

## "21ST CENTURY MEDICINE"

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### EPISODE OPEN

ALAN ALDA If this guy were real, he'd need surgery fast. On SCIENTIFIC AMERICAN FRONTIERS, we'll see how he gets it - from a surgeon who isn't even here.

ALAN ALDA (NARRATION) We'll also see how computers give a surgeon X-ray vision... ..and help cure a fear of heights. We'll see how a human gene helps save a leg... and how legs once paralyzed are made to walk again.

ALAN ALDA I'm Alan Alda. Join me for a glimpse of 21st century medicine, on SCIENTIFIC AMERICAN FRONTIERS.

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### IMAGE-GUIDED SURGERY

ALAN ALDA On the eve of the 21st century, medicine, along with the rest of society, is being transformed by the computer. At the heart of every story we'll be doing in this episode is the computer's ability to process vast amounts of information. In the operation being performed here today, the critical location is the exact location of a brain tumor that's threatening the life of a young woman named Lynda Tolve.

ALAN ALDA (NARRATION) Without that information, the operation that's about to begin - and through which Lynda will be awake - may not even have been attempted - leaving her 2 years to live. It's a few days after the East Coast's Blizzard of '96. Lynda, her fiancée and parents have journeyed from New Jersey to Boston's Brigham and Women's Hospital. For 8 months, Lynda has had daily

seizures from a tumor that's slowly pushing into the part of her brain that controls movement and feeling.

LYNDA TOLVE When I found out the tumor was growing, the doctors in New York didn't want to touch the tumor. So I wrote to Dr. Black and he told me to come on up and he said with his new technique that he could do it. And that's when we came up here and that's what we're here now for.

ALAN ALDA (NARRATION) Neurosurgeon Peter Black is ready to take on Lynda's case because of a powerful new technique for peering into her brain.

PETER BLACK It's a very interesting process. I think you'll like seeing how it works.

ALAN ALDA (NARRATION) The process begins with what is now a standard technique for scanning the brain - magnetic resonance imaging. The MRI makes cross-sectional pictures of Lynda's brain, and in separate scans also locates its major blood vessels. The information is combined and processed to create a 3-dimensional image of Lynda's head, revealing the brain inside. This technique has been pioneered at Brigham's Radiology Department as part of an ambitious program to give physicians unprecedented power to see inside their patients - both before and during surgery. In Lynda's virtual brain, the veins are colored blue, and the tumor - located in the region that controls her ability to move her body - is marked in green.

LYNDA TOLVE My biggest fear in having surgery is that I might become paralyzed, and not be able to walk. That is my biggest fear.

ALAN ALDA (NARRATION) This fear that cutting out the tumor will damage her motor skills lies behind another innovative test - an attempt to pinpoint her brain's motor region with the aid of a magnetic wand.

DOCTOR Okay, five, four, three, two, one, go. Okay, fine.

ALAN ALDA (NARRATION) Placed on her skull, the wand stimulates the brain beneath. In this case, they are searching for the spot that controls movement in her left hand. By moving the wand - and tracking its location with flashing lights - Lynda's motor region is precisely located.

DOCTOR Okay, very good Linda. We found the motor strip. We are all done.

ALAN ALDA (NARRATION) This is the first time this method of mapping the brain has been used here, and an eager crowd of researchers awaits the results.

DOCTOR If you start going down towards where the ear would normally be you see a little red spot, which is almost slightly off-center on this little strip of cortex.

ALAN ALDA (NARRATION) The day before Lynda's surgery, I shared the remarkable experience of seeing inside her head with the help of 3-D glasses.

ALAN ALDA Is this the first time you've seen this 3-D picture of your brain?

LYNDA TOLVE Yeah. It's amazing.

ALAN ALDA (NARRATION) The 3-D image, plus the mapping of the motor strip, gives Peter Black much more insight into what he will face tomorrow.

ALAN ALDA So this is helpful in making sure you don't invade that motor area, right?

PETER BLACK This tells us that it is reasonable to go ahead, assuming that the tumor is now behind the motor strip and not in it. If it were in it, we would say this would not be a possible operation.

ALAN ALDA So this gives you a chance to know whether or not to do the procedure and then it also guides you during the procedure so that you don't...

PETER BLACK Yes.

ALAN ALDA Are there any other parts of the brain that, like blood vessels, or something, that this could guide you in...

PETER BLACK Yes. I think there are two other important areas. One are the veins, which are extremely important not to injure, and we know where they are now, and the second is the fact that the tumor itself appears to be in the sensory area of the brain. And the question of what implications that has for Lynda's recovery after the surgery are fairly important.

LYNDA TOLVE Isn't that something? Amazing! Thank you very much.

WOMAN It's a good thing you did your homework, Lynda.

LYNDA TOLVE What do you mean I did my homework? Dr. Black did his homework.

ALAN ALDA (NARRATION) Eight am on the day of the surgery. Lynda is sedated but awake, her head uncomfortably clamped at the best angle for getting at the tumor.

ALAN ALDA When I saw you yesterday, I thought you had a tremendous amount of courage, and I still see it in you. I see you riding this.

ANESTHETIST She is an excellent patient.

