RaySearch Americas User Meeting 2021

# Friday, December 10

### Welcome to the 10th RayStation User Meeting

### RaySearch Roadmap

RaySearch’s ultimate direction is harmonized functionality among all aspects of RT, from CT to any tx modality.

The RaySearch portfolio consists of the following four products:

* RayStation
  + Planning system
  + Featured updates
    - Support for more delivery devices
      * Radixact
      * Cyberknife
        + Since v9B
        + First tx, for mets, was this year
    - Chemo planning
    - Dual-layer MLC
      * Useful for, e.g., Halcyon
    - ROI protect for VMAT
    - Synthetic CT from CBCT
      * Almost diagnostic quality
    - Deep learning automated planning
    - Multimodality deep learning segmentation
    - Support for tx chair
    - Task integration w/ RayCare
* RayCare
  + OIS
  + Includes RayTreat
  + v5B comes out 12/2021
  + Featured updates
    - User-configurable documents and workflows: create your own and modify RaySearch’s
    - Interface w/ Truebeam 3.0 software
      * Coming spring 2022
    - RayCare Flow: tx planning workflow automation suite
      * RayStation + RayCare and RayCare PACS workflow mgmt.
      * You can create/modify a workflow for each tx site
      * Supports scripting
      * Can ignore PACS if you don’t need a dedicated RT PACS
* RayCommand
  + Tx control system
  + Features
    - Replace tx machine control console
    - Online adaptive for any technique and modality
* RayIntelligence
  + Cloud-based oncology analytics software
  + Quarterly instead of annual releases
  + v1D coming 1/2022
  + Contact your biz director, product mgr, or acct mgr to try RayIntelligence

### RaySearch Partners

RaySearch partners with academia, industry, and clinical.

RaySearch adheres to the vendor-neutral IHE-RO for optimal integration of its products with products with other vendors. This includes:

* Technical IT
* Sales
* Support
  + QA. E.g., a Scandidos support agent should be able to support a clinic with both RayStation and Scandidos products, and vice versa.

The IHE’s mission: Clearly defined & automated info exchanges among hardware & SW systems

Systems that RaySearch products must integrate with:

* HW/physical device
  + TDD
    - Photon partnerships: Accuray, Shinva, United Imaging, Varian
    - Proton partnerships: IBA, AVO, Hitachi, MedAustron, Mevion, ProNova, Sumtomo, Toshiba
    - Neutron partnerships: Neutron Therapeutics, TAE Life Sciences
    - Brachy: Eckert & Ziegler (Bebig)
  + imaging devices (CT/MR)
    - Partnerships: Canon, Fujifilm
  + in-room imaging system (CT/MR)
    - Partnership: VisionRT
  + patient positioning system
  + motion mgmt.. system
* Control room
  + TSM
  + TCS
* Clinic-wide SW systems
  + HIS
  + OIS
  + QA meas/calc
    - Partnerships: IBA Dosimetry, Scandidos, PTW
  + PACS
* Contouring system
* TPS

RaySearch has no defined partnership with Elekta, but they are considering starting a TDW-II interface. A TDW-II interface is an IHE-RO standardized tx delivery workflow that connects the TDD to the OIS. To streamline this partnership, mention it to your Elekta contact!

#### Audience Questions

1. Does RayStation support Varian HyperArc?

HyperArc is a tx technique that uses multiple couch angles in a single beam. The beam stops while the couch moves. This not yet supported in RayStation.

### RayStation 2021 and Beyond

New features in v11A:

* Photon Monte Carlo on multiple GPUs
  + I don’t think this applies to us. We do not have multiple GPUs on our physical servers, and we’ll likely never move to virtual servers (although there is more info on the latter later in this document)
* New framework for GPU validation
  + Also N/A
* Improved Cyberknife planning
  + Requires a separate license so that 11A could be released before RaySearch got FDA approval for this functionality
* Nominal dose per beam
* Tolerance table mgmt
* Guard leaves for DMLC
  + 10B supported IMRT and VMAT
  + I wonder if it uses the same method as my script
* Restrict collimator angles when using smart angles for conformal arc

Some of the ERs implemented in 11A: Multiple Rx’s, tool to help upgrade scripts, Cyberknife planning, ComboBox filtering in more places

Some new features in v11B: CBCT conversion, persistent ROI viz settings, EQD2 dose calc (for brachy)

11B will be released in Europe 12/2021. As soon as it receives FDA clearance, it will be released in the U.S. They once got clearance in nine weeks, and 11B doesn’t have any *major* changes.

