[MUSIC PLAYING]

SAIF ALJABAB: For those who have seen some of these slides in the past, I've updated the last third of this talk-- I've updated it quite extensively. So I have nothing to disclose. I don't have any affiliations.

So this is really meant to be more of a superficial, hopefully, talk to bring everybody up to speed with the current status of proton therapy and particle therapy in general and for those who have some knowledge of proton therapy, just to introduce to some of the more advanced and newer technologies that are coming down the pipeline that are shaping the field of particle therapy.

And I think this is just a quick test to see if this response system works. So if you have it ready, we'll just do a quick question here and also participate.

[VIDEO PLAYBACK]

[MUSIC PLAYING]

[END PLAYBACK]

SAIF ALJABAB: OK. So it definitely works. The music is quite exciting, right?

SPEAKER 1: [INAUDIBLE] right-click. Right-click.

SAIF ALJABAB: Right-click, OK. OK, good.

SPEAKER 1: Then you can use the arrows--

SAIF ALJABAB: OK. And this is just for me to get a feel of how-- the experience of the audience I'm talking to. So--

[VIDEO PLAYBACK]

[MUSIC PLAYING]

Few people rushing at the end.

[END PLAYBACK]

SAIF ALJABAB: OK. Oh, nice we have some people who are-- so for those who have a very good experience with proton therapy, you definitely want to stick around to the end because that's where I'm going to talk about the more newer advancements in particle therapy.

So without further ado, I'll right-click here. So why talk about proton therapy at all? So there's definitely an increased uptake of proton facilities worldwide. And in the US alone, we're going up to 30 proton facilities. And a lot of the bigger centers are acquiring this technology. And a lot of newer-- fewer-- smaller centers are also acquiring it.

So I think it's important that we're all up to speed to what proton therapy is and what we'll offer for our patients because patients are more aware of this. They will ask about it. And you guys, being the forefront, seeing patients all the time, they might mentioned this to you or may ask you about it.

So I won't spend too much time in the fundamentals. So I'll go quickly over it just as a quick refresher and also to introduce some of you who are fairly new to the field. So particle therapy includes a variety of particles, as you can see down here. We'll talk mostly about proton therapy because that's the most common one used in the US. I'll go a little-- I'll talk a little bit about neutron therapy heavy ions such as carbon and helium. And for those who do not think they don't have any particle therapy experience, you actually do because electrons is actually considered a particle.

So a quick, short history. Ernest Rutherford discovered the protons back in the early 1900s. And then Robert Wilson described it for clinical use. And then the first treatment was at the Lawrence Berkeley National Lab. And they used pituitary tumors as a first site of treatment. Before that, the cyclotrons were used in the Manhattan Project. After that, they started to use it also outside the US. So Uppsala University in Sweden, where they used it as a neurosurgical tool, again, in CNS treatments.

The first FDA approval of this was in 1988. So this has been FDA approved for about 30 years. And the first hospital based proton facility was at Loma Linda in 1990. I'm going to stop over there. I'll talk a little bit more-- what happened more recently with proton development.

Just a quick talk about the basics of particle therapy interactions. You have ionization, excitation, and nuclear interaction. Most of protons work very similar to photons. That's through the indirect route to damaged DNA. The heavy particles rely more on the direct route. Also neutrons as well. And that's why their RBE is vastly more higher than proton therapy.

One of the key features of proton-- probably a lot of you have heard of the Bragg peak described by Sir William Henry. Bragg-- and this was basically the main feature of protons is that it has a very low dose entrance in the dose-- in the beam profile here. And it peaks at where the tumor is.

And to gain that coverage of the tumor that are 4 or 5 centimeters in depth, you want to have multiple Bragg peaks. And we'll just call this spread of the Bragg peak. So you can see here, just quickly, that the entrance dose is usually low for one beam. But you actually put it in multiple beams, that entrance-- those actually goes a bit higher.

Because of that key feature, there's two main advantages of proton therapy and in carbon-ion therapy as well. And I'll talk about both briefly. The first is reducing toxicity by just reducing normal tissue dose. And we know that there's definitely a dose response in general.