ALAN ALDA (NARRATION) By this point in the surgery, a piece of Lynda's skull has already been removed and her brain exposed. A video camera has been set up to peer over the surgeon's shoulders. It's now that the computer image of Lynda's brain puts in an almost magical appearance. Because by carefully aligning the virtual brain with the real one, the tumor's location is revealed.

ALAN ALDA There, there's the vein. Right there. Can you see the tumor yet?

PETER BLACK Yes, it's right exactly where we predicted that it would be. The only area that I'm not sure about is an area that we thought was a motor strip and the question is, does the tumor impinge on that, and we will be testing that in about 1 minute. Linda, we want now to test your movement, okay, hon. You're doing great, everything is going very well. We see the tumor. No question about that. It looks like it's going to be removable, but we want to just check some of the things about movement and feeling. I want you to tell me now if there is any movement in your hand or your arm on the left side, okay. Got it, perfect. Right on it. This is exactly where they found movement yesterday, by the way, with the mag stim. And so lets try four here. Lynda, this is very good news in terms of what we can do here.

ALAN ALDA (NARRATION) The testing confirms that the motor strip is next to the tumor but separate from it. But now there's another concern - the tumor seems to occupy a spot that normally would allow Lynda to feel sensation in the left side of her body.

PETER BLACK We're now stimulating her wrist. That stimulus is being picked up by that grid. So, each of those locations has a number on it so you can tell if the stimulation of the hand is being picked up under a number you know exactly what part of the brain is receiving that stimulation. If you found that the tumor was receiving signals, what would that do to the operation. Well, this would be a situation we talked with Lynda a little bit about. We talked before the surgery about that issue. And she said she would rather have as much tumor taken out as possible, even if it ended up with some trouble with sensation for a month or two.

ALAN ALDA (NARRATION) Lynda's wrist is stimulated.

ALAN ALDA You feel anything, Lynda, in your thumb, in your hand?

LYNDA TOLVE An electric shock.

ALAN ALDA An electric shock. The fact that your getting this typical pattern on every part of the grid. None of it's on the tumor probably, uh?

PETER BLACK No, I think we're probably below the tumor.

ALAN ALDA (NARRATION) As they move the grid around, they get more good news. The tumor doesn't seem to be receiving signals when Lynda's wrist is stimulated.

ALAN ALDA He was very excited when he got that report on what areas were stimulated, because it seemed to be exactly what he hoped it would be.

LYNDA TOLVE Dr. Black did very good work. He's a very good doctor.

ANESTHETIST She should have complete resection without any weakness after the surgery. We are all very excited about that.

LYNDA TOLVE I went to a lot of doctors at a lot of hospitals. Everyone refused to do this kind of operation. That's why when Dr. Black wanted to do it on television, I didn't have a problem with it. If it can help other people besides me, it will be great.

ANESTHETIST It's really a team approach, as you can see.

PETER BLACK I have to show you something.

ALAN ALDA Okay, I'm coming over.

ALAN ALDA (NARRATION) It's now about 2 hours since the operation began.

PETER BLACK We outlined the tumor, here in blue, but you see how it's lifting itself out now, almost, it's really bulging out of the rest of the brain on it's own. Okay, so that's the first part of the tumor that we've just taken out.

ALAN ALDA How much of the tumor do you think that is?

PETER BLACK It's about 1/4 to 1/3.

ALAN ALDA (NARRATION) Peter Black now switches to an instrument that first breaks up tissue with ultrasound, then sucks the scraps away. By now the hospital's pathology lab has confirmed the tumor isn't malignant.

ALAN ALDA Now, I still see little white spots in there, I presume you're going after them - other little spots of the tumor. It seems it's not malignant, is there less of a need to get every last drop of it out of it there?

PETER BLACK Well, in a way, you want even more to get every last drop because the surgery is the definitive treatment in that situation.

ALAN ALDA In other words, you're saying that because it's not malignant and you won't be radiating it, or doing anything to it...if you leave anything in there, it could grow again.

PETER BLACK And even though it is not malignant, it still may tend to grow again. That is why we would like to see if we can't get all of it out at this time. Now, the big question, Alan, is the one you asked yesterday. How do you know how deep to go? The advantage of the 3-dimensional reconstruction becomes particularly apparent here because this small cyst is something that we see in the 3-dimensional picture which you don't appreciate so much in the regular MRI. It identifies the base of the deepest part of the tumor.

ALAN ALDA (NARRATION) Using the virtual cyst in the image to guide them to the real thing in Lynda's brain, Peter Black and his colleagues over the next 40 minutes scour out the tumor. All the while, Lynda's motor and sensation responses continue to be monitored.

PETER BLACK I think we are pretty happy with that, in terms of the resection. I think now it's just a matter of making sure everything is nice and dry. We're essentially done.

ANESTHETIST Lynda, Dr. Black has just completed the resection of the tumor. And we're going to be finished very shortly. Yes, we're almost finished. The tumor has been removed.

ALAN ALDA That's great. Congratulations.

LYNDA TOLVE Good doctor, huh?

ALAN ALDA (NARRATION) Just three weeks after the tumor was removed, we met with Lynda again.

LYNDA TOLVE It's hard to believe that, not only the surgery was 3 weeks ago, it's hard to believe that I'm alive, everything went well, everything went great. I have no more seizures, and I can go to sleep at night knowing that I'm not going to wake up having a seizure, I can drive a car knowing that I'm not going to have

a seizure, I can walk out my front door knowing I'm not going to have a seizure. It's fantastic. I'm going to get married, and I'm going to have children, and I'm going to get rich, hopefully. Those things I could never do, because I wouldn't be here to do those things. It all seems like a dream, a dream that came true.