ML is a separate license so that the main product can be approved more quickly. The ML update should be available around 3/2022.

EQD2 clinical goals can be added only for brachy.

There are two more deep learning models: 4x and H&N.

Persistent settings include colorwash!

ROI name mapping means many of my TG-263 naming script ideas are unnecessary.

I once really goofed by deleting approved plans. Nice to have a safeguard against that.

The dose rounding will save dosimetry time by not having to manually fix daily dose in MOSAIQ.

We need full elemental composition for the brown solid water (cheese phantom)!

Always view the release notes for later versions to ensure you don’t submit an ER that’s already been implemented.

### Research Update

Note that much of the following is not clinical! But it is coming up soon.

RaySearch has three departments: research, development, and ML.

If you want to help try to find jaw optimization that improves Elekta, email RaySearch.

Automatic target selection is cool.

Another IHE-RO feature (though it doesn’t apply to us): can import Vision RT clearance into RayStation

What version is the collision detection in? That’s not research’s call, but they guess around a year from now.

New support for MR linacs:

* Beam modeling
  + Prototypes for Unity and MRIdian
* DL segmentation
* Workflow (e.g., adaptive planning)
* Synthetic CT from MR

Also very cool: image conversion. Could we use this to test every day whether we need an adaptive? I’m thinking of things I’ve heard about automatic daily adaptive. Another way this could be useful: I contoured on some CBCTs for our structure templates. Not fun.

Hyperthermia optimization. Also doesn’t apply to us.

Optimize and calculate dose using different voxel sizes.

Scheduling algorithm. This is a variation on a classic problem in computer science.

### RaySearch Machine Learning Update

The department consists of three teams: imaging, planning, and analytics. Analytics only works on RayIntelligence. The department’s work is 90 percent product, 10 percent research.

To introduce ML, they used the classic diagram: deep learning ⊆ ML ⊆ AI

Consistent training data is essential! An example is naming conventions.

Segmentation and planning in the same system allow full automation up to plan review. For example, run a script overnight and review the generated plans in the morning.

DL segmentation will soon include:

* User-created models that allow you to configure what organs to include
* The new models will be released back. So as long as you have the license for DL segmentation, you won’t have to upgrade RayStation to get them.
* Other imaging modalities (e.g., MR)

DL segmentation takes around a minute.

So weird that some features use TG-263 naming while others don’t. I wonder if this is because TG-263 names are only in English while RaySearch products support multiple languages.

Since v11A, the results of DL segmentation are stored for analysis of user changes to automatically segmented contours.

Case study: DL segmentation reduces contouring time per patient from 45–60 minutes to 10–15 minutes.

DL segmentation is a separate license, but each DL model is not.

Do not train your own models! The presenters really emphasized this with the following points:

* You’d also have to validate them.
* Data augmentation, such as image rotation and scaling, is performed on training data.
* Unlike with atlas-based segmentation, your own clinic data does not go into models. It’s more like MBS, whose data comes entirely from RaySearch.

Case study of prostate plans: 72 of plans were accepted over human-created plans.

Unlike MBS, which is free, rayMachine license is volume based (# pts).

RaySearch is investigating federated model sharing. This could use RayCommunity to distribute models, but clinics should not share their own models. RaySearch is also investigating federated learning.

#### Audience Questions

1. When will synthetic CT support other image modalities, and CTs with contrast?

RaySearch has encountered no problems with using synthetic CT from images from contrast. This is likely due to data augmentation before model training. The MR model is FDA cleared but not released in the software. The model has been trained on yet other modalities.

GPU is necessary for DL segmentation and DL planning.

### QA, Physics, and Scripting

#### Lung target delineation

Tumor board: interdepartmental mtg re pt cases

Chart rounds: Oncologist RT plan peer review

To enhance and speed up collaboration between ROs and radiologists, print a physical copy of some images from RayStation. This script is available from RaySearch.