And we want doses to these normal structures to be as low as possible. We have those limits for sure. And when you say a mean dose of 45 gray, the ideal dose to that structure would be 0. That's what we want it to be. That limitation is just based on trials-- what we think is safe for the patient. But ultimately, having a 0 dose to that structure is the best approach.

And we know that there's definitely an increased risk of second cancers and cardiotoxicity. And that is why there's an initiative in the radiology world for imaging, where they actually try to reduce dose exposure as much as possible. So that is definitely one important feature of why people use proton therapy.

This is an example of a case-- a patient that had a simultaneous locally advanced lung cancer and esophageal cancer. And we were able to achieve a [INAUDIBLE] directly responsible plan for this patient. We met all the dose constraints for both the lung and the GI structures. And that's not something that we were able to obtain with regular VMAT or IMRT planning.

Because of that, we can also go into the second important feature of particle therapy, which is widening the therapeutic index. So if you go to the TCP/NTCP models, for your tumor control probability curve here, the higher dose you go in to improve your tumor control, you also increase the dose that can cause normal tissue toxicity.

So the idea is that you want to widen the separation between these two curves. And what proton therapy allows you to do is it allows you to dose escalate safely. Because of the Bragg peak, you limit the dose to the normal structures nearby. And we know that all the-- some of the recent studies-- or not the recent studies. It's been quite a while since these were published. But esophageal and lung cancer studies that dose escalated were actually negative-- not negative. It was actually more harmful to do escalating in these patients. And that's something that we want to avoid.

Some of the core disadvantages of particle therapy-- the first is the setup and range uncertainty. Particles are much more sensitive than X-rays. And that's just because of translational shift and organ motion. And it's estimated to be about a 3% difference plus/minus a millimeter.

And you can see in this illustration here, the photons-- in the photon world, if you have a shift in the tumor within the PTV, there's some changes you can see. But the 95% isodose line is ultimately not that changed-- but not that altered a lot. So you have still some good coverage. But in protons, you can see that the 95% isodose line shifts completely. And then you have some tumor within the low dose [INAUDIBLE]. So a proton is much more sensitive to these tumor motions.

One way to counter that effect is to do what is called robustness planning. So you do multiple plans with this same patient, not just at the base positioning but also do all the translational shifts and include range certainty. So you do plans that end up looking like this.

So you have a range of-- your deviation looks-- appears with a range. And you have a dose limitation for each of these ranges. And you want to make sure that the tighter these ranges are, the better for the patient. So that is one way that that is-- and you'll see-- you'll hear the word "robustness" all the time in the world of proton therapy, which we don't do necessarily with photons.

An interplay effect is kind of another segment of range certainty when you have organ motion versus a static tumor. You can see that there's a dose difference. And that is just because as the beam goes through the patient, the tumor is moving. And each beam [INAUDIBLE], when it reaches the patient, the tumor is in a different location. So that's called an interplay effect.

Another core disadvantage is the uncertainty of the radiobiologic effectiveness. Roughly, we say it's about a 1.1%. And so it's 10% radiobiologically effective. And so that's why we need to reduce the dose-- the physical dose by about 10%.

Another example being electrons. The RBE is actually 0.9. So you need to increase your physical dose by 10% to get the same radiobiologic effectiveness. However, that is a bit of a rough estimation with protons because the energy transfer is actually-- dramatically increases, especially at the Bragg peak and then after the Bragg peak. And so the range can actually go from 0.9 up to 1.7. So there is definitely some uncertainty, especially at the end range of proton therapy. And there's some clinical implications of that that I might go through later on in the talk.

Data. This is a-- I'm not sure why there's a-- oh, it's probably just automatically generating a response there. So data is a big factor-- a very big problem in the world of proton therapy. We don't have a lot of phase I-- sorry-- phase III, level I evidence for proton therapy. And there are several reasons for that.

There was a recent presentation over at the [INAUDIBLE] meeting in that all the NRG trials that included proton versus photon studies. And the two main delaying factors were that patients were not accepting the fact that they needed to be randomized between protons and photons. And the other thing is that there were some limitations from the insurance policies. So their insurance policy would just not pay for protons even if the patient was on a randomized study. And so there's a very slow accrual for all the major sites that have phase III studies.

