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Automation in radiation oncology

Dr Petit: Good evening. My name is Steven Petit, and my presentation will be about automation in radiotherapy. So, today I will show you that already a large part of the radiotherapy workflow can already be automated, for a large part of the patients. Namely, all the boxes that you see here in green or greenish. But not without effort, dedication, program expertise and the right tools. So, a large part can be automated, but it takes effort. So more specifically to the contents, first of all, I'll show you more about rationale for automation and we will talk about automation of workflow steps, and with specific attention for auto contouring and automated treatment planning. Then I will talk about automation of the workflow, which is different automation workflow steps, because it means that steps are automatically started off first steps or ended. Then, something about quality assurance, which is really important for automation. And a couple of words about artificial intelligence, which is a very hot topic with respect to automation. So, rationales for automation. There was a review in 2013 by Moore and Med Physics, and it named five reasons, and I think they are correct, were why automation would be very worthwhile. First of all, its productivity. Its ultimate task can do something fast in human camp or can do it in the time the human can do something else, we can prepare more patients at the same time with the same number of people. It could also mean the availability goes up, for instance, for instance if with ultimate task patients can be scanned or processed faster their availability goes up because they are treated earlier. Also, reliability of automation tends to be a bit higher than reliability between two different users. For instance, in some case, the performance can go up by automation because there's no inter-server variation anymore and you can treat more patients with the same number of resources. And also, probably the costs will go down. So, automation of the different workflow steps. So, these are, in a relatively schematic way, simple way, all the different steps you have in the radiotherapy process. Making a C.T. scan, contouring OARs risk, contouring the tumor, expanding the PTV margin, treatment planning, plan approval by a physician, all kinds of plan checks, independent dose calculation, and import in the RVS. So, whether a certain activity be automated depends on different factors. So, first the solution is known. Namely, that is known how something should be automated, for instance, the PTV margins there are mathematical description about how you should expand certain restrictions 3D with a certain margin. So that's solved. But it should also be available in clinical software and if it's not available in a clinical software it should be able to be programed in house in the same way. So, only if the solution is known, if it is available in a clinical software or it can be implemented safely it can be automated, otherwise it cannot. So, if you work through all these steps, I think that CT scanning cannot be automated to initial therapy. It is very easy, very straight forward, you cannot automate it. Contouring. Although there is a risk. I will come to that with more details, but I think that to a large extent, we are there, or we are almost there. Contouring tumors and CTV on the other hand, I think there has been