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## VIRTUAL FEAR

ALAN ALDA For a lot of people, what I am about to do is pretty much impossible. This elevator goes up 47 floors in about 30 seconds, and the view is fantastic. But for people with a fear of heights, this ride would be a nightmare. The best way to treat phobias, like fear of heights or of flying, is to expose people to just a little of what bothers them, and to have a therapist along to help get them through it. And then bit by bit the stakes are raised. Of course bringing a therapist with you every time you get on an elevator can get to be unwieldy, not to mention a little strange for the other guests. But in the 21st century the elevator may not have to be real.

ALAN ALDA (NARRATION) At Georgia Tech in Atlanta, Larry Hodges has built a virtual version of that same hotel elevator. The helmet gives me a 3-D computer-generated view that moves when I move my head.

ALAN ALDA Oh, you know what I hate, is looking up. LARRY HODGES That's what I've always said. Looking up is much scarier than looking down. You can look down over the rail.

BARBARA ROTHBAUM Your holding onto the railing, you can look down.

ALAN ALDA Look at that. Is it okay if I spit?

BARBARA ROTHBAUM No, ha ha.

ALAN ALDA Well, okay. It's pretty realistic.

ALAN ALDA (NARRATION) The question is: is it realistic enough to help someone like Christopher Clock?

WOMAN We are going to dinner at the Sundial. But we were wondering if there is an elevator that was inside instead of outside?

HOTEL CLERK No, this is the only one.

CHRIS CLOCK You don't have one going up inside.

HOTEL CLERK No sir.

WOMAN Do you think you can do it?

CHRIS CLOCK No, I'm going to take the stairs.

WOMAN You can face the other way.

CHRIS CLOCK No, no I can't. I'm going to take the stairs. I've been afraid of heights for as long as I remember. Since I was real young, we went to New York and tried to climb the Statue of Liberty and got half way up and just was too terrified and had to crawl back down the stairwell. And I avoid hotels: if I have to sleep above the second story I throw a big fit, and not around windows. It's kind of bad.

BARBARA ROTHBAUM How you doing?

CHRIS CLOCK It's kind of scary actually.

BARBARA ROTHBAUM All right. Your doing fine. We'll take it a little bit at a time.

ALAN ALDA (NARRATION) Chris Clock is a patient of Emory University psychologist Barbara Rothbaum.

BARBARA ROTHBAUM You want to give me a rating?

CHRIS CLOCK Ah, 70, 80.

BARBARA ROTHBAUM Okay, what's bothering you about it?

CHRIS CLOCK Just being over the traffic, the moving traffic.

BARBARA ROTHBAUM What are some of your fears?

CHRIS CLOCK Falling, the bridge collapsing.

BARBARA ROTHBAUM Are you ready?

CHRIS CLOCK Ha, Ha, yea, I guess.

BARBARA ROTHBAUM Can you get a little closer?



ALAN ALDA (NARRATION) By asking her patients to keep reporting how they feel and offering sympathetic reassurance, Barbara is working on gradually lessening their fears.

BARBARA ROTHBAUM You want to give me a rating?

CHRIS CLOCK Um, 90, 95.

BARBARA ROTHBAUM Okay, if you feel like you want to, you can go ahead and lean over. Good job. You want to give me a rating when you did that.

CHRIS CLOCK About 100.

BARBARA ROTHBAUM 100. Okay, you're doing real well.

ALAN ALDA (NARRATION) Barbara Rothbaum is collaborating with the Georgia Tech virtual reality researchers to see if patients like Chris find virtual height as scary as the real thing.

BARBARA ROTHBAUM You want to get a little closer to the front railing. And if you want to look over a little bit. You want to give me a rating of your anxiety 0-100 now?

CHRIS CLOCK Um, about 90 I guess.

BARBARA ROTHBAUM About 90. And where are you feeling that in your body?

CHRIS CLOCK Kind of weak in the knees. Hard to breath.

BARBARA ROTHBAUM What scares you to look at?

CHRIS CLOCK The tables. You can see that they are lower.

ALAN ALDA How long does it take somebody who's got a really solid fear of heights to work through it in this kind of a situation?

BARBARA ROTHBAUM Well, we take it slowly. In the study we did 8 sessions about 35-40 minutes each. We would take it up to whatever floor they felt comfortable with, stay with that until their anxiety came down and when they felt comfortable...

ALAN ALDA Wait a second, excuse me, I'm sorry to interrupt you. I can't understand anything your saying because when I took the helmet off I was really disoriented.

BARBARA ROTHBAUM You're disoriented.

ALAN ALDA I mean you guys are like... I'm standing on this floor inside this railing instead of being in the elevator, I got really used to the elevator.

BARBARA ROTHBAUM Well, that's what a lot of people say, you know it's animated, how can that really do it? How can that make me feel that I'm there?

ALAN ALDA I want to go back to Oz.

BARBARA ROTHBAUM Okay.

ALAN ALDA I like it better in here. Oh, now I'm home again.

ALAN ALDA (NARRATION) Chris Clock has now been through all eight sessions in these virtual environments - and here at least, his fears are almost gone.

