of a wondrous musical-making set of devices that entertained the Chinese emperors. In 1200 A.D. we see the first autonomous robotic clock, which was pioneered and spearheaded by numerous Arab inventors.

Fast forwarding to the time of da Vinci, we see the advent of the humanoid robot. This robot was never constructed but is being studied today in numerous Italian universities. There has been a proposal to construct a working model of da Vinci's famous humanoid design. It is really remarkable in the degrees of freedom that the limbs allow and is remarkably versatile in terms of its design. The only limitation is that the device as da Vinci conceived it is extremely heavy. It's something like three tons, so unless you build it out of super lightweight aircraft aluminum or something, it's going to be extremely difficult to realize da Vinci's vision.

This is a three-foot tall wooden monk which was created in Germany. This was a favorite pastime of some of the religious figures of the time who are really kind of the academics of their day. This monk actually bows down and prays at regular intervals. It was thought that this was used to help direct prayers and direct the activities of lay people when monks were otherwise indisposed.

In the 1700's, (Inaudible) was an art which developed around the idea of automated puppetry. Today you can see vestiges of that in Vietnam with the underground water puppets which are operated on a crank-based system. In the 1700's we have the evolution of the field to help in instruction. This mechanical bird was fabled to be able to consume food, be able to flap its wings and help budding aviators understand how birds could fly. It was moderately successful in terms of its public popularity. It was definitely an advance in terms of the science.

Moving to the last century, we can see the anime here which was one of the first automated robots and helped General Electric to produce light bulbs in the post-war era, and actually helped catapult General Electric to the top of its industry segment. They were one of the first companies to embrace robotics. Then the academics, particularly at Stanford and out west, helped to expand the use of these devices. One of the first robot controlled arms was later employed in manufacturing processes.

In the 70's we saw the advent of independent navigation with what was essentially a camera-based device that provided some feedback to a glorified cart. It was called the Stanford Cart.

In the 90's we saw probably the low point, the first (inaudible) robot named Choo-Choo, that actually produced its own gas for propulsion. Thankfully, this hasn't become too popular.

To this day we can see that there are numerous devices. This is actually one of the industrial robots that is used in Germany. You can see the articulating arm has many more degrees of freedom than a human hand so we have moved beyond replicating human form and function and begun to use these robots in situations that humans simply could not be employed.

So, robots have not only begun to replace humans but to sort of transcend what they can accomplish. And why is this important and why, in particular, are we focused on the application of these devices in medicine? It is essentially becoming big business so to speak. In terms of government funding there are nearly $300 million which have already been allocated in the last year that statistics were available, which is 2003, and that number has only increased in the interim. In addition, there are numerous bills pending in Congress which from a national security and from a public health aspect are aiming to increase the number of ways in which robots can be employed and deployed. In fact, we, as a nation, spend a relative paucity of our research and development funding in electronics. The EU and Singapore, in particular, are taking the lead in these areas. So this is becoming an international endeavor.

The way that we are going to conceive of medical robotics in this talk is from three major realms. The first is the hospital-based inpatient, as well as the outpatient, setting. The second is in terms of biosecurity; and the third is in terms of basic science aspects. Maybe we are not even aware but robots play a very important role in, not only the medical setting, but also in cellular level work. In particular, robots are instrumental in DNA sequencing work. The completion of the Human Genome Project would not have been possible without the use of hundreds and hundreds of robots that helped to prepare self-samples as well as continue sequencing.

Robots are also now being used in cell culture. This has important implications as we begin with rapid mass scale vaccine development. Many vaccines depend on these, with either egg ova or rat or hamster kidney cells and so forth as a substrate in which we can grow virus. This are relatively labor intensive and layered steps, and through the use of automated devices we have the potential to increase the efficiency and rate of production of vaccines by up to ten or twenty-fold by some estimates. So this can be very important from a public health standpoint. We even now have robots that are able to manipulate single cells. There have been proposals to use them in invitro fertilization to help decrease the level of resulting defective embryos that are produced as a result of manipulation errors.