some attempts to do that, but we are far from automating those processes. It is too difficult at this point in time. PTV margins is easy. Treatment planning, I will also go in more detail. It is also a solved issue for treatment sites given that you have the right tools and right protocols. Plan approval by physician, that is something that is not automated today in most of the clinics, I know at least. But it is something that, if the wishes of the physicians can we expressed in a clear and concise way it probably could be automated as well. Plan checking. Whether plan needs surgical material that can be automated, independent dose calculation. Including making an automated comparison between the treatment plan and independent dose calculation can be automated importing it into the radio, verified system as well. So, here are some instructions about asking questions during the presentation. You can use the Q&A button, send in your questions and comments and we'll discuss them at the end of the presentation. So, let me now go into a bit more details about auto-contouring. Basically, there are two methods for auto-contouring and the first one is atlas-based. And atlas-based means that you try to find for a new patient, a patient that was treated before and delineated before, that's more or less similar. This is a schematic picture on how we can do that, looking for a patient that looks a lot and resembles a lot your current patient and you could try to deform one patient to the other and also deform their contours with the other's. Or you can do it with multi-atlases, where you repeat this process for multiple times, and get multiple delineations, and you can get some contour consensus' so based on, so, the idea of this is that if you have outlier with one atlas patients you might not have that outlier in the other two atlas patients if you go for the majority of delineations. Or you can select the best atlas, or you can select the best atlases. So, there a couple of ways, it is very nicely described in a paper written by Schipaanboord in 2019. But none of this will lead to perfect results. An alternative, which has become very popular now is deep learning based contouring which is a form of artificial intelligence and the idea is that CT scan, for instance, with no-delineation and all the CT scans with delineations are being processed in a network, which contains a lot of layers and delineation comes out. This is a process that typically needs between tens and hundreds of patients and if you have them, it works very well and here are some examples by zone and you see here in green, called standard contour, segment contouring and in reds the results of automated delineation deep-learning network. And you see they resemble pretty well, there are some deviations, here and there, but in general it's all pretty good. These are some examples we acquired in our own group where you see in green the reference contour and in red the deep-learning contour and also in these cases it goes pretty well. There was a recent paper in the group from the MAASTRO where they compare atlas-based contouring with deep learning-based contouring. You see here in blue the atlas-based, in yellow the deep learning contouring compared to red, the standard contour, the physician contour. And also, here, you can see deep learning, it doesn't do its job perfectly, but pretty well, and better than atlas based. This was a study by the University of Groningen and here you can see the comparison between all different organs and in green means is deep learning is better, orange means atlas contouring is better and blue means there is no difference. And also, in the far majority of cases, depending on which metric you use you see that deep learning over-performs, atlas-based, contouring. So, you saw in the previous slide that deep learning is not perfect yet, but how accurate should it be? And this is. And this is an interesting example, I think, on how accurate it should be. What you see here is the average dose distance relation for 50 lung cancer patients. And you see on the x axis, the distance from the PDV and on the Y axis the dose normalized to the prescription dose, and this means that, for instance, that at a distance of 10 centimeters from the PDV average dose in the lungs is about 10 percent of the prescription dose. So, you could use this kind of graph to get a feel about how big the effect is of delineation. So, say you have an organ, which is located at one centimeter from the PDV, which is two centimeter wide. Then, the average dose to that organ will be somewhere about 40 percent of the trial dose those. Let's say you make a very big delineation error, and overall, on average, the organ you delineate is one centimeter bigger in one dimension than the actual organ is. So, it's a big mistake. So, 50 percent is more or less. If you then look, what's is the mean dose to that organ, it's about

thirty six percent of the prescribed dose, only a three percent difference compared to the prescribe dose, which is one point eight Gy, 60 Gy. So even if you can, you can have a very big delineation errors, in this example, for instance, but the effect on your dose is relatively limited, and especially for the organs that have mean dose constraints tend to be pretty forgiving for delineation, for instance. So, for max dose, it can be different. If the delineation error would be in this direction, maximum dose would be effective, more. For me knows it's pretty much forgiven. So, I think that is something to keep in mind that we try to delineate very accurately. We are very picky on how well automated delineation software does it. But in general, the dosimetrist consequences of contouring inaccuracies may be affecting others. So, I think that that is a challenge to actually translate for certain patient delineation error into the effective dose. But I think we're pretty close to automating that contouring process, at least for these treatments. So, now, automated treatment planning. So, here is again, the instruction for asking your questions. There was a review in 2008 which describes that basically three different methods for automated treatment planning. First is protocol based automatic iterative optimization, for instance, Pinnacle auto plan. And that's a very difficult phrase, which basically means it basically means mimicking what a human planner would do in a treatment. The second one is knowledge-based treatment planning, for instance the Varian RapidPlan, package does that. It tries to predict what is possible for certain patients given patients that were treated previously. And this third method is Multicriteria optimization and it's something that was created by Erasmus-ICycle and is now being purchased by [Audio not clear]. So, the pinnacle auto planning method, which is the first one, what it basically does it mimics manual treatment. So, in this example, there are six optimization loops. For excessive constraints, the first optimize the target homogeneity and optimize OARs that it fine tunes OARS, optimizes fine tunes/add OARs. It's basically automating what a planner will do as well. And it's relatively effective and I think a lot of institutions would really benefit from using this automated planning. So, it's really automating what a manual user would do already. With knowledge-based treatment planning that the concept behind that is the second method at the dose distribution that you could come out only depends on the patient anatomy. So patient anatomy could be one on one related to the dose distribution. The only thing is we don't know what is in this black box that describes the relation of the dose distribution of the patient. And the idea of knowledgebase treatment planning is that if you have a lot of patients that go into the black box, a lot of dose distributions come out and you could use that information to see what's in the black box in order to predict what is possible for new patient, when dose distribution is possible. If you know what is possible, you could use that very easily to state the optimization algorithm in that way in automated treatment planning. So, and in fact, there was a recent study that came out that shows that entire Pareto front, which describes how good a treatment plan can be, is only determined by patient anatomy, which is which is logical in a way, but it is not also as shown. So, let me give you an idea about how you can try to fit what's the model within the black box? So, on the left, you see a new patient with PTV in blue and you see the rectum in red. And if you would take a certain voxel of the rectum, if, for instance, at five millimeters from the PTV, you can do that for all voxels, and you get distance histogram. This histogram describes how far the voxels of the rectum are from the PTV. Some are within the PTV, some are far away from it. And if you make a cumulative histogram out of this, you've got support data on what it's called in literature overlapped volume histogram. I'm sorry, overlapped volume histogram. And the idea behind this is, this line describes how close an organ is to the PTV. So, if it's more located on this side than this means that this patient is more difficult because the organ is closer to the PTV, than the patient in green, which is further away from the PTV. The further you go away from the PTV, the lower the dose will be and the closer you are to PTV, the higher the dose will be. So, this DVH, which is a measure of patient anatomy says something about what's the achievable dose to the rectum for the particular patient with DVH diagnosis. So how could you use that? In this case, you could calculate this overlap volume histogram and if you have a database of prior patients with all their deviations, also from those you can calculate overlap volume histograms