But there's a-- don't worry about reading this. There's a huge number of phase III studies and phase II studies that are ongoing. A lot of the newer guidelines are endorsing the use of proton therapy. And I've actually listed indications to when to use it best.

This is probably the biggest limiting factor with proton facility, which is the high cost. And it could range from $200 to $350 million US. And it's a huge burden. Although the cost effectiveness-- there's been some studies saying that, because you reduce toxicity in the long term with a lot of these patients, you might actually end up saving money. But still, the upfront cost is very, dramatically high, which limited the number of proton facilities in the past.

So some of the-- some of the past key features of particle therapy or proton therapy facilities I'll talk about in this segment here. It's a very high-cost endeavor to go through building a large facility, again, between $200 and $350 million US. It's a very large facility. This is the example of the Seattle proton facility. Because they're so big, they're usually far away from the main campus.

It requires a lot of maintenance. They actually have an on-site engineering team to do ongoing maintenance. And it's not just the upfront cost of it is high, but also the operational cost is quite heavy too. A big part-- the main reason for that high cost is the cyclotron, which is the main or the core component of a large proton facility.

The very first cyclotron was developed in 1932. And it was quite huge and big. These are some of the new modern proton or cyclotrons. And to accelerate-- to accelerate carbon ions, you need a synchrotron, which is a bit different. And these cyclotrons can accelerate particles to about 2/3 of the speed of light. And you can treat patients-- patients with tumors up to 31 centimeters in depth.

A lot of these old facilities have multiple rooms connected to the cyclotron or synchrotron through a shared beam line, as you can see here. And as you can see, if the beam line is affected, then all four rooms are down. That is usually the typical structure of a large facility.

The delivering system-- the proton delivery system is a passive scatter system. So basically, you have what is called a range modulator to modulate the energy of the proton beam. And then you have it scatter some things, just like when you use a linac in an electron mode, you have a double scatter.

And then you have an accessory to limit the penumbra or the lateral field edge of a proton. That's called the brass aperture or the collimator. And then you have also compensator, you can see here, to limit the distal edge of the proton. So you can end up with a dose cloud that covers the target with some-- it's good conformality. But you can see there's a lack of proximal conformality with the system.

To develop these accessories, you need a milling room with some heavy machines. That adds to the cost of a facility. And so these are all custom-made in the milling rooms. And inside the treatment room, there's the treatment head that contains both the nozzle and the snout. The snout contains the slots for the accessories to be put in. And these are put in by the therapist. So there's a lot of manual labor.

A lot of these proton facilities had a fixed beam from a fixed angle like you can see in this room. It just-- the beam just comes from one side. And most proton facilities-- these larger facilities were built this way with mind to treat prostate cancer patients because you can treat just two lateral beams-- one from the left. You move the patient around and then treat another beam from the right.

A lot of these facilities had basically just kVkV imaging, no advanced imaging at all. Some of the clinical applications of protons back in the 1990s and a little bit afterwards. Mainly prostate was a big focus back in the day. You might not think of it much today because we have IMRT and SBRT and all that. But back in the old days, as some of you might know, we used to treat these with four-field boxes. And this was much more appealing for patients than a four-field box.

Pediatrics-- we've been treating pediatrics for a very long time. You can see here the dose difference between a VMAT CSI and a proton beam CSI. I won't go through the clinical data, but that's why I'm not going to talk about all the text here. But feel free to read it later on. I think this is published. [INAUDIBLE] the presentation will be available online.

And then you have here the CNS. There another site that-- remember the first treatment site was a pituitary tumors. But CNS has been treated for a very long time with protons. And you can see here in this last line of images the dose difference between the proton and the photon plans.

And ocular melanoma-- if anyone's ever asked you is there any phase-- is there any randomized data for any particle therapy? You can say, yes. Actually, this is one site where we do have randomized data. And actually, it was with helium ions versus iodine plaques for choroidal melanomas. And we actually also have a randomized trial looking into different dose regimens for proton therapy. So it's been a course site that we treat with proton therapy.