CHRIS CLOCK I can actually look over and not be terrified.

BARBARA ROTHBAUM You're doing a great job. You want to look up at the next bridge? See where that is. Good. How is it when you look up at that?

CHRIS CLOCK It's not too bad.

BARBARA ROTHBAUM All right. Rob, can we go to the top bridge, please. We are there.

CHRIS CLOCK Wow.

ALAN ALDA (NARRATION) The first time up here, Chris rated his fear at 100.

BARBARA ROTHBAUM You want to give me a rating?

CHRIS CLOCK Um 25.

BARBARA ROTHBAUM Yea, it still catches you a little bit when you go up there.

CHRIS CLOCK It does.

BARBARA ROTHBAUM How does it feel looking down and seeing the open slats?

CHRIS CLOCK Kind of scary, actually. But, it's manageable.

BARBARA ROTHBAUM Give me a rating.

CHRIS CLOCK Um, 20.

BARBARA ROTHBAUM 20. 'Cause keep in mind what we talked about before, that anybody is gonna feel it in their body if they are up on a bridge this high and with open slats. I mean that's what some people call thrilling, exciting. Just because you feel something in your body when your up this tall, doesn't mean it's fear. Doesn't mean that your scared. It means you're human.

CHRIS CLOCK Right.

ALAN ALDA (NARRATION) Of course, the real test of virtual environment therapy is whether it helps in the real world. Chris was now at least confident enough to try.

CHRIS CLOCK I think the virtual environment helped me because I was able to get up into a high situation and feel like I was up high, but in the back of my mind know I was still on the ground. And with that safety feeling, deal with the anxiety and cope with it.

ELEVATOR RECORDING In a few seconds you will arrive at the top of Atlanta, our tri-level Sundial restaurant and lounge.

CHRIS CLOCK It's such a weight off my shoulders knowing that I can come up and I've conquered my fear of heights. I can go out and come up 72 flights and look out. I'm not afraid of it anymore.

ALAN ALDA (NARRATION) The Georgia researchers are now constructing a virtual airplane. I got to try out the prototype.

ALAN ALDA The plane is moving here.

BARBARA ROTHBAUM Right, look out the window and you see the wing, and we are moving.

ALAN ALDA (NARRATION) It still lacks some crucial details.

ALAN ALDA I don't have a seatbelt.

ALAN ALDA (NARRATION) The plan is to use the virtual plane to help some of the millions with a fear of flying, without having to take real flights with a therapist

on board. The thunderstorm was pretty convincing - but for thrills, I still preferred the elevator.

ALAN ALDA Make me go real fast. I like, where's the hand?

BARBARA ROTHBAUM I think we've got a virtual junkie here.

ALAN ALDA Here we go. Well, that's pretty fast. Wow, look at that. Wow. Oh, that is great!

BARBARA ROTHBAUM Do you want to dangle your foot over the edge? How does that feel?

ALAN ALDA It feels pretty good.

ALAN ALDA (NARRATION) With the price of computing power coming down fast, it won't be long until virtual reality systems could be cheap enough for every therapist to have one in their office. And it will become even harder to tell where the virtual world ends and the real one begins.

ALAN ALDA Wow, wow, you know that is really something. I had my eye on the floor and the floor really came up at me. Don't do this at home kids.

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## BYPASS GENES

ALAN ALDA (NARRATION) By 7:30 in the morning, long before the stores are open, this shopping mall in Natick, Massachusetts, is already humming with activity. One of the most enthusiastic of the mall walkers used to be Lillian Cooper.

LILLIAN COOPER I started about 7 years ago, and I could walk 5 miles every morning. I don't want to be immodest, but I was a good mall walker. I was usually at the head of the group.

ALAN ALDA (NARRATION) But for 2 years now, Lillian has been sidelined by a badly narrowed artery in her left leg.

LILLIAN COOPER If I don't find a way to get it fixed, I'm gonna lose the leg. I've been advised of that by two doctors. And I'm not ready for that.

ALAN ALDA (NARRATION) Lillian has already had all the standard therapies for her blocked artery. But now there's something new: involving a form of therapy

many believe will revolutionize medicine in the 21st century. At Boston's Saint Elizabeth's Hospital, her doctor is Jeffrey Isner.

JEFFREY ISNER We are only numbing that because we like you Lillian.

ALAN ALDA (NARRATION) She's been through this procedure often. A catheter is being slipped into the main artery of her leg, and then a dye that shows up on x-rays is injected. The resulting angiogram shows the dye reaching the blood vessels in her lower leg.

JEFFREY ISNER This is where the problem is. It takes a long time for that dye to wind its way all the way down to her calf muscle and foot. That's why she's having all the pain. And so the need here is to find a way to somehow deliver a significantly larger volume of blood flow down to the lower leg.

ALAN ALDA (NARRATION) Restoring blood flow in a blocked blood vessel is usually attempted with by-pass surgery or by inflating a small balloon in the artery. But for Lillian, these have already failed.

JEFFREY ISNER The main vessel, the main street, is totally blocked.

LILLIAN COOPER So, then what do you think you can do for me?

JEFFREY ISNER I know you've heard about gene therapy.

LILLIAN COOPER Yes, I have.

JEFFREY ISNER And in this case what we are going to do is use gene therapy to try to make new blood vessels grow from this artery that's right about in the middle part of your leg.

