**ROBERT K. LEE, MD:** So, I'm briefly just going to talk about what happens after the acute hospital and when patients come to rehab, what are we able do to maximize function for these patients. I also don't have any financial disclosures. And some of the objectives that I'll be talking about today-- I'll describe patterns of natural recovery in patients. We'll talk about some of the goals that our stroke survivors will have. I'll talk about impairments that are common in strokes and also some of the complications that we hope to minimize after a stroke in order to maximize recovery.

I'll also talk a little bit about pharmacological interventions that we can use, particularly serotonin, in stroke recovery. And I'll use two examples of test-specific therapies that we use to maximize nerve plasticity and motor function in our stroke patients, looking at upper extremity recovery and also ambulation.

So, a brief history lesson on rehabilitation. So pre-World War II, if you had a stroke, unfortunately, rehab wasn't really part of the program. It was basically a death sentence if you had a severe stroke, so patients would end up in nursing facilities or wards such as this one, and they were bedbound. Usually, nurses would care for basic needs, but they would develop complications such as ulcers, pneumonia, urinary tract infections, develop severe muscle spasms, contractures. Usually would either have a second stroke or, unfortunately, pass away.

Fortunately, in the 1970s and 1980s, there was the development of stroke units where specialized physicians, nurses, teams started treating these stroke patients after they left the acute hospital. We also started seeing more outpatient rehabilitation after they left. And all this led to improved outcomes and less disability amongst stroke survivors. We also saw a reduction in stroke mortality. This was mostly credited to better diagnosis of hypertension and treatment of hypertension.

And in the 1990s, we saw growing bodies of evidence that recovery was even possible after six months after a stroke. Unfortunately for those who had strokes in the 1940s and 1950s, they were bedbound, but that did allow for a neuroscientist in Boston to do this study on natural recovery of strokes with no rehab. So Thomas Twitchell at Boston City Hospital basically followed 121 large vessel stroke patients. They were bedbound, and he basically took thorough notes. He would examine the patients every single day and document what returned at what time and use that to prognosticate recovery.

So what he saw initially was for large vessel strokes, not looking at our mini strokes, PIAs, but large vessel strokes, there was an initial period of placidity, which we commonly see, and reflexes, if they return, should return within about 48 hours in the first week. Initial movements that patients saw weren't coordinated movements, but they were kind of like what Joanna was doing when she was holding her microphone.

So you have a flexion synergy pattern in the upper extremity, where patients would first start-- you would ask them to move their elbow, but they wouldn't be able to just move their elbow. They would have to internally rotate, abduct, flex their elbow. They'd also flex their wrist, pronate, and also flex their fingers.

And in the lower extremity, we saw extensor synergy patterns, where they would extend their hips, extend their knees, extend plantar flex. And over time, as patients recover from strokes, you see that they're able to move out of these patterns. So they're able to either supinate while they're in the flexion synergy pattern, or they're able to externally rotate or shoulder abduct while they're still in that synergy pattern. Over the months, Twitchell saw that, as they moved out of these synergy patterns, individual movements came back if they were able to progress to full recovery.

Spasticity, tightening of certain muscles, usually muscles that cross multiple joints in the body, was seen in patients. If spasticity does occur, it usually came on around five to seven days. If patients did not develop spasticity within the first month, they generally didn't. And what we see in the upper extremities is spasticity of the flexors. In the lower extremities, we see extensor spasticity, followed by flexion spasticity in the lower extremities.

And volitional movement. So in most of these 121 patients, they were MCA strokes, so there was a very predictable pattern of natural recovery in these patients. So if patients were to regain function and volitional movement, you would first see the hip flexors return, followed by the knee extension, plantar flexion, dorsal flexion, knee flexion, in the lower extremities. And then you would see a return of function in the upper extremities starting with your shoulder, your elbow, and the last thing that would come back with your hand-- so, finger extension.

Prognostic indicators that he saw-- so, the biggest one is the severity of the stroke and the severity of the deficits initially. The larger the stroke, generally, the worse the recovery at six months. If you had delayed return of finger-tapping-- so patients who actually were able to finger tap within the first week did pretty well. He saw that at six months, many of those patients were able to use their hands. Their dexterity tended to return. But if finger-tapping was delayed for a prolonged period of time, the chances of patients regaining hand function was pretty low.