So that's all what's been done in the past. Let's talk about some of the newer changes that kind of formed the field a lot. And we know that-- I showed you this graph earlier. So there's something that happened between 2000 and 2010 that caused an exponential increase in the number of proton facilities worldwide. And that also includes the United States.

And so I'll talk about some of these advances. The first thing is pencil beam scanning. So we talked about the passive scatter. The best way to compare them is a spray can versus a spray gun. A spray can paints layer by layer. The spray gun does the same, but within each layer, it also slowly goes through it and then as you can see in the image, paints it spot by spot within each layer.

And the way to do that is just to get rid of the scatterer and then put in magnets to bend the beam. And for that reason, you can get rid of both the milling machine and all the accessories related to it. And what this helps is you can actually improve conformality with-- using pencil beam because you can now control all these weight spots within your target. And you can now improve the conformality even from the proximal side. You also get rid of all the accessories that can cause neutron contamination. And this was a study that showed that with passive scatter, you have a lot of neutron contamination. With proton pencil beam, you lose all that contamination.

Cyclotron size-- so you can see with time. This is probably the biggest-- one of the biggest changes in the world of proton and particle therapy in general. The same goes for a carbon ion facilities. So we have these large facilities. These large cyclotrons weigh about 700 tons. The IBA, in 1996, about 200 tons. The Varian, about 100 tons in 2005. More recently. We have about 50 tons of much smaller cyclotrons and down to-- up to less than 20 tons that some companies were able to achieve.

So these cyclotrons are much, much smaller. And what that has caused is that now most of the-- most of the companies now offer single-room options because of that. And actually, the first FDA-approved single room was in 2012. So we now have all these single-room proton facilities that have dramatically improved accessibility to this technology. And this is caused a decrease in footprint, energy usage, capital costs, operational costs, and operational staffing. So you have a huge advantage in reducing the size of a proton facility.

You now have access to both full gantries and half gantries. This allows more freedom in terms of planning and planning patients. These gantries are actually quite huge. You can see here that's the treatment room. And these can be 30 feet in diameter, 120 tons in weight. So they're actually now more heavier than the cyclotrons.

Some of the companies have adaptive apertures or dynamic apertures. So you don't-- the benefit of having a passive scatter system is that you can actually control a number of very well. With some of these newer single-room treatments, they have the capability to sharpen the number as we already have a very good Bragg peak effect. And now we have, actually, a very sharp number as well. So it definitely improves conformality even more. A lot of these new facilities also have access to new modern imaging IGRT options, like cone-beam CT, CT on rails. Surface guided radiotherapy is also in the mix there.

Monte Carlo calculations. So this has actually been widely-- most centers have used-- started to shift over to using Monte Carlo calculation as opposed to pencil beam algorithms. And that's because it's just much better in terms of calculating the dose cloud within a homogeneous patient. Especially in head and neck, lung and in chest wall treatments, there's a dramatic change actually when you use Monte Carlo calculations. And that definitely improves the range certainly. So it decreases our uncertainty with the range. And you can see down here that that 3% does not put into account all the inhomogeneity that's going on. With Monte Carlo, you can really strict that uncertainty.

And a part of that is also mixing it with multi-field optimization as opposed to a single-field optimization. So now you can actually optimize each beamlet individually. And you can combine it into this dose cloud here that's very conformal. And this is what we truly-- this is what's called true IMPT-- Intensity Modulated Proton Therapy.

So as an example-- I think this was presented recently in another meeting-- this is CSI with proton therapy. But what we can do now with protons is not only we can do a very nice CSI plan that can spare a lot of the normal structures, but we can also do a kind of a proton plan that spares certain structures within the brain. So in here, we're actually sparing both the pituitary hypothalamic axis and the hippocampus.

And you can see here DVH comparing both. There's still good coverage. And you can see your hypothalamic pituitary. Mean doses from N of both hippocampal mean doses are dramatically reduced.