ALAN ALDA (NARRATION) Gene therapy has been highly touted as the future of medicine. A huge research project to locate and read all the 100,000 or so human genes is now in full swing. It's another dramatic example of how information - in this case the spelling of the operating instructions for the human body - is transforming medicine. And it's led to the hope that human genes can themselves be used to treat people. One of these genes manufactures a chemical that can make blood vessels grow. Jeffrey Isner's idea is to see if putting this gene into blocked arteries will cause them to develop shoots that will bypass the blockage.

JEFFREY ISNER The idea that people could grow their own bypass is an intriguing one because there is nothing like letting nature do the surgery.

ALAN ALDA (NARRATION) To deliver the gene, Isner employs a narrow balloon, that can be slid into Lillian's artery to a point just above the blockage and inflated to squash the gene into the blood vessel's walls. Hundreds of millions of copies of the gene are coated onto the balloon, then dried so that they stick there.

JEFFREY ISNER Seems like a lot. But we know that not all of the DNA is going to come off of the balloon and onto the wall or into the wall of the artery. And even all that gets into the wall of the artery will not necessarily find its way into the cells, the smooth muscle cells, of the arterial wall. And even the amount that gets into the cells will not all become operative, in terms of making the growth factor.

ALAN ALDA (NARRATION) Everything is ready for the genes to be delivered. A pump inflates the balloon. Now all everybody can do is wait and see - if the genes got in...if they work...if new blood vessels bypass Lillian's blockage.

LILLIAN COOPER My immediate dream is to go back to the mall walkers and be able to walk right in. And I'm sure they are all going to be there hoping for the same thing. That means I'll start my life again, doing the things that I've always wanted to do.

ALAN ALDA (NARRATION) If the gene therapy grows a bypass for Lillian's blocked leg artery, it has implications for other places bypasses are needed - most obviously, the heart. Jeffrey Isner's ultimate goal is to use gene therapy as an alternative to bypass surgery in people with coronary artery disease. It's been 4 weeks since Lillian's treatment.

LILLIAN COOPER Yesterday I walked from the hospital down the main street - over a half a mile - and I kept going. I feel that there have to be new blood vessels forming because what else would cause this? My leg is better, my foot is better, I can walk better. Has to be that. NURSE We'll have to use that cane as kindling.

LILLIAN COOPER Ha, Ha.

ALAN ALDA (NARRATION) To find out if more blood is flowing to Lillian's leg, she has yet another angiogram. The result at least partially justifies her optimism. While before it took 15 seconds for blood to reach her calf, now it takes only nine.

JEFFREY ISNER Now we are not seeing tufts of new vessels, and we're not seeing splashes of arteries we've never seen before. It's possible that the new arteries that are developing are of a size that they're a little too small for us to see on these angiograms. But yet, they're still enough of them, and they're still

functional enough that they're producing new conduits, new avenues, for blood flow to the lower leg.

ALAN ALDA (NARRATION) Gene therapy is still in its infancy - and so far most of the 100 or more clinical trials using genes have been disappointing or inconclusive. But this one just might be different.

JEFFREY ISNER Whenever you try something like this for the first time, you always wonder: is it science fiction, or is it going to be real therapy? A lot of things we try turn out to be science fiction, they make good movies, but they don't help too many patients. I think this has the potential to be great science fiction, but now we are seeing a few indicators that suggest that it actually might be useful, might actually be therapeutic for certain patients.

ALAN ALDA (NARRATION) Six months after Lillian's gene therapy, and she's back at the mall.

LILLIAN COOPER It feels wonderful to be walking again. There were times when I thought walking a few steps with a cane would be about it. But now I can walk around the mall, mostly without stopping. So, I'm really thrilled with the way everything has turned out. And I'm hoping that it will get better all the time, and I'm sure it will.

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## CYBERSURGERY

ALAN ALDA (NARRATION) There was once a television series set in a Mobile Army Surgical Hospital near the front lines of the Korean War. Although you may not have known it from watching the show, MASH units like this were a major breakthrough in battlefield medicine. Before the early 1950's - and the helicopter - many soldiers wounded in battle didn't survive simply because they couldn't be treated by a trained surgeon quickly enough.

RICK SATAVA That was our first opportunity to get closer to the casualty where he was wounded in what we call the golden hour.

ALAN ALDA In the Korean War, that was the first time you could get a patient under the knife that fast?

RICK SATAVA That was one of the main advances that we had there. The absolute evacuation from the far forward area quicker to where the surgeon is.

ALAN ALDA (NARRATION) Fast forward to the 21st century, as viewed through a promotional video made for the Pentagon's Advanced Research Projects Agency, where Colonel Rick Satava heads a program to bring new technology to battlefield medicine. The goal is to shorten still further the time between a soldier's being wounded and his getting expert medical attention - because of a starkly dramatic statistic.

RICK SATAVA We looked at the data from the Vietnam database and the Korean database and found out that of those who died, the soldiers who died, approximately half of them could have been saved. Because they bled to death, most of them bled to death, or had wounds or injuries that could have been treated had a) the medic been there quickly enough or if the medic got there but didn't have the expertise, we could have projected the surgeon to him.

ALAN ALDA (NARRATION) And when Colonel Satava talks about projecting the surgeon, he means it almost literally.