so they can compare to similar patients. And one of the ideas of this is that say, here the overlap volume histogram again and in grey, you see all different prior patients. So, all the patients that are on this side from the current patients means that their organs are closer to the PTV of the current patient, which is blue. So, for these patients, treatment planning would have been more difficult than for the current patient in blue. And then, if we looked at the deviations of these old patients, you can see that they may lie here at this point and because people are more difficult at all points and gravitation means that's what you could achieve for current patients should be somewhere along this line because older red patients are more difficult, so you could do, at least as good as the red patients but this line then becomes your prediction, and if you have a prediction, you could use that very effectively to directly steer your optimization, because you don't need to say to your optimizer, give me a mean low dose, a mean rectum dose that is responsible if you just going to give no more, it actually comes from addiction, which is, for instance, 30 Gy. And that's much easier for optimizing. And there have been various papers about that, for instance, head and neck, prostate, another one on the head and neck and that and this method is very popular. I think it's used in a lot of clinics, especially [Audio not clear] users are using it and it works relatively well. The disadvantage is that you need to have a database of prior patients and you need to train your model. I think most institutions do that by themselves. So, quality of the treatment plan you get out also or it depends on the treatment plans that were inside your database. So, say, if you would have very bad treatment plan database, maybe also your new treatment plan for new patients will not be so very good. So, the third method is what we've used in the Erasmus-Icycle, and that makes its multi criteria optimization and it makes very clear distinction between constraints and objectives, with priorities and uses the so-called wish list. Here's an example. It's just this is a hypothetical example. So, the constraints are always met, for instance, and in this wish list it says its final cord dose should be below 50 Gy, brainstem always below 50 Gy and the maximum tumor dose less than 107 percent prescription. And then it contains objectives in order of priority, and the first one is maximize PTV homogeneity, and then the second one is minimize spinal max cord to 20 Gy and minimize brainstem to 20 Gy and the fourth, minimize spinal cord dose to 2 Gy and minimize brain stem dose also to 2 Gy. And what the optimizer first does in the first run it maximizes PTV homogeneity and whatever it reaches, it makes that a constraint. And so, using what is left, it tries to minimize the second objective and then reached a certain value, for instance, twenty-three Gy, then it continues with the brainstem. And this is a way where if you can beforehand specify what you really find important in terms of sparing your spinal cords, your PTV and your brainstem it’s an effective way to actually to plan that really represents this kind of trade-offs specified beforehand. And that's also at the same time, the challenging part of this, because the wish list requires from the physicians to specify priorities and in our experience that is possible, but it's also challenging because you really ask questions that are difficult to answer. For instance, here minimizes spinal cord to 20 Gy, is that is it really you want to go to twenty Gy or maybe to twenty- two Gy or maybe to 18 Gy or please give me a number and then I can I can make wish lists. That is a process that requires typically some time. Once you have it, you also know that all plans that come out fill this wish list. So, here's some example. So, this is that one of the wish lists we actually used in 2012 with the system and here you see it was a prospective study with 20 patients, the iCycle plan versus dosimetrist Monaco IMRT plan, and the physicians selected blindly the best plan. And in 70, 97 percent of the cases, physicians preferred the automated plan compared to the manual plan. So, this actually shows there was quite a bit of potential. And in the meantime, we've also demonstrated it works very well for lung cancer, for prostate cancer, even in a multi-centre validation study, and also for cervical cancer. So, we're using this routine. So, the instructions. So, I talked about optimization to workflow steps, mostly auto contouring and automated treatment planning. And I think for a lot of cases, this auto contouring is very close to being solved and automated treatment planning is already solved. Given that you have either, for instance, if you make a protocol for your Pinnacle type of solution, you have the patients with the model for your variant type of solution, or you have the