Another capability is we can now combine different particles together. So in this study, we've actually done neutron therapy for adenoid cystic cancer, and we did a proton boost. Or you can do even a gamma knife boost. And so you can actually mix and match these particles. In some other centers, they're using carbon ions with protons-- protons being the main treatment when you do a carbon-ion boost. And that just allows more flexibility. And you can actually with carbon ions and neutrons take advantage of that RBE and then not take the normal structures to a high dose.

So some of the newer sites-- some of the new clinical sites that we're treating with proton therapy nowadays that we did not do as much back in the 1990s-- so head and neck. You can see here the difference between the photon and proton plan. There's a lot of unnecessary dose within the oral cavity, definitely in an area patients are not happy about. And now you can understand why patients would refuse to be randomized. Like, why would a patient want to get dosed to the oral cavity? So that's always been a problem with all these phase III-- all these phase III studies.

Breast is another site where you can see the difference. It's not as much as of a difference. But hard doses can be dramatically reduced when you use a proton plan versus all different modalities of photons, whether it's 3D conformal, VMAT, or [INAUDIBLE] therapy. So you can see the differences in dose there.

Chests, lung cancers is another site where we can reduce the dose to the contralateral lung and heart. And I showed you that initial case where there was both a simultaneous lung and esophageal cancer. We're doing more treatments in lymphoma former patients. We actually can now combine protons with breath hold techniques. So we actually can reduce the heart even further more and get very beautiful DVHs. The GI-- we can use it both in esophageal cancer and hepatocellular carcinoma. And especially in the larger tumors, HCC, where you cannot do SBRT safely, proton therapy is very good in terms of sparing the normal liver.

So all what I mentioned was actually what is presently available and all the vendors provide all that technology. So that's actually not-- that's not what's new with proton therapy. So what I'm going to mention now is actually what's coming down the pipeline. And a lot of this might seem like science fiction, but it's actually not. And that is just because we're entering a very weird era.

That's at the airport in Singapore. If you ever want to visit, it's pretty-- a very beautiful airport. So the very first thing that I want to talk about that actually will affect the entire field of radiation-- not just proton therapy, but definitely, proton will be affected about it-- and that is automation through AI and robotics. Now you probably have noticed this in your life. So you've noticed a lot of the manufacturing, agricultural jobs are gone through AIs, I'm sorry, through robotics. And if you've ever been to Las Vegas, you'll notice that MGM actually kicked out all their bartenders because now they have robotic arms that do all the drinks for you. So they took their jobs away.

The Roomba-- you probably-- you guys have some Roombas doing all the vacuuming for you at home. These self-driving vehicles. And if you go to, let's say, an airport or if you go to, let's say, McDonald's or any other store, they have all these self kiosks that you do everything. Nobody really takes your order anymore.

Call center-- you know, if you call customer service, you get this annoying bot that you just press 0, 0, I want to go and talk to a human. Nobody really wants to talk to a bot. But in a couple of years, an AI will actually just-- hello. Hi. How are you doing? What can I do for you? That's how it's going to be. It's going to be indistinguishable.

This-- she's a-- I think her name is Shudu. She's a model on Instagram-- 200,000 followers. There's another one with 1.6 million. She's not real. She's an AI visualization-- an AI that creates visualization. So she's doing all the modeling for all of these social media.

So there's a lot of developments, and you can Google all of this. It's all available online and all the achievements of Boston Dynamics and Hanson Robotics and IBM Watson. Do you remember the first time you watched videos with your phones? That's the era of the 3G. So now we're rolling into-- a 5G network will actually, exponentially enhance data sharing and will actually facilitate a lot of this technology to be implemented.

So Bloomberg actually produced this chart talking about the potential of automation of tasks in different jobs. And you can see in the left spectrum here, these are the most vulnerable-- on the right spectrum, is that correct? Your left? These are the most safe from automation. And the general rule is that any kind of repetitive task, whether it's cognitive or manual, can be easily automated. And all of these jobs are actually already taken away through automation.

And you can see that medicine actually is on the left side of this chart. But actually, we're not entirely safe. It's not a safe haven. So what about automation in medicine? One thing is biometric verification. So I don't see why there's a reason why two therapists at this end of the consult say, is this patient XYZ. Oh, yes. Are we treating this site? That's the MRN.