ALAN ALDA If this person had been wounded in the battlefield and he happened to be lucky enough to have a surgeon here, what's wrong with him?

ALAN ALDA (NARRATION) Jon Bowersox is a surgeon. He's working with scientists and engineers to project his hands into the battlezone while he himself is miles away.

JON BOWERSOX What it looks like is there is about an inch long hole in the small intestine. If we didn't treat that, what would happen is the casualty would develop a severe infection and die in a relatively short period of time. So what's needed to take care of this is emergency repair of the intestinal injury.

ALAN ALDA (NARRATION) These are pig intestines from a local butcher's shop colored with red paint. Jon's substitute hands are poised above them.

ALAN ALDA What do these things do? They get right down in the wound? This is the machinery?

JON BOWERSOX As you see, why don't we move them into position here if you just move our position control.

ALAN ALDA That's this red button?

JON BOWERSOX It is. Stop please. Good, Good. So as you can see, just like the surgeon's hands, they're placed right over the site of the wounding and these are instruments the surgeon normally uses.



ALAN ALDA (NARRATION) Right now the armored operating room is connected to this tent by cable, but soon a wireless system will allow OR and surgeon to be many miles apart.

JON BOWERSOX So this is a surgeon's work station, instead of being at the patient's side in the normal operating room. I put on these polarized glasses that give me 3-D vision. Instead of talking directly to my assistant, I put on a pair of stereo headphones, and instead of picking up the actual surgical instrument handles, I put my hands, into the halves of the instruments that are attached to the console. And now, it's like being at the patient's side.

ALAN ALDA (NARRATION) What Jon sees is a 3-D version of the image shown on the monitor.

ALAN ALDA How much like the real experience is it when you were over there?

JON BOWERSOX Well, I think the most telling thing is that every surgeon that has used the system, after working with it for about 15 or 20 minutes, will move their hand out of the instrument handles and try to push bowel out of the way, it's getting in the way.

ALAN ALDA (NARRATION) Jon appeared to be as dexterous with the remote instruments as he was with the normal ones, aided - as he would be in a regular operation - by a skilled assistant. Jon sees Michelle in a small monitor in his work station, and together they speedily repair the wound.

JON BOWERSOX As you can see now, I am able to tie the knots in the suture just as if we were in the actual operating room. So, would you like to have a go at this?

ALAN ALDA Ah, yea. Let me try. I can't wait. This is the going to be the first time I've ever done this.

ALAN ALDA (NARRATION) Despite years of doing fake operations in a fictional MASH unit, this was the first time I'd tried anything like the real thing. Fortunately, it wasn't the real thing.

ALAN ALDA Oh, oh my God! Oh wait a minute. I'm terribly sorry, I banged into the instrument and jammed it into the guy's intestines. Wait a minute. Michelle, control yourself. Snip, snip, okay.

MICHELLE Alan, you're ruining my image of you as Hawkeye, you know that.

ALAN ALDA I am not a real doctor, I just play one on TV. Now, I need to pick this side up.

MICHELLE Yea. Pick it up. Right where you are. Okay.

ALAN ALDA Okay, Oh it went through.

MICHELLE Yes

ALAN ALDA Do I have too little of it?

MICHELLE No, that's just fine.

ALAN ALDA Oh, pull it with this?

MICHELLE Yes

ALAN ALDA Oh, I see, I see, pull it with the right hand. Okay.

ALAN ALDA (NARRATION) The most remarkable thing about the experience was that the computer interface between the instruments and my hands allowed me to feel what I was doing.

ALAN ALDA There I got it. Look at that.

MICHELLE Yes, you did great.

ALAN ALDA I made a stitch. But the poor guy; I mean he's gonna have cramps from that stitch. I'm not really good at sewing, anyway. But, I could feel it, I could feel the resistance and I would imagine it would be easy to feel the resistance of something really hard, but to feel something like tissue which has so many kinds of resistance, I mean it's soft, it gets a little tougher, and then you push your way through and you feel yourself going through, you feel that release. That's a subtle difference, and I could feel all those changes in there.

ALAN ALDA (NARRATION) This feedback from the instruments is critical to the system's effectiveness.

JON BOWERSOX The most common cause of abdominal injury in combat is from shrapnel, which results from mines, like what's happening in Bosnia or from grenade injuries; it puts a lot of small fragments of metal in someone's abdomen. It's important to try to get as much as you can out of the body. Here's a good size piece.

ALAN ALDA One of the things we used to do on Mash all the time was run the intestine, I always took that to mean that we would feel along the intestine or the bowel for fragments or holes. Was I right about that? You would use your fingers?

JON BOWERSOX You're right. That's one of the most important parts of trauma surgery is to take a look at the entire 12 feet of small intestine to make sure you haven't missed a piece of shrapnel or a hole in the intestine that could go on to cause an infection. And that could be readily done by telepresence. But the most common cause of death after trauma on the battlefield is bleeding to death. Right now we are going to simulate bleeding from an arterial wound such as would be encountered by a combat surgeon.

ALAN ALDA Okay, wait a second. I am going to watch this from the battlefield. Don't start.