Volitional movement-- so any volitional movement at one month. If they're completely flaccid on that hemiparetic side, it was a poor prognostic indicator. And prolonged periods of flaccidity, usually up to one month also, was also a poor prognostic indicator.

The severity of proximal spasticity-- initially, if they had severe tone develop within the first week, it was difficult for these patients to eventually go through the stages of recovery to get out of the spasticity, and their ability to use those arms were severely decreased. And sitting balance was an indicator. So initially after a stroke, within the first few days, if the patient has poor sitting balance, the chances of them walking are seriously reduced.

Other poor prognostic indicators-- these weren't in Twitchell's study, but were in other cohort studies that followed. Neglect-- so if patients are not able to perceive one side of the world, are the hemiparetic side, these patients generally did not do as well. Patients who are depressed also were unmotivated to participate in therapies. Patients with any sort of global aphasia or receptive aphasia who aren't able to process the instructions from therapists generally don't do as well.

And incontinence I have on this list, not because it predicts whether or not a patient's going to walk again or whether they're going to be able to use their hand again, but incontinence is one of the biggest reasons why patients aren't able to return home after strokes, from acute hospitals and rehab facilities. Basically, family members don't want to change diapers, and unfortunately, if they're incontinent, they end up in nursing facilities when they could otherwise return home.

So, timing of recovery. So like I said, any time you see a patient here at Saint David's or anywhere in the country, volitional movement within the first week significantly increases their ability for full recovery. So if they're able to get to the rehab facility already extending their knee, we know that they're probably going to be able to at least stand by themselves, transfer, walk, and at one year, most of these patients are able to walk if they get enough therapy.

If there was no return of volitional movement at one month, these patients usually didn't get return of distral muscle strength. And several cohort studies-- the Framingham study that looked at cardiovascular risk factors-- stroke was part of that study. So all of the patients that were in that initial cohort in the 1950s, in the 1980s, they did a study for about four and a half years, looking at any patient that was admitted to their local hospital. And they basically tested their motor function sensory, cognitive deficits, depression scores, at three months, six months, and 12 months.

And what they saw was motor recovery, generally, in these patients, plateaued at three months and just stabilized all the way up to the end of the study. Cognitive improvements were continued up to six months, followed by the similar plateau. A Copenhagen study that they did-- this was in a community of about 220,000 residents-- and they saw similar results, where the plateau would happen around five months. In the 1990s, there were studies that basically suggested that all-natural recovery ended at about six months and further recovery would be very limited.

So where does that leave us as far as disability? Looking at these percentages, it's pretty easy to see why stroke is the leading cause of disability in the US and the world. The CDC in 2012 actually reported that there were over 900,000 hospitalizations for strokes, and just looking at these percentages, half of those patients are hemiparetic at six months. About a third of them need some form of assistance to walk. A quarter of them need assistance with their activities of daily living, just basic life skills that we need to get through the day. A fifth of patients had trouble communicating. A third of patients were depressed, and this bottom number-- a quarter of patients were living in nursing facilities at six months after a stroke.

Looking at the biology of recovery, Dr. Waldron alluded to some of these things, as far as the schemic infarct. You have a central area, the core of the infarct, where those brain cells are basically gone forever, and they're not going to return. But there's this area surrounding the core called the penumbra, and this is an area that the brain cells are either getting compressed by edema, there are metabolic dysfunctions, inflammatory factors that are causing them to not work as well as they once were.

So these pathways that are going to be the penumbra are thought to be partially disrupted and are reversible the edema, the swelling-- whether or not we can decompress them. They slowly return, usually within the first week to a month, and that's where we see a lot of the quick recovery in our stroke patients.

There's this thought in mice models, neurogenesis, so after you induce strokes in mice, we see that neuroblasts are migrating towards the penumbra of the strokes. And this usually takes place two to four weeks after the infarct. Whether or not this happens in humans is still up for debate. There are limited regions in the ventricular system in the hippocampus that do have neuroblasts after a stroke, but whether these cells actually are able to migrate to the area in humans is up for debate.

Compensatory-- so, we talked about the core area of the stroke. Those pathways are gone forever, but surrounding those areas, there are redundancies and latent pathways that are able to be unmasked after a stroke. And plasticity-- this is basically the hard-wiring of those latent pathways with training and practice and repetition over time.