resources to make the wish list for your solution. It will definitely not work for all patients, but I think for big group of patients, it actually works great today. Now, I will talk about automation of the workflow, this is different from automation of the workflow steps. So, because what it means is that if you want to automate a workflow, you need to be able to start the step and plus one automatically after finishing step. And so, make this bit more concrete, say your n minus one step is generating your GTV or PTV, your n step is making a PTV and then the next step is planning. So, to actually automate the workflow means that the system you use that after it automatically generated PTV, it should automatically start treatment planning. So, it can, ultimate the PTV part is easy, ultimating the planning part can also be done automatically, starting the planning after you generate your PTV. That's a bit that's a bit tricky. So, I tried to make a decision tree here to see whether it's possible or not. So, if so, what is required that this step, the n plus one step should be independent of new user input, just if it requires user input and automated. And meaningful user input, that's not known at this point. So, if it's performed in the same program or some software as a step one, and it helps, but also the program should be capable of starting step medically. For instance, I know that's identical phrase, but also ray station F.D. scripting interfaces, where you can script part of the workflows and automate part of the process. But if you have a system where this doesn't work or if step order who doesn't work is also the question, so if you if they are not performing the same program, then the question is, can this program of step one stop automatically the program of the next step? Or is there a third external program that can start both step n and then step n plus one. And that can be automated. So, to give you an idea about how we're doing it at my hospital is ever workflow management system, which is a commercial system, and it just contains the steps that everybody needs to do for every patient. And this system can communicate using HL7, which is like a messaging protocol to sample our program. The problem is that a lot of these, which is very nice for automation, but the problem is that a lot of these things cannot receive these measures or read these messages. So, what we have done, we have created some kind of shell which will party exchanges in our developed software. This is a matter of configuration programming based on the messages we receive. We send tasks to, for instance, the automated contouring software we use and to do automated plan checks. And dose calculation is being reported back to the workflow management system. So, for instance, at this point, the physician finishes plan approval. Then automatically the plan check is being started and the results are sent back to these workflow agencies. And this is a way how you can actually achieve that. You can automate parts of the workflow, which is more complicated than just automating the different steps. So, to give you an idea why it's complicated to automatically select a step. So, for instance, if you want to do atlas-based auto delineation, that requires a protocol because you will use a different protocol if you would try to delineate a leg, then when you would delineate a brain. So somehow the system needs to know giving a set of input parameters, what is the protocol I should use? So here's an example of how things are being followed, the system and sorry it’s in Dutch but it shows, for instance, if it shows the tumor type, so say it's a cervical tumor and system needs to know okay it’s a cervical tumor, but depending on the patient position, you should use the female pelvis supine protocol or the female pelvis prone protocol. But are there also lymph nodes that are a bit higher up in the pelvis? Also, for you, maybe you should use an extended contouring. So, there's all this type of configuration and logic that is required in order to ultimate the workflow, because you need to not specify beforehand what a certain step should be able to know, as input once the previous step finishes. So, if there's no user in between anymore, everything should be protocolized or on-figure, and that's typically requires programming. Another example is PTV margin. It's very easy to automate because tools are already there, but it's difficult to configure because, for instance, for lung cancer patients, PTV margins may depend on the breathing attitude. So, in order to ultimate that, systems should know what the breathing attitude is or what the online set of protocol or automatic set. So, it's a bit difficult to configure, then there are always unforeseen situations of bugs that shouldn't delay treatments and manual backups should always be available. So, automation is nice, but it will never work for all patients.