#### Scripting environments

Share scripting environments using rsbak files.

A virtual environment consists of:

* Hardware
* Abstraction (e.g., VMWare virtual machine)
* OS
* Applications

A virtual environment with GPU consists of:

* Hardware
* Hypervisor
* Nvidia virtualization
* vGPU
* Graphics driver
* OS
* Applications

Things to install to host RayStation in a virtual environment:

1. Server
2. VMWare (costs: enterprise licenses)
3. OSs
4. GPU drivers (costs: vGPUs, license server)
5. RayStation

An application layer allows you to group installed programs onto the VM. An application layer needs:

* OS (Windows Server)
* RayStation
* MS Office
* Drivers
* Etc.

To update all apps on the layer, just update the layer.

Virtual environments with application layers can help avoid build drift and enhance security across RayStation servers and enhance security (e.g., protect against ransomware). Here’s how to do it:

1. Start with a VM. You can do this using ESXi Hypervisor to divide your hardware into VMs.
2. Set up the VM the way you want every VM set up (e.g., add an app layer).
3. Use certain Citrix software to build a golden image of the VM.
4. Every day, when everyone logs off of the VMs, wipe them and replicate the image and propagate to all VMs.
5. Make and test any changes to the golden image before propagating.

#### ML to predict patient QA results

It’s useful to determine in advance which measurment QA plans are likely to fail. Reducing the number of QA plans you actually shoot has several advantages:

* For urgent new starts, such as sim and treats, adaptive plans, and next-day starts, when there may not be time to shoot QA and give dosimetry the appropriate feedback about a failing QA plan
* Save time in general
* Allow residents to focus on school instead of routine tasks like QA
* “If you have physics assistant doing that, you can save money.” Good thing this MPA does other things, too. :)

Obviously, skipping *measurement-based* QA is not the same as skipping QA all together. Whether or not you perform measurement QA has no bearing on your decision to perform 3D dose reconstruction and log file analysis.

Their RayStation script that creates a QA plan also exports the RTPLAN to their REDCap database. The app itself uses Streamlit, a Python package that allows you to build data apps with no web programming! (I briefly looked into this, and it looks *amazing*!)

The training data had ≤3 percent error. Their clinic policy is to measure any plan that may have ≥4 percent error, so they measure anything with predicted error ≥1 percent.

The model has been used in two other clinics, which decide not to measure if the MU calc is below a certain threshold. One of these clinics uses the app retrospectively, the other prospectively.

##### Audience Questions

1. Does the model predict which plans won’t mode up on the machine?

No. Instead, in the presenters’ clinic, as each issue comes up, they find the root cause and automate resolution using a RayStation script.

1. Is ML really necessary for this?

The researchers have also published a paper using a non-ML model, which had more false negatives than the ML model.

1. What measurement method did the research use?

They only used ion chamber measurements; the model only predicts point dos. But the literature shows that similar models work with other measurement methods. Not only that, but you can use a pre-trained model of a method that you don’t have. For instance, we could use an ArcCheck model to get approximate ArcCheck results.

##### Customizing the RayStation Experience through Scripting

This presentation was just some cool scripts from the Inova Center Cancer Institute.

* Naming standardization: namer GUI
* DICOM Tag Manipulation
  + Replanning/copying
  + Plan export w/ DSP dose rounded to the Rx
  + CT duplication w/ unique UIDs
  + CT extension
* Aria access & oncology services used w/ RS
* Portal dosimetry
* Automated TPS QA

#### Maintaining Plan Quality when Switching to Monte Carlo

The clinic switched from Pinnacle pencil beam collapsed cone to RayStation Monte Carlo. They imported several Pinnacle plans into RayStation and recomputed the dose using MC in order to investigate the effect of MC simulation uncertainty on PTV dose homogeneity.

The results obviously differed, but this is to be expected even if the same algorithm were used, because the beam models, etc. are different in Pinnacle vs. RayStation. The difference due to these other factors should disappear with re-optimization. Yet it didn’t: the MC hot spot was higher than the CC, and this is not due to the fact that CC reports dose to water while MC reports dose to tissue.