There's also collateral sprouting of neurons, where they can basically connect with adjacent cells that were damaged that can assume the function that those brain cells that died were doing. And there's this thought of cortical reorganization. So within the brain after a stroke, the brain will remap itself. So if you leave a patient with a hemiparetic arm and they don't do any therapy, the cortex that used to represent that hand will slowly shrink a little bit. But with therapy, we've seen that these areas can actually expand after a stroke.

So y what we see after a stroke when they come to acute rehab-- most rapid rates of recovery are usually due to these reversible injuries and the compensatory mechanisms. But we do know that significant recovery can occur after six months, and even years after a stroke if patients are placed in aggressive therapy programs. And this is due to the neuroplasticity.

So key points in this whole continuum of health care. In all the studies that we've seen, the initial severity of the deficits is a huge prognostic indicator. So the time that your first symptoms occur to the time that you can get to the primary stroke center, the time that you can get the interventions that we have available, such as TPA or neurosurgical decompression, is basically saving brain cells and lessening the degree of impairment and generally leads to better outcomes.

Early initiation of rehab has definitely been shown to improve function-- maybe not as soon as the ICU. Because there have been rat studies that show if you start aggressive therapy right after a stroke, it actually increases the size of the infarcted area.

So this is a graph from the CDC basically showing the average length of stay for stroke patients across the US. You can see in 1989, it was a little over 10 days, but today, it's hovering right around four days. So before you know it, the patient is in the ER. They're admitted to the unit. They're medically worked up and stabilized, and now they're moving on to the next level of care, which is usually an acute rehab facility if they need that aggressive therapy.

Common impairments that keep patients from going home directly from the hospital. So most patients will have some weakness, semiparesis. They'll have difficulty communicating, whether it's understanding or expressing what they need. Many patients will have a form aphasia, depending on the location of the stroke. Incontinence is generally an issue for most stroke patients. Fortunately, most patients, unless they have an infarct in the pons, will generally be able to be continent after a stroke.

Balance and coordination issues. Strokes in the brain stem, any cerebral distribution can cause visual deficits, and sensory deficits are seen in these patients. And cognitive deficits are a huge problem in stroke patients, because it affects their ability to problem solve, motor plan. Usually, patients can be impulsive with frontal lesions, and their safety is at risk. So they sometimes will need 24 hour supervision, even if they're physically able to return home.

So choosing a rehab destination is a huge decision for the patient and their family members. Usually, the case manager on the acute side is able to assist with this, but it's a pretty complicated decision, too, and multiple variables are involved. I really like that U-turn from the second lane. Anyway, so the case manager-- all these variables such as comorbidities, age of the patient. How impaired are they currently? What is their discharge plan? Are they going to have significant family support after they leave the acute hospital?

And insurance actually plays a huge role to determine where they go after rehab. But if they are able and they qualify, acute rehabilitation is their best that as far as regaining as much function as possible long-term. For patients who aren't able to tolerate the three hours of therapy that are required by CMS, long-term care facilities or nursing facilities are sometimes options. Long-term care facilities are great for patients who are either pretty lethargic or require vent management.

Nursing facilities are an option for more elderly patients who may require more time than the average length of stay at an acute rehab hospital, which is about 17 days across the US. And for the subgroup of patients that are fortunate enough to be able to return home, outpatient therapy to continue working on the deficit they have is an option. And for patients who may have difficulty getting out of the home, home therapies are also an option, although they don't have access to all of the equipment that an outpatient gym would have. But some therapy is better than nothing.

Studies have shown that an interdisciplinary approach is important in overall recovery, so if you've got a whole team that's looking after you and managing all the comorbidities and minimizing transfers back to the acute hospital, these patients are able to focus on the therapies, and they're able to improve their ADLs. They're more likely to return home versus getting bounced back to the acute hospital or ending up in a skilled nursing facility. And these patients also have decreased mortality.

So all these members of the acute interdisciplinary team all play a vital role. At the center of the team, of course, is the patient and the family. We strategize and individualize plans for each stroke patient. Everybody's different. Everyone has different goals and they're at different points in their lives. The young stroke is going to have different goals than a 90-year-old. So being able to manage their mood, their adjustment disorder, making sure they're eating, sleeping, making sure their blood pressures are under control, are all important in getting patients to the physical therapy, the occupational therapy, the speech therapy that the patients need.