My phone has biometric capability. It can identify my fingerprint. It can scan my iris. Can do facial recognition. I don't see why there's no reason for today's modern vaults to have just a panel to identify patients. And that technology does exist.

Medical scribes-- Robin is actually a medical scribe that can do everything for you. It can generate notes. It can do billing. It can generate documents. So it's like an Alexis-- or what is it called? Alexa. Funny thing as well, in preparing these slides, I actually got an email from the Royal College of Physicians and Surgeons in Canada. They have a task force regarding-- regarding emerging AIs, asking for some input on how it'll affect the training for new medical physicians.

We're going to talk a little bit more about medicine. There actually is an autonomous robot surgery that looked into suturing pig's gut and compared it to humans. It was actually much more accurate and much more consistent. In the world of medicine also-- if there's any one medical specialty that would disappear in the next coming decade, it would probably be diagnostic radiology.

So this is actually a published study that compared accuracy of human readers versus machine learning algorithms. This was done with skin pigmented lesions. And they found that the AIs were actually much more proficient in diagnosing and identifying lesions the same as well as for diagnostic radiology.

And radiation medicine, oh, boy. If you go to the meetings, there are so many publications on automation, whether it's in the planning phase or the segmentation QA phase. And I highly advise that in your meeting, you actually have a talk dedicated for this because there's so many publications, I cannot go over this. I'm just bringing it upfront to your awareness that there is a lot of ongoing automated-- automation publications out there. And a lot of people are working on this.

And just an example, here is something that we do over a Roswell is-- this is not an AI. It's a bot that's running a script on MEM, where it does autosegmentation. So it just kind of puts all these contours from a huge library. And then it just puts on contours at the end. That's the final product. It's not perfect. But I think we're getting there, hopefully, in the next couple of years.

So this is not-- this is not an AI. And AI would be me going to a computer and saying, computer, can you please run this sequence for patient 2237, head and neck. And the computer would say, yes, sir. I will do it. And it goes and just does everything-- import the scan, do autosegmentation, put in the fields, do optimization, generate the documents, do a QA even. And they'll come back to me and say, Dr. Aljabab, your plan is ready. Can you review it [LAUGHS]?

And I'll review it. And I'll, like, I'll say, I actually do not like it. And actually, there's three more patients. Can you please go do them simultaneously? And the computer will say, yes. Sure. You please have a good day. And it'll go on and just keep on doing the plans. So that's what an AI would do.

I won't talk much about this. I know the next speaker, [INAUDIBLE], will talk more about FLASH radiotherapy. This is definitely a very hot topic. And the world of radiation and proton therapy is no different. There have actually been some publications using FLASH radiotherapy. And just a quick, basic definition is just it's ultra-high dose rate that's given in less than a second.

So if you think about the traditional radiotherapy, we give treatment over several minutes. This is giving the entire dose-- typically the minimum range is about like 40,000 centigrade within a second. So you put the patient on. And within a millisecond, the treatment is done. So that's what's called FLASH radiotherapy. And there's actually an entire machine that they're developing dedicated to that. And you should look it up. It's called the PHASER. It's a very interesting device. And so there are many publications. I have actually treated a patient using FLASH radiotherapy. So I think that's coming up in the next talk.

Particle immunotherapy. So you've probably heard of immunotherapy. We're using it now in conjunction with particle as well. This was a patient that we treated with neutrons and immunotherapy. And we treated these lesions in red. And you can see that the blue tumors here responded as well, an abscopal effect, or I like to call it in situ vaccination. And so we're combining a particle with a high RBE with immunotherapy. And we're getting some good responses. So that's also coming up down the pipeline.

Does anyone know about 5DCT? No? So it's a five-dimensional model. So it takes into account some of the variations in-- within imaging sequence. So instead of doing 10 scans within each phase, you're doing 10 phases. It uses a fast helical scan and does 30 scans while the patient is doing a free breathing. So you do 30 scans. And then you generate from a reference point-- you generate an entire scan that is not 4D. A little similar to 4D, but it has a fifth dimension to it. And that includes the geometry and the breathing amplitude and rate.