ALAN ALDA (NARRATION) The demonstration ended with a theatrical flourish. But if this were a real wound, having the experience and skills of a trauma surgeon right there on the battlefield could have saved a life. The major funding for telepresence surgery comes from the military, where it's the key part of an ambitious program to use communication technology to locate, diagnose and begin treating casualties within minutes. It would all have made Hawkeye and the gang from the 4077th green with envy.

ALAN ALDA So, that scene we used to have where the helicopters would come in where everybody would be laid out on stretchers, and we would be bending over them figuring out for the first time what we had, what the injuries are, who gets to go first, and that kind of thing. That all would be done already, it would be in the computer as the people were arriving? We would know exactly what kind of procedure you were headed for?

RICK SATAVA Exactly. You can allocate resources before they come. If you need expertise, the command and control know what's going on as well, and they can provide expertise that you would need. So it's the flow of information and even telesurgery is information flow. I move my hand, bits and bites travel down and the knife cuts. And that's why we say we have to think of medicine in a different term. It's no longer blood and guts, but it's bits and bites.

ALAN ALDA Well, I've got a great idea. If you reach the point 50 or 100 years from now, where you don't need a real person there at all, then don't send a real person out there to get shot at.

RICK SATAVA I'm sure they're working on that in other programs. That is for sure.

ALAN ALDA Well, mention my name.

RICK SATAVA Well, okay great.

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## NERVES OF STEEL

ALAN ALDA (NARRATION) Three years ago, we visited Dan Kemp at his home in suburban Detroit. Six years earlier, he'd been in a jeep rollover accident. His spinal cord was damaged, leaving him with no control of his legs, and limited strength in his upper body. Dan Kemp became involved in an experimental program aimed at eventually restoring to people with injuries like his the ability to move their limbs - perhaps even to walk. It was a remarkable glimpse of 21st century medicine. Dan Kemp was helped by his daughter Kendra... and his wife and biggest fan, Brenda.

DAN KEMP We got married after the accident, so that can tell you a lot about her moral character. She bought the whole package, not just the outside wrapping. The first thing that I'd like to do when I finally do stand, would be to stand up, look my

WIFE in the eyes, and give her a big hug.

DR. MARSOLAIS What I'm trying to get is his gluteus maximus muscle.

ALAN ALDA (NARRATION) Helping him reach that goal is Dr. Byron Marsolais.

ALAN ALDA Now, what you're inserting into the muscle, that's not the electrode itself?

DR. MARSOLAIS No, no, this is just a little probe.

ALAN ALDA Right

DR. MARSOLAIS A very tiny probe.

ALAN ALDA And the reason you're doing this is to see if you can get the muscle to react, to give its greatest response?

DR. MARSOLAIS Exactly, and I want just the right muscle, that's the muscle we want, it goes right down here into the femur.

ALAN ALDA Yeah

DR. MARSOLAIS Exactly, and I want just the right muscle, that's the muscle we want, it goes right down here into the femur.

ALAN ALDA Yeah

DR. MARSOLAIS Which is the big leg bone, and you see how it's beginning to jump there, it's beginning to do what we want. I think I can do better, and in order to do better I have to get it right beside the nerve.

ALAN ALDA (NARRATION) There's nothing wrong with Dan Kemp's muscles - it's the nerve-brain connection that's the problem. That's why he feels no pain during the procedure. Normally fifty muscles are involved in leg movement. In Dan Kemp's case, sixteen will be controlled by eight implanted electrodes. If all goes well he'll get back limited use of his legs.

DAN KEMP If you don't use it, you lose it and you know, it stands to reason the more I can use, the healthier I'll stay healthy.

ALAN ALDA Now, I think Dr. Marsolais looks like he's found the spot here.

ALAN ALDA (NARRATION) Now the permanent electrode, attached to a wire as thin as a hair, can be implanted. The electrode's not much bigger than a pin, and it's at the tip of this tube, which will be removed once the electrode has been placed right at the point of maximum muscle stimulation.

DR. MARSOLAIS Measure. Now we bring this down to exactly the position that we were before.

ALAN ALDA (NARRATION) This is an experimental program - so a question occurred to me...

ALAN ALDA How do you feel when you're going through this? Do you feel a little bit like a guinea pig?

DAN KEMP Yeah, I do, but it's well worth it. You know, and down the road, people will be able to look back, and say if it wasn't for people like me, that they wouldn't have gotten as far as they've gotten in the new procedures. So it goes down the line.

ALAN ALDA Yeah.

DAN KEMP Everybody helps everybody else, whether they realize it or not. Okay.

KENDRA Now Dad?

DAN KEMP Okay. Hit the "G" button.

ALAN ALDA (NARRATION) Back home, Dan and Kendra began his daily routine, using a computer to control the impulses which stimulate his leg muscles.

DAN KEMP Okay. You ready?

KENDRA Go!

DAN KEMP Go! Here they go.

KENDRA Here they go.

DAN KEMP Thank you very much.

ALAN ALDA (NARRATION) An essential part of the system being developed by Dr. Marsolais and his team is exercise - and that's what's happening here. Right now the control box is automatically working Dan's quad muscle group, at the front of the thigh. It's fortunate they've been able to turn it into a game, because Dan has to do this for a minimum of an hour every day. Once a week, Dan returns to the Cleveland VA Hospital, where the research is based, for a session with the team's physical therapist, Paul Miller. Eventually, the control box will transmit its signals directly through the skin. So these external connectors - difficult to maintain and keep clean - won't be necessary. The joystick controller is designed to be used by patients with very limited strength. Here Paul selects an exercise program, then records the muscle power and endurance. Five months earlier Dan could do this for just seconds at a time - now he can keep going for an hour or more. He's almost at the point where he can attempt a real task, like standing up.