And 30 days after a stroke, the risk of mortality is the greatest. Most common causes of death include the stroke itself and related complications, but pneumonia, generally from aspiration from difficulty swallowing, myocardial infarctions and pulmonary embolism. And these are all things that we're hoping that we're preventing as a team. So common complications include pneumonia, deep vein thromboses from just not moving around.

Generally, they'll be on some low-molecular weight heparin, unless they had some sort of an intracranial hemorrhage were or hemorrhagic conversion. Or sometimes patients with large MCA strokes, DBT prophylaxis is held for a little while. Fall risks-- so in the rehab hospital, we're getting patients up, and we're encouraging them to move. So their fall risks are actually the highest of any rehab group. Urinary tract infections are very common in stroke patients.

Neurogenic bowel and bladder, adjustment disorder-- this is a huge, life-changing event for stroke patients, so it's perfectly common for patients to have some sort of depression and adjustment disorder. We're trying to prevent ulcers. Our nurses do a fantastic job of that. Spasticity is managed, and we're also trying to prevent the recurrent stroke or the bounce-back to the acute hospital.

So, goals of acute rehabilitation. Prevention of all these complications I just mentioned. We're trying to improve their activities of daily living, all those things we take for granted-- bathing, dressing, feeding ourselves, getting to the toilet. All of our therapists work with the patients to do these things. Also, patients decreasing caregiver burden. This is a pretty stressful time for the caregivers, too, and caregiver burnout is a huge issue. So whatever we can do to minimize the amount of assistance that the stroke survivor needs will help in the long run.

And hopefully, we're able to safely transition these patients back to the community, and we're hoping to improve their quality of life by maximizing their function. Other goals-- we want to educate the patient to prevent another stroke from happening. They should know all the risk factors for strokes. They should know the signs and symptoms. They should know how to access care by the time they leave the rehab facility. And secondary stroke prevention should be on board by now.

Like I said, every patient is different. Every goal is different. Some patients want to return back to work. Others want to spend time with their grandkids. Everybody wants to walk. Everyone wants to be able to take care of themselves.

Now, this idea-- compensating versus recovery. So all patients want recovery. They want to use their hand again. They want to walk normally again. Unfortunately, in our current system, we're limited by time and resources. Like I said, the average length of stay is only about 17 days in an acute rehab hospital. So a lot of the initial therapies are kind of geared towards working on ADLs and compensatory techniques to get the patients home.

And the long term recovery, trying to get back to normal, in the patient's words, continues after discharge in the outpatient setting. So just compensatory strategies that our occupational therapists and physical therapists use-- hemi techniques, so training the patient to use their unaffected arm to perform activities of daily living. We can use different adaptive equipment to make dressing easier or getting to the toilet or eating easier. Orthotics to assist if patients have a weakness to walk. And of course, mobility aids-- rolling walkers, wheelchairs.

And goals. Every patient's different. Some want to get back to recreation. Some enjoy traveling. And in order to get there, we need to consistent goal-oriented therapies, and I'll talk about a couple of them. But first, I want to say, a lot of this depends on each patient. The motivated patients are easy to work with, because they're working outside the therapy hours and they're doing additional therapy. But it requires a lot of effort and a lot of patience on the patient and family's part. Recovery takes months-- years-- and it requires dedication on everybody's part. Because if a patient doesn't want to recover as much as our therapists want them to recover, it's going to be hard.

All right, so, it really isn't this easy, just taking a pill. I'll talk about serotonin in stroke recovery. It's thought to be involved in embryogenesis and organogenesis, so they've got neurotropic effects. It's also been shown to up regulate neurotransmission in neurons, so this is essential for long-term potentiation or learning and neuroplasticity. And obviously it improves mood, so a patient that's happy and motivated is going to do a lot better than somebody who's depressed.

So this was a flame trial that was done. It basically was a randomized double-blinded placebo-controlled trial that they did in France, but they looked at 118 patients with ischemic strokes, and the control group received a placebo. And fluoxetine was the SSRI of choice in the study. And so patients, within five to 10 days of the stroke, were either started on the SSRI or the placebo. Patients with aphasias or severe cognitive deficits were excluded from the study.

But basically, they used a Fugl-Meyer score, and they looked at hand function. And at the end of the study, the patients who received the serotonin re-uptake inhibitor actually did a lot better. Depression, of course, was less. And they thought this was due to increase hyperexcitability in the motor cortex and improvements in procedural learning.