And the reason we do that-- the advantage of that is that even when you do a 4DCT scan, you can sometimes get these cutoffs that are not very great. And that can affect the planning when you-- and remember, protons are very sensitive to changes. So that's an interesting thing that's coming. Actually, this was developed back in 2005. So I'm not sure how far they got with this technology.

Real-time adaptive therapy. I won't talk too much about this because I'm running out of time. But basically, why do one plan and then fit that patient to that plan every day if you can generate a new plan each day for the patient and treat the patient with that customized plan? The issue, of course, is the time to generate a new plan while we're setting up the patient.

And that's why this is also related to automation. They're doing a lot-- there's a lot of publications on deep learning and where machines are actually learning how to autocontour and plan on spot when you put the patient on. And fast adaptation-- the conclusion of all these studies is that it can be achieved within three minutes. So within three minutes of putting the patient on, it's able to recontour. You do cone-beam CT. And then you preferably would have a better imaging device. And then the machine will do the contouring and then planning.

We talked about the radiobiologic uncertainty, especially at the end of the Bragg peak. And so some of the new dose algorithms actually look into LET. And that is actually a very useful tool because we can use it in conjunction with Monte Carlo calculations. And we can-- it can help us identify areas at risk when using proton therapy because right now we're kind of eyeballing a plan and kind of estimating, oh, OK. Where's the Bragg peak-- where's the Bragg peak ending? And what structures are we concerned about? Well, with this, you can actually visualize the area that is at risk.

ProtoArc, which is similar to VMAT-- and the benefit of using ProtoArc with pencil beam scanning is that you can improve the conformality even further more. An example here is a unilateral head and neck. You completely spare the opposite side with proton therapy. But the parotid is still being-- getting a hefty dose. So with ProtoArc, you can actually improve that proximal conformality where the beam is entering to the point where you can spare that parotid on the ipsilateral side.

And here, you're comparing SBRT with VMAT. And you have here a ProtoArc. Can't be better than that, where you have a very low dose-- very small area of a low dose path while getting extreme conformality.

4 pi radiotherapy-- this I think also [INAUDIBLE] will talk about in the next talk. But it's basically using noncoplanar beams. If you ever have a CyberKnife machine, it actually does that. It gives you a lot of these noncoplanar beams that improves conformality. So having that fifth degree, that will also help proton therapy. If you have photons, you can actually use this. And it's actually called the cheap man's protons because you can get extreme, good conformality with using just 4 pi with photons. And so this is an example of a 4 pi with photons. This is not proton therapy.

So there's a lot of other things. I didn't talk about helium therapy or stereotactic ablative or nanoparticles. 3D printing and hyperthermia-- there's a lot of-- newer technologies are coming down the pipeline. I just don't have time to talk about all of them. But it is interesting field that's exponentially growing for sure.

This is just a-- just to see what you all think as an audience. So I'll give you a moment to read through those options. And then I'll run the audience response system.

[MUSIC PLAYING]

Oh, wow. OK. OK. That's interesting. So a lot of you think that automation is going to be a big part. And I agree, actually.

OK. So this is going to be an interesting one. Will automation negatively impact our job market? Yes, very much. Yes. Maybe. No. It will actually improve the job market. So--

[MUSIC PLAYING]

Oh, OK [LAUGHS]. OK. So a very-- a huge majority-- oh, interesting. I'd like to see the opinions of this. But there actually is a thought of artificial augmented intelligence. So instead of using AIs to do our job for us, it'll just help us do our job better. And there is definitely a group that's trying to implement it-- implement AI in that way.

But your concerns are definitely understandable. And just to give you some statistics, the prediction is that in the next 30 years, 44% of all jobs will be automated. So that is a prediction. Of course, it's not reality. But it's 30 years, and a lot can happen in 30 years.

OK, let's right-click here. So in summary, proton therapy is a growing field worldwide. And the technology is evolving rapidly. It is not for everyone. We do need to carefully select patients for it. There's a lot of phase III data that's ongoing. And single room proton therapy provides state of the art proton technology at 80%, 90% of the cost.

[MUSIC PLAYING]