PAUL MILLER When you're stimulating a muscle or contracting a muscle that hasn't been used in five, ten years, it's like starting all over again, like a little baby. So, we have to build the strength so that they have enough strength to do a functional task.

DAN KEMP Sitting around after six years of not doing anything and seeing your legs start moving, and feeling the fatigue after a while, it gets you back into a normal pattern of life. It's a great feeling, it really is.

ALAN ALDA (NARRATION) We'll come back to Dan in a moment. First, meet Eric Bellamy. A motorcycle accident five years ago left him paralyzed from the waist down. He's one of six people using the largest implant system, with over 50 electrodes now in place. Eric's a kind of pioneer.

ERIC BELLAMY You can't count life out 'til you go out there and try it. And swimming is something to try, all sports is something to try, anything that gets you in better shape physically and mentally. Life's still out there.

ALAN ALDA (NARRATION) Life is still out there - but the problem is getting at it. Access has improved in recent years, but for Eric a small increase in mobility would make all the difference.

ERIC BELLAMY I see being in a chair always, but I see being able to go up steps, and knock on the front door, and say, hey, you know, I'm down here. Instead of running around the house, and screaming you know telling the guy, hey I'm here, I'm here. I see, even convenience stores, one step you know. So being able to get up and go through this narrow door to get into the bathroom. Just for them answers. If they can come up with that right there, just, your life's in a chair, but being able to overcome difficulties would be a tremendous step. And that's what we're working on right now.

ALAN ALDA (NARRATION) On the outside, Eric's system looks like Dan's. But on the inside it's much more complicated - both within the control box, which right now is programmed to handle 41 of the fifty implanted electrodes, and within Eric's body, where a network of wires runs under the skin from above the waist to below the knees. Why so complicated? Because Eric's system is designed for walking. The first thing to do: Eric selects "stand" and "walk" from the controller's menu of programs. Then he'll hit the "go" button.

PAUL MILLER Okay. go ahead and stand up.

ALAN ALDA (NARRATION) The controller goes into its pre-programmed walking cycle, putting out about a hundred muscle commands for every pair of steps. Remember, Eric has no natural lower body control at all. This is completely synthetic movement. But he is using his upper body strength to balance - and as with all these research patients, his muscles have to work immensely hard.

PAUL MILLER They're using tremendous amounts of muscle mass. Their quadriceps are on 100%, their gluteal muscles are on 100%, their hamstring muscles are on 100%, their back muscles, everything is just blasted.

ERIC BELLAMY Whenever they do something, their using 100% of all their strength. Whether it's one step, two steps, they're using everything they got. Like

when you stand, everything goes right into it. 100% bam! Total exertion, you know. Everything it has.

ALAN ALDA (NARRATION) Now for the other key function - stairs. Today will be the first time Eric has faced a commonly found design. Eric can maneuver past the lips on the steps only by using his tremendous upper body strength. It's an example of the biggest challenge facing the research team - the control system has to be able to adapt to a changing world. The aim is to add sensors to the feet and legs which can feed information back to the control box. Then part of the enormous burden of concentration and effort, which so far falls on the user, can be transferred to the computer control.

BUS DRIVER You guys ready to go?

ALAN ALDA (NARRATION) Eric has a personal challenge: to reach these seats unaided. Today, he's going to try for this simple goal - for the first time. Success will bring the world at large a few crucial steps closer - to Eric and the others who'll eventually benefit from this research. Things don't look good. For some reason, Eric's left knee is not locking up. Eric and Rudi Kovetic, who programs the computer controllers, run through the muscle stimulation sequence.

ERIC BELLAMY Up left?

RUDI KOVETIC Looks like he's got enough power in that left leg, but it doesn't seem to bring him up.

ERIC BELLAMY Could be fatigue.

RUDI KOVETIC Yeah, but it looks like you have a lot of strength in that left leg.

ALAN ALDA (NARRATION) They decide to try again. This time it works. They don't know why, but artificially stimulated muscles often seem to change in strength. Now, it's back to the "walk" program.

PAUL MILLER You have to pivot back a little bit more.

ERIC BELLAMY I said I'm going to sit down Rudi.

PAUL MILLER Good job Eric.

ERIC BELLAMY Onward!

ALAN ALDA (NARRATION) We're back with Dan Kemp, and today's the day he'll face his personal challenge - to stand... and to hug his wife.



PAUL MILLER You ready?

DAN KEMP I'm ready

PAUL MILLER Okay. One...Two...Three... Alright! How's it feel Dan

DAN KEMP Oh, it feels vertical

RUDI KOVETIC You getting dizzy?

DAN KEMP C'mere. No I'm fine.

WIFE Are you sure?

DAN KEMP Yeah.

WIFE You're fine?

DAN KEMP C'mere. Gimme a hug. It's great!

WIFE Long time since I've seen you that tall.

ALAN ALDA (NARRATION) Dan, like Eric, was a pioneer - of a technology that in the 21st century could change the lives of thousands.

DAN KEMP That's the best feeling I've had in a long time.

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