Cochran Review looked at 52 clinical trials looking at more than just fluoxetine, and in all of the SSRI arms, there was increased independence and decreased levels of disability and mood was improved. Patients had decreased anxiety. This is just a funnel plot of all the studies looking at fluoxetine-- Celexa, Paxil, Lexapro. And basically all of them, regardless of which SSRI you used, helped.

Neurostimulants-- so these medications aren't quite as effective as far as stroke recovery. The data isn't as consistent as all the SSRIs, but amantadine has been studied in brain injury patients and its increased effect in improving concentration, attention. Bromocriptine has been studied in patients with expressive aphasias. In certain select patients, it has been shown to improve fluency and word-finding.

Modafinil-- really, the evidence is equivocal on whether or not that actually helps with any sort of long-term recovery and function. Ritalin does have probably out of all these the best evidence as f as whether or not it will help with recovery. And just taking a pill by itself isn't going to do anything. You have to take it within a certain amount of time that you're going to give the patient therapy.

This is a rat study that I thought was well-designed. It looked at controls, amphetamines, and also Haldol. Basically, they induced a stroke in these rats, and in about half of them, they put them in a constraint. So basically, they constrained their unaffected arm with a cast, and basically put them in an environment that they would do different tasks. And at the end of 12 days, they removed the cast. And they basically tested them at three weeks to see how they did on this test using a forepaw touch and how many times they would be able to tap the button.

And what you see is with all of the rats that actually got the constraints, obviously they did better than the sham group. But when you look at amphetamines, they were basically equal to the control group except for basically the second bar. It looks like there may be a little benefit in amphetamines means within the sham group. Haldol is sometimes given to patients for agitation, but it's been shown to decrease nerve transmission, so any sort of haldol or benzodiazepine is actually very bad for anybody with a brain injury or a stroke.

All right, so it's not just a pill. You've got to put in the time. And there's this idea of learned non-use in stroke patients. So you've got to use it, or you'll lose it. So most patients, if they're right hand dominant and they have a stroke that's affecting their left side, most patients are going to be able to get through their day using their right hand, and they'll tend to ignore the left side. And that basically just leads to learned non-use. And with that decreased sensory feedback, the cortical mapping within the brain is actually decreased. And neglect, unfortunately-- if the patient doesn't realize their arm is there, it's going to be difficult for them to use it.

So our therapists-- we can use task-specific repetitive training. This is basically a specific form of a therapy that focuses on motor learning by focusing on skills that are acquired with just repetitive tasks doing the functional activities that become more challenging over time. And the keys to this include mass practice, so you have to have huge blocks of time where the patient is specifically focusing on achieving a certain task.

Shaping is basically adapting the task to make it more challenging over time. So just tapping your finger over and over isn't I going to allow you to open a bottle. You have to make the task more challenging to have the patients improve over time. Intensity does matter. So the frequency and also the duration that the patients are doing the tasks, and this experience usually induces neuroplasticity.

So looking at squirrel monkeys, this evidence-- in the early '90s, they basically took squirrel monkeys, and they had them basically touch a textured wheel a over and over again. And then they used a--

**SPEAKER 2:** I think they're owl monkeys.

**ROBERT K. LEE, MD:** Oh, were they owl monkeys? OK. Well, the squirrel monkeys were involved in another study. So basically, they were able to map the sensory motor cortex of these owl monkeys, and they basically tested them pre- and post-training. And what they saw was-- in A up there, that was pre-training, and at the distal tip of their index finger, that was the area that lit up when they did the cortical mapping. And after therapy, you see how the similar area expanded. So this gave more weight to the brain being plastic and not static.

Here are the squirrel monkeys. All right. [INAUDIBLE], down at UT Houston, decided to test this in the motor cortex after inducing strokes in these monkeys. He basically constrained them and put them in a little body jacket to force them to use their unimpaired hand in half of these monkeys and basically put them through occupational therapy. And they trained them to reach into a little plastic container to reach pellets of food. And what he saw was in the monkeys that were actually trained-- as they gained skills, they would make these tasks more challenging.

So initially, the monkey could reach in with their whole hand and just scoop out all the pellets. And then he would make the hole a little smaller, so that he would only be able to put in a few fingers, and then eventually, the monkeys would only be able to put in two digits. And what he saw was, you see how they're very quick at picking up a skill when there's food involved. So the number of flexions that the monkey actually had to do to get that pellet decreased in all of the monkeys that were studied. So they were able to actually grab the pellets within just two fingers flexions, where initially the average was about 25.