The difference in hot spot appears to be due to the fact that the PTV (geometrical) extends into air and/or bone while the CTV/GTV (clinical) does not. This was fine when everything was dose to water, but now that we use dose to tissue, bone or air inside the PTV makes it harder to achieve coverage, leading to excessive renormalization and thus a higher hot spot. In other words, the optimization increases the fluence in order to get dose in order to achieve dose homogeneity in the inhomogeneous PTV.

Other than moving away from PTV-based planning (discussed in a later presentation), you can get around this problem by planning robustly, putting bolus of tissue density in the inhomogeneous areas of the PTV, and increasing the number of arcs.

#### Optimizing the Optimizer

This was my favorite presentation. We never think about multiple optimization *cycles*, but this is evidently just as important asthe number of iterations per cycle.

There are many ways to optimize, such as NTO, dose fall-off, and rings.

This research investigated the effect of number of iterations, number of iterations before conversion, number of cycles, and intermediate dose computation, on optimization speed, dosimetric quality, deliverability, delivery time, and plan complexity (and thus gamma). The number of iterations per cycle was held constant.

Ideally, an optimization is “fire and forget”: the only post-processing is normalization.

An optimization consists of three parts:

1. Iterations before conversion: Setup. Machine parameter optimization. Optimize fluence at 15 static beams, 24 degrees apart. Convert this to two to four degrees.
2. Optimization according to objectives and constraints
3. Final dose calc: Last five iterations

Every time you click **Continue**, a new iteration cycle (the above three steps) starts.

Optimization speed, as evaluated by CCC on GPU, is affected by:

* Target volume (positive relationship)
* Dose grid size (positive relationship)
* Constraints are slower than objectives

Optimization speed is unaffected by:

* Number of objectives
* Number of iteration cycles. Keeping a constant number of iterations in step (2) of each cycle, optimization appears fastest with three to five iteration cycles.

Target dosimetric quality, as measured by coverage (V100%) and hot spot (%V>105%), is affected by:

* Number of iteration cycles. A single iteration cycle (what we use!) means poor dosimetric quality.

Target dosimetric quality is unaffected by:

* Whether intermediate dose is computed. (RaySearch recommends disabling it.) There was some difference for Parotid\_R and Larynx, but I recognize this conclusion as a statistical error called the multiple comparisons problem. When so many statistical are performed, you should expect *α* percent significant results.

OAR dosimetric quality is affected by:

* Number of iteration cycles. Average OAR dose is lowest with three to four cycles.

Plan complexity was measured by the following factors shown to affect gamma pass rate:

* Modulation factor = total MU ÷ dose
* Plan average beam area (PA)
* Plan average beam irregularity (PI)

Modulation factor is unaffected by number of iterations.

There is a positive relationship between number of cycles, and PA, and a negative relationship between number of cycles, and PI.

Most of the variance in plan complexity was caused by plan type (e.g., H&N).

Forty to 60 iterations (two to three cycles) produces the best tradeoff among the factors studied.

GUI to make choosing the number of iterations and number of cycles easy for the user.

##### Audience Questions

1. Could it actually be the number of times the machine is optimized (number of iterations before conversion) that makes the difference?

Possibly. This and the number of optimization iterations were held constant in this study; the number of cycles was the only change. But the effect of number of iterations on the factors studied is worth investigating.

1. In my experience, constraints take longer than objectives in optimization. Was this your experience?

This study only used objectives, no constraints.

#### Head and Neck VMAT Planning with Robustness against Shoulder Motion

Even with patient immobilization, shoulder motion for H&N plans can exceed 15 mm, causing statistically significant dose changes. The maximum motion in the study sample was 32 mm (!).

This was a retrospective study that investigated the magnitude of inter-fraction shoulder motion when using various techniques to reduce this motion. Shoulder displacement is defined as the online match shift to the C-spine, less the offline match shifts to humeral heads. Shoulder rotation was ignored.

Of course, shoulder motion depends on immobilization setup.

The following types of plans were compared for the 10 patients in the study:

* BASE
* 2–3 coplanar arcs
* Obviously, the dose goes