So, this is a very important point. So quality assurance. Quality assurance is important if the user doesn't have to play a role anymore, for instance, for auto contouring it can be visual inspection, so are the contours okay or not. And that's an effective way of quality assurance. But for treatment planning, it's more complicated. For instance, these are DVHs of rectum patients and for all patients, this is the best plan you actually can get. The variation is large even though all plans fill the constraint that is here. So, if you just check whether it's within the constraints, it's not good enough, you need to have independent checks. And based on that, we showed that with our own treatment system automated, on if you use independent deviation, you still select outliers that could be improved, also preplanning. And also, we did the same for the Pinnacle auto planning system and there we found that depending on the institutes, the data came from eight percent or twenty five percent of this plans to be the improved. So, so that's important to keep in mind. Its quality assurance becomes much individual quality assurance, much more important if you automate. I was developed software in two thousand twenty-one, there will be a new legislation, the EU medical device regulation and basically if software as a medical device, MDR applies, this has a huge impact on any in-house software you're building. Because it's a there's lot of additional work. To arrive at the last point, which is artificial intelligence. So, there was a recent review paper in Nature about artificial intelligence radiotherapy. Basically, it said that a lot of the steps in the process could be artificial intelligence driven decision imaging, treatment planning, you name it. But AI is very powerful. This is an example of auto contouring, how it would work well. This is an example where it's being used to de-noise MRI scans that you see also here it works well. And this is not really unpredictable or, you can at least compare the original image, the new image with the original image. But if you're going to use it to pimp up the quality of your CT scan to planning CT scan, you're introducing contracts that are not really there. So, that's very difficult to tell because is this really a muscle or is this really a tumor. If you don't see it there, how can you know that this result is correct? Especially because we know that deep learning-based type of imaging modifications can really need to be perfect, well, training, contain some data training doesn't know. So, I think there you could and the method, you could divide and having mild consequences or severe consequence errors. And then if errors are detected and if there's time to adapt. So, for instance, everything within this blue field, I think artificial intelligence is really, it may be the way to go. For instance, auto contouring, the consequences can be big if you make changes. But errors are can easily be detected, and there's always time for modifications. Also, for de-noising, the consequences could be severe, but you could easily detect if the original image. However, by generating a CT scan from a common CT scan, can lead to severe consequences and it's very difficult to detect because you don't see the tumor in the scan how do you know if deep learning didn't imagine it. And also, in terms of making prognostic models, it's also you have time to adapt you detect errors and consequences as well. So, I think all applications within the blue contour are very interesting for artificial intelligence while the other ones are much more tricky. So, for the AI, the main challenge is limited predictability, and it's manageable if errors are detected and can be adapted, but that means that the correct answer is unknown. So complex, the complex task for AI creates new knowledge. So, to conclude. Most of the individual radiotherapy workflow steps can be automated for a large part of the patients. But automating of the workflow meaning that automatically the next step starts as the previous step and that's far more challenging. It requires the correct tools, correct configuration correct programs. There are always exceptions, so we should always have a manual backup, quality assurance, automated steps and in-house software is very important and will become even more important. And AI is very powerful but at the same time you should be careful, know what you're using it for, and whether you can detect errors. So, thank you for your attention, I will be happy to answer questions.

Prof Franco: Thank you very much, Steven, for this very clear and talk and this very fascinating topic. So, there is no question coming from the audience, so I would call him Dr. Zeverino to start the discussion, Michele please.

Dr Zeverino: Yeah, thank you, Steven, it was really interesting. Just one of your first slides concerning the steps and different steps in automation. You put in yellow this type of contouring the PTV tumor and PTV. And so, I see what you meant and but what, in this step, I think there is a sort of sub-steps which is hidden, and it is the legislation of multimodality images. So, do you think that there is room for automation for this task or at least I would say we can automate the QA procedure for this task, such as implementing the TG 132, for example.

Dr Petit: Yeah. So, I didn't mention the multi, about [Audio not clear] just to stay in time more or less stay in time. And I think that a registration process could be automated in most cases. But I think even in case, if even with the best scan and the most and the best MRI scan that you may have, it's very difficult to, what to read, which it's very difficult to really automate that GTV, let alone the CTV, what we don't see. So I think it could help in making the first suggestion, in coming five years or so, I think suggestion always be checked by an expert, maybe use as a starting point for delineation to really do that automatically, I really don't see that happening .Also because the validation is really difficult.

Dr Zeverino: Yeah, that's why I was saying maybe a QA. It's difficult the QA as well. Yes, you're right. You're right. I agree with you. Yeah. Yeah. And concerning the automation in treatment planning. Do you think because, actually what we are adding in literature is the only concern, I mean, well let's put it this way - maybe when large variations, anatomical variation, occurs, do you think that automation can lose its powerful? Let's make a clear example: breast treatments. For breast treatments we never use a single arc, so we don't optimize only the fluence. We only have to optimize, let's say, the geometry for this patient. Which never occurred when you do h and then the treatments, the neck you put an arc, you put your thumb, which is rolling around your patient. So, what about what's you're feeling about that? Do you think that for this? Because if you think about that, in literature there is a very few literatures concerning the few examples concerning the breast.

Dr Petit: I'm not an expert in breast treatment planning myself, but I know there are a couple of studies by or at least one already used in clinical auto planning to automate their breast treatments.

Dr Zeverino: Yeah also in another location there is a model, which is based of Francis Margarite Hospital algorithms.

Dr Petit: So, in that sense, I think that works relatively well. It also will work if you have patients that have anatomies that are deviating a lot from the patients the model was based on. And it may not work so well anymore, I think. Maybe that is a bigger challenge even for the knowledge-based treatment planning done for the type of mimicking use our treatment planning that's clinical dose.

Dr Zeverino: OK.

Dr Petit: Does that answer your question?

Dr Zeverino: Yeah, the real question was, do you think that automation can improve the selection of the correct entry angles? It's more like that.

Dr Petit: Yeah, I think it could.

Dr Zeverino: OK, it is something based on the model that the on the model, the patient models, I mean, the population that the patients that populate the model with you. Maybe this is something that can award.

Dr Petit: I think it depends a bit on the method of automation. But if, you know, if you could program an algorithm that selects the best beam angle or the best aperture.

Dr Zeverino: Yeah.

Dr Petit: And you could also automate it. Whether certain commercial packages capable of doing that. I'm not sure. But that's what I meant in one of my first slide in part of the solution is known. So, if you know how to do it, if you would have the programming expertise, etc., that's one thing. But also, it should be in a program. You should do it yourself in order to be able to use it.

Dr Zeverino: Yeah, I see what you mean.

Prof Franco: Yeah. Can I make a comment because like I was thinking when you were discussing about this, like, don't you think that it's just a matter of being able to stratify correctly the anatomical characteristics of the patient and the requirements to properly treat from a dosimmetrical point of view the patient? And I mean, if you're able to correctly identify the category of patient where you are single, specific, patient belongs, then you can just, like, easily be able to automate the solution. I mean, like probably there's, it's more difficult to have like a standalone, like a single solution. But then if you can clusterize and classify properly a specific category of patient, then you can just allocate your single patient to that category and find like, your specific individualized automated solution for this patient.

Dr Petit: In principle, the only difference between patients, from a planning point of view is their anatomy. So, what you can achieve only depends on patient anatomy. So if you can find out what that relation is and in the paper we published on the Pareto from the prediction, we show, it's relatively simple that you with some relatively simple geometric measures, at least for rectal cancer patients, you could with prostate cancer patients, you could exactly determine what is possible based only on the patient anatomy.