And then when they looked at the motor cortex and mapped this, they saw that this area in red is basically the area that represents the digit, and you see actual expansion of these areas in the monkeys that were in the constrain arm. In the monkeys that weren't in the constraint therapy, these red areas actually diminished.

So translating this over to humans-- so the classic example of task-specific repetitive training is basically constraint-induced movement therapy. And basically, we use a mitt. We put it on our patient's unaffected e hand, and we constrain them to force them to use the hemiparetic side. The Excite trial basically looked at 222 first-time strokes and used constraint-induced movement therapy. And basically, the protocol was all these patients had to have at least some wrist extension and finger extension-- at least 10 degrees in both.

But basically, they were forced to wear this mitt 90% of their waking hours. So outside of therapy, the patients would have to do all of their ADLs-- feed themselves, try to brush their teeth, everything, with this hand, which can be pretty frustrating. So the patients that actually made it through this trial did pretty well, but the ones who didn't were usually pretty frustrated and dropped out. But basically, in addition to that, they got six hours of intensive therapy five days a week for two weeks. And it basically was mass repetition, forced use with more challenging tasks as the weeks went by.

And basically in the group that had constraints, the take-home point of this slide is, they had improved strength, function, and quality of the skill, and they were also more likely to use that unaffected hand. The big point is at 12 months, all of these effects from the therapy that they got during this two weeks were still there.

So in clinical practice, why don't we do this for everybody? A lot of patients-- they need to have some arm function, or else they're not going to be able to perform these ADLs. But also, lack of time and resources and reimbursement. So six hours of therapy would be fantastic if everybody could get it, but given our current healthcare system and resources, that's not possible.

So because of that, various modified protocols have been developed, changing the frequency, changing the duration, the length of time, that patients actually participated in therapy. Over the last 10 year span, there have been over 75 studies. Unfortunately, with any stroke rehab study, getting the numbers to power study is usually difficult. But there are 27 articles with Level A-1B evidence. And of all those protocols, the best outcomes generally were the ones that had at least two hours of therapy a day, at least five days a week for three weeks. And this is more possible in our current system.

When you look at functional imaging after a stroke within fMRIs. The basic gist of this is, there's overactivation bilaterally and on the affected hemisphere. So basically, overactivation-- when you ask somebody to just tap their finger, everything lights up, instead of just the focus. And when you take patients and do FMR studies looking at constraint-induced movement therapy versus conventional therapy-- conventional therapy using hemi techniques and still using the unaffected arm, versus forcing the patient to use their hemiparetic side, you see that on the top line is the constraint group.

And there is more activation bilaterally versus the conventional group, where these patients were right-sided hemorrhages. So the affected side is there on the left side of the scan. But you look and you see that on the affected lesion side, there's actually decreased activation when you ask the patient to use that hand. And that's thought to be due to this idea that both hemispheres are constantly inhibiting each other. So when you have a stroke, now there's an imbalance, and the side that is unaffected is inhibiting the hemiparetic side even more.

Task-specific repetitive training. So every patient wants to walk again the normal cycle. This is a busy slide, but at the top there, you can notice that the gait cycle is basically symmetric. So whatever is happening on one side of the body is just happening exactly on the other side, but 50% out of phase. And all of the muscles that are involved in ambulation are down at the bottom. But you should see that this is a pretty efficient gait cycle. Antagonistic muscles aren't firing at the same time.

Most of the force that's generated for propagation of gait is [INAUDIBLE]. So basically your Achilles tendon reflex is storing potential energy, and then it fires right at the end of stance phase. When you have a stroke, all of that symmetry is lost because of the hemiparesis. Muscles are firing at the wrong time, so you have co-contractions of muscle groups. You also have discoordination, because they're firing out of phase, and then some muscles are actually firing too much. So the spasticity of that can impair our ability to walk.

So normal humans are able to walk probably 80 to 85 meters per minute. When you see a stroke patient, generally they're walking about 15 to 25 meters per minute, and at the upper limits of that range, they're basically almost able to walk around the house with household ambulation. But by no means are they going to be able to cross the street during a walk sign or walk long distances, and this is due to the increased energy demands that are lost when they lose the efficiency.