Now, clinically, where we are seeing a lot of interest and excitement is in the realm of the operating room and the inpatient ward. This all began in the early ‘80’s with the first and very brave use of robots in brain biopsies. Essentially, in a brain biopsy, a patient is placed within the border of the CT scanner. The lesion is vocalized. In the prior era and even today a surgeon or radiologist will take a long catheter and place it within the brain and try to essentially characterize where that lesion is in three dimensions. It is a relatively challenging task. This is also the same which is done for lung biopsies and other sorts of small procedures. The advantage of using a robot is that it already knows what the registration cues are coming from the image dataset so you really only need to make one pass so you can be assured that you are hitting the center of the lesion. And, you greatly increase the yield of a biopsy. For example, if somebody you know has had a breast biopsy, for example, you know it is entirely possible to go through the entire procedure, all the emotional aspects, and a small degree of medical risk as well, only to receive a necrotic tissue which is not able to be characterized pathologically and you have to go back for another procedure. When using something like an automated CT-guided biopsy regime, it dramatically decreases the levels, theoretically, of false-negative biopsies.

In the intervening years, we saw the evolution and application of robots in everything from orthopedic to prostrate surgery. In 2001, the Zeus device, which you see here, was first used to perform the removal of a gallbladder, which is really a landmark event. Essentially, the surgeon was able to use a micro-manipulator arm on both sides along with a couple of screens and direct what is considered a pinhole surgery or laparoscopic surgery. This created a tremendous amount of excitement in the field.

Again, you see the use of robotics in terms of cell culture and PCR. In terms of other inpatient applications, robots have a tremendous role to play and tremendous potential role to play in terms of the dispensation of medications in the inpatient ward. It has been estimated that there are billions and millions of prescriptions written each year. However, we have a tremendous shortage of pharmacists that are skilled and able to fulfill that need. As we know, in the National Accounting and Science Report, to err is human. A significant percentage of medication errors are due to human error and dispensation error. Using a robot such as the Autoscript or the Intellifill system, you can actually increase efficiency. A human might be able to fill something like 100 prescriptions an hour. What that entails is checking the prescription, making sure that the medication is appropriate for the patient’s body habitus. For example, some medications need to be scaled by weight. They need to make sure that there aren’t any interactions, and additionally they need to make sure that they can drop the medication in the appropriate amount of saline if it’s in injectible form or dispense the appropriate number of pills if it’s in a tablet form. Then they need to make sure that the prescription actually gets to the patient. So, there are a lot of places, a lot of potential breaks in the chain. You might be able to fill 100 prescriptions an hour if you are a very competent or capable pharmacist. A

machine such as the Autoscript can actually verify prescriptions, verify dosage, and provide -- essentially, this is an arm that articulates around a huge bay that contains thousands and thousands of medications. It is able to lift up the appropriate number of medications, suck out the appropriate number of pills, place it into a specialized container for a patient, and then in some cases as we'll see, place that container within a mobile robot which goes to the patient ward. So a human never touches the prescription, ever. In this case, it can fill something like a thousand prescriptions an hour. So we are talking about a significant number of – a significant increase in efficiency as well as decrease in potential medical errors.

This is exactly the type of device that is able to take a prescription to any other sort of small containerized item to and from patients. This is called the Health Maid system. There are about 100 in use today. It is estimated that a hospital can recoup the cost of one of these devices within six months of its deployment. These are really autonomous small devices that navigate hallways. They are very polite. They say, "Excuse me, sir, I need to move. I need to make my way through." They coexist perfectly with the rest of the medical staff. They serve, essentially, as glorified couriers. They free up individuals and skilled labor to do other tasks. They also help prevent the abuse of medications. For example, in order to remove a medication from this device, you might actually need to place your fingerprint on a thumbprint sensor so that only your medication will come out of this device. And if there is a controlled substance that is being administered, you might actually require a nurse, as well, to have their thumbprint registered. So, this actually has several applications in the clinical setting.

As we'll see later immediately following this topic, a live demonstration (inaudible) from the InTouch Website of the device that is being deployed in clinical settings to help change the paradigm for how medical care is delivered from a rounds perspective and from a patient assessment perspective.

Additionally, within the field of medical education, we also see an increase use of robots. The way that a lot of medical education is conducted today, basic procedures are often conducted in either inanimate models, animals such as poor center pig models or even dogs and rabbits or on volunteers, on humans who might volunteer, for example, to undergo a prostate exam. For reasons that are understandable, there are not too many volunteers for those sort of activities. And number two, it is not quite as realistic to work on an inanimate model to, for example, intubate a patient or to insert IV lines. And so, robots have actually been developed that have human-like skin, have vessels that can be punctured, that actually can develop arrhythmias that have various types of heartbeats that can help to direct student.

I wrote here that there is a $100,000 cost for this one robot that comes from McNaff University in Canada. There is a more recent version which is being deployed in Korea that costs somewhere around $10,000, so we are rapidly

moving toward a time and a place where these are actually going to be practical for medical education.

Then we move back to the surgical suite. Why even consider using robots? Well, robots are not necessarily a replacement for a surgeon but in many ways, an augmentation for what a surgeon can do. A surgeon often has, during a pinhole or so-called laparoscopic surgery, very limited views. What we are doing is using a trocar, and this is a robot with three independent articulating arms, but in lieu of this device you actually have three or four medical students or assistants holding trocars or long catheters that contain a camera or scissors or a small laser, and essentially, the surgeon is forced to use that small view port to visualize the entire abdomen or lungs or whatever field he might be working in. Robots can actually help to address a limited field of view by use of multiple independent arms that can help to provide a 3-D stereoscopic view for the surgeon. So it actually looks extremely realistic and provides a larger field of view.

In addition, the human arm and the human-controlled instruments have a limited number of degrees of field. So you might be able to move an arm in/out, rotate or twist, but let's say, for example, you have a lesion that is behind the heart. If you actually have to move the heart anteriorly or posteriorly or displace it somehow in order to get behind the heart to remove a tumor. Well, in using a robot you can use a device that can articulate and move in different ways that a human arm can't. So, this is actually very promising. This is probably one of the most important ways in which robots can help us in the operating room.

There is also reducing the need for human intervention and it actually helps the surgeon endure a long procedure. A long neurosurgery might last anywhere from eight to nine to 10; some surgeries even last 12 hours. And to be standing all that time is technically difficult. This actually that you see here is the da Vinci automated robotic system with the surgeon sitting within this 3-D stereoscopic view port. The surgeon is looking entirely through a set of 3-D glasses. His arms are controlling two robotic manipulators. He still needs a couple of assistants to help place the robotic arms over the patients, and then the rest of the sterile field is very similar to that used in conventional laparoscopic surgery. The da Vinci system is being used in upwards of 20,000 procedures a year, so it is actually being used quite effectively. Each unit costs around $1,200,000, and there are over 300 in use worldwide. There have been numerous procedures that have been conducted with the da Vinci system. What you can see here is, again, the system which is draped in a sterile cloth. We can see that one of the articulating arms has as many degrees of freedom as a human hand, and in some cases, even more.

These are the view ports in which the hands are placed, and they provide a surgeon with a very similar feel to that of conventional instruments. Essentially, what you are seeing is a surgeon using this two-handed device. It is sewing together a blood vessel, likely within the inner portion of the chest. You can see

that it is extremely realistic. The view that the surgeon gets is a three-dimensional view so it looks very much like you are actually seeing the results of your work. It is extremely satisfying to work in a setting like this because you receive instantaneous tactile feedback as well. You can feel the needle going through the vessel using a forced feedback mechanism. If any of you have had a chance to play around with the new Sony Playstation, they use a similar technology. The evolution of technology is always good.

The da Vinci has been used in numerous settings from heart surgery, and if any of you have had a relative that has had coronary artery bypass, they are now, in many cases, are eligible to have this done laparoscopically instead of having an open heart surgery. Instead of cracking the chest, we can make a few pinholes, and in many cases, we are able to reduce a hospital stay, reduce morbidity and reduce the level of pain that they experience. We're actually now encroaching on an era where we can do heart and valve replacements through a robotic laparoscopic approach. This is really a revolution and considering that for example, the patent foramen ovale or ventricular septal defects, they can repair endoscopically or the most common congenital heart defect, the range of applications is extremely broad. And as you know, prostate cancer is also an extremely morbid condition in many cases. Up to 80% of individuals at the age of 80 will have prostate cancer. If you live to be 89, you have a 90-95% chance of developing prostate cancer. So, for many of the gentlemen here you are guaranteed to get it if you live long enough. Unfortunately, most people that have a prostatectomy at the current time emerge either impotent or incontinent. So, those are two very poor choices to have to face. If you leave prostate cancer in place, there is controversy but the typical time force is bony metastatic disease, a very, very painful course. So for those who do face the prospect of prostatectomy, the use of a robot to help delineate very delicate neurovascular structures to avoid incontinence and avoid impotence, potentially, is extremely compelling.

What's the evidence when you talk about the potential? Have there been any studies? And in fact here have. In prostatectomies, in particular, there is actually a small cost premium for using a robot. Most of that is probably related to the time premium in terms of set up and sub costs of draping a device. But that is being reduced as people become more proficient with the machine. There have also been other studies that have shown that in many cases, robotic surgeries are comparable in terms of outcome to that of conventional surgery. In fact, there are a series of studies that demonstrate, really, in many cases the level of morbidity or side effects that you experience from undergoing robotic surgery is minimal. What I'd like to draw your attention to is a couple of cases of gastric perforation which you can experience in almost any type of laparoscopic surgery, and furthermore, a few technical errors, a few technically-related challenges which are being worked through as physicians become more competent with the device. In terms of other settings, in terms of outpatient settings, we can see the use of robots. This is actually a robot developed at MIT to help with stroke

patients. The patient actually presents with, for example, arm hemiparesis, lack of use of the arm. They can place their arm on this device and watch a screen which helps to guide them through the use of that arm. Studies have shown that if patients receive this sort of care or some sort of physical therapy within 30 days of stroke, that their level of use of that limb improves by 8-9 times. Unfortunately, many people who have strokes do not receive this kind of care because it is extremely expensive and labor intensive to provide it so the point of robots in an outpatient setting can be extremely potentially valuable.

In terms of home care, this is another area in which demographic shifts are providing impetus for commercial companies to help move into this space, particularly in Japan where you have the burden of an aging population and a younger population that is often wedded to their workplace and does not necessarily have time or even the resources to provide full time care for their parents. And so, these are devices that are in play in Japan and Korea. This is one is sort of a glorified walking chair. And of course, we have all seen the IBO robot, which unfortunately has been discontinued by Sony. That was sort of a very early attempt to bring robots in your home.

There are also robots that can help children recognize emotions. This is the cat which Dr. Libin has helped to developed. It has an ear which helps children develop cognitive language as well as facial recognition skills.

And then we have robots in an area in which I am personally involved in which is the use of robots in aging. Robots not only replace humans in terms of courier tasks but robots can be used, for example, in ultrasound. If any of you have seen the spectacular 3-dimensional pictures of babies in third trimester ultrasounds, those are kind of technically challenging to produce, and so essentially what we are able to do is using robots is 3-dimensional rastering arms that can help relieve some of the sonographic burden. We can achieve pictures which are really dramatic and help reduce the rate of repetitive strain injuries in sonographers, which has been the number one occupational hazard in that area.

We also have these robots (here’s one of the CT-guided biopsies that we talked about before) in everything from bowel imaging. If any of you have ever had a colonoscopy, the prospect of having a creeping robot creep through your colon might seem pretty reasonable. We have these robots, for example, in oncology. This is one of the first. It’s called the Cybernac. It is used in brain cancer surgery routinely. It shoots a series of gamma rays to help localize tumors and can help treat cancers that were otherwise unreceptible.

And then we have the use of MRI compatible robots, non ferromagnetic robots they can use, for example, in breast biopsies, ablation, and even through these electroparetic methods new sorts of drug delivery.
Unfortunately we are running through our time so I’ll quickly run through the rest of these. The other areas where robots are being employed medically is in terms

of the battlefield. We've seen at a prior Future of Health Technology Summit a device called the Bear which was designed to help move patients from the battlefield. Basically, it is a device that helps to carry individuals using a gyroscopic mechanism. In other areas we have the use of micro-robots in surveillance in areas in which humans can't reach.

This is a robot that was deployed for a NASA mission and which has now been redeployed in airports to help monitor people who are moving in and out of smaller airports.

We also have the use of humanoid robots, which have had a mixed degree of success. The Assimo, which was pioneered by Honda, had some dramatic failures, as well as successes. This was just a year after that very embarrassing public defeat so we see that robots today have pretty - so this is actually fairly astounding in terms its curb appeal. Quickly, robots can sing and dance. Really, what we are interested in in the medicine is the use of robots to help understand human movement. This is robot in Korea that uses gyroscopic load balancing to help physicians model human acrobatic behavior. We hope to use this in physical therapy and regenerative and reparative settings as well.

Unfortunately, I won't be able to go through the rest of these but the future of where is takes us, again, is in terms of augmentation as we face an aging population, we are going to need robots to help people with not only failing limbs but decreased levels of muscular trainability. So all of these are sort of robotic exoskeletons or second skins that help…this is actually a hundred pound bag of rice, so this gentleman is able to carry this without too much difficulty. And then taking to an extreme, a little bit of eye candy, this is kind of the Luke Skywalker version of where exoskeletons might lead us. So really the challenges of where we go are going to be in terms of some of the challenges that face the deployment technology in general, and really the promises are really quite broad so as we begin to think about the ways in which we can incorporate technology into our healthcare delivery system, it certainly would behoove us to save a very important and prominent role for our autonomy systems.