Dr Zeverino: Yeah, maybe the question I'm looking at time, you spoke in the end of your presentation about the AI. What do you think, well better, where do you think AI can be used right now in a safe way? You know, in all the steps that you have mentioned, if there is something that we can, a step we can use it safely.

Dr Petit: And I think if the model is being trained, is being trained well and checked by a human then I think it can be used for automated deviation. Given that you have a well-trained model. And that's because you will check the errors and you can modify the errors and the errors will be detected and there's time to adapt. I think those are the two main important things. So, it can be, I think it will be relatively easy to use for tasks where the user itself knows the right answer. We know if it's correct or not, if you have time to adapt it and then it's fine. But if one of these criteria are not met and it's more tricky.

Dr Zeverino: Thank you very much, Steven.

Prof Franco: Steven we have a question coming from the audience. I would take the chance to ask you about that. So, the audience is asking your opinion about the entity. So how widespread is the use of automation in your country, in the Netherlands? So how is it spreading clinical practice?

Dr Petit: I would say that the institutes that have [Audio not clear] probably only use Racket's plan for at least part of the treatment sites, in term. I think a lot of institutes use auto contouring, but it'll be mainly atlas based and artificial and deep learning is getting there. So basically they're using it in a way, they use it for all to contribute but then modify the contours needed and I think for the automated checking of the plans, and that's I think most of the institutes will have some parts automated, some parts manually. We I think that are a couple of what we have, not entire nations at least, entire plan checking by physicists and ultimate those calculations fully automatically. If we do a gamma analysis on the statistics, and if its green on the screen then the physicist doesn't need to look at it anymore. And I think there are some issues that may also do that for some treatment sites that are familiar. I hope that answers your question.

Prof Franco: Yeah, it does, does thank you. Thank you, Steven. So, Steven, I was kind of fascinated by the, the point where you talk about the automation of the whole workflow. So, the automation of the workflow in the radiotherapy processes relies on the fact that what is done before the next step is correct, right. So, as I could get from your talk, there's no way to check if the results are correct of the previous step that. Am I getting it right or no? So, how do we check the quality of the previous step when we need to proceed with the forthcoming steps

Dr Petit: I think if there are consequences for making errors, it makes a lot of sense to be checked. So, for instance, if we would have automated treatment planning, I could ultimate that and then it's finished and that's being sent to your workflow management system. Ideally, that should start automated QA for a specific, automated treatment planning QA for specific patients. Meaning that it should start these algorithms which to send checks if you want to detect whether the protocol, actually one of the best, is actually very good. But if you have to send detects, you could automate that. So, and then there are the maybe all the steps were direct verification, it's not maybe necessary as long as it's being verified, couple of steps further or down the process. For instance, if it is incorrect or was not done for some reason and then the automated treatment plan is started as long as a physician then looks at the plan to check whether the plan is fine, then he or she will notice that it is not. What was not created, for instance, so the step could also get further down the, further down the line. I don't think you need to really check every step right after it's finished, but, as long as this is being checked, if there are consequences.

Prof Franco: So I mean, like one of the key points is like to be able to very precisely analyze all the steps and then and try to come up with a decision which step can be easily automated and safely automated with no quality check and which are which are, need to be properly checked in order not to have errors down the road. Oh, that makes sense.

Dr Petit: And it's also how good you want to be for instance, if you have automated treatment planning, then you check if the plan fills the constraints, that could be good enough because filling the constraints means filling the constraints. And that's a you could easily do. But that doesn't say where for that particular patient, it's really the optimal plan because for some patients, the rectum is further away, and you could do much better than your constraints. While if it's much closer than you may your constraints may not even be feasible.

Prof Franco: Makes sense. Thank you. Thank you, Steven. Michele any other burning questions?

Dr Zeverino: Yeah. That's why it's important to have a Pareto plans, Pareto optimization in order to avoid any suboptimal plans. And then it helps in this way in this world.

Prof Franco: Ok, guys, I feel like we are done with the time. It’s being a very, very interesting session, very fascinating topic. Very, very educational talk from Steven. And I thank you, everyone, for joining. And thank you, Michael and Steven.

Dr Petit: You're welcome.

Dr Zeverino: You're welcome.

Prof Franco: Have a good night.