Barriers to walking. So most stroke patients, if you brace them enough, you put them through enough endurance training, be able to regain some ability to walk. Limitations include standing tolerance. So a lot of patients initially, when they come to acute rehab, aren't able to tolerate just being upright, so that decreases their ability to actually get up. They're limited by cardiovascular endurance. They've got reduced walking speed, so a lot of patients aren't going to be walking long distances. And a lot of them do require assistive devices to get around.

Prognostic indicators. Purely motor strokes generally do better if they have intact distal strength. So if a patient comes in and they already have dorsal flexion and intact plantar flexion, we know they're going to be able to do pretty well and hopefully not require any assistive devices for movement. Intact sitting balance-- so within 48 hours after a stroke, if they don't have intact sitting balance, that's usually a bad prognostic indicator.

And then things that affect them if they have multiple things on top of the motor deficit. If they don't have the proprioception, if they don't have the sensory feedback, they're not going to be able to regenerate that walking cycle quite as easily, because they're not able to process the information with the repetitive steps that our therapists are trying to give them.

So in the interest of time, I'm going to skip through a couple of these, but focus on body weight-supported treadmill training. So the idea behind this is getting patients up and walking sooner than they normally would be able to. Basically, the idea is, you put them in a little harness and you offload some of their body weight so they're able to actually stand up. And you put them on a treadmill so you can increase the number of steps they're taking earlier on in rehab. This is generally well-tolerated by the patients. For therapists, it requires a lot of effort, so maybe not as well tolerated for them.

So studies-- basically, we looked at cats that had spinal cord injuries. And if you took the rats and you took their hind legs, put them on a treadmill, and helped them walk, over time they would be able to ambulate for short periods. So for these patients with strokes, they've done lots of studies on patients who are wheelchair bound and basically put them through these programs. And by the end of the studies, they're able to ambulate at least household distances.

And then let's speed this up. All right. So why do we not do this as much? Same thing as CIMT-- limited resources, limited time. It requires two to three therapists, generally, to perform these activities, and it's pretty labor intensive. It's hard on the therapist. It's bad for their backs. And even with treadmill training, the number of repetitions generally aren't enough.

So in comes the companies that want to try to capitalize on this, so there are robotic devices that are used. So on the left is the Lokomat, which is basically an exoskeleton that tries to mimic normal ambulation. Unfortunately, this was based on a Swedish gentleman who is about six three, so for a normal gait cycle for him, it's a little different than for our patients. And basically, it's a body weight-supported device with this exoskeleton that goes over a treadmill, and they basically help the patient move their hips and knees, and the ankle actually passively just goes along for the ride.

The gait trainer on the right is basically an elliptical device that tries to mimic the phases of gait a little bit better, so 60% stands, 40% in the swing phase. This has been compared to body weight-supported treadmill , training and based on their studies, they claim that it's equally efficacious.

Mass practice-- so, few patients actually reach the target heart rates that are required to build endurance, even with treadmill training. So there are new studies that have come out where basically, we're trying to maximize how many steps patients are taking during a physical therapy session and during their hospitalization, and we're basically forcing them to work at levels pushing them by increasing their target heart rate. And we can do this by just gradually using the incline. And these studies' initial results show improved cardio fitness, improved gait speed, increased endurance.

I just want to close with one example of what is possible. So this is Senator Kirk when he was getting rehab in Chicago. He had a pretty severe stroke. He was densely hemiparetic when he first came to rehab, but he probably got more therapy than most people will and in our healthcare system. So in addition to the three to four hours of inpatient rehab with our therapists, he also had a private therapist, there in yellow, that worked with him outside the regular hours.

And basically, he was put through several protocols, but by the end of the stay, he averaged probably 3,700 steps a day, and he probably went up 145 flights of stairs during the time that he was there. In addition to that, he got a lot more outpatient therapy based on his Cadillac plan. And afterwards, his big goal was to return to the capital, get up the steps, and go back to work. So he was able to do that.

And he also participated in a fundraising event for RAC. Every year, we have an event where we climb the Sears Tower, and he was able to do 37 flights of that. So most of our patients, because they're not going to have these resources, aren't going to be able to do this. But we know with enough therapy, neuroplasticity and motor recovery is very possible. So hopefully we'll see more of this available to the general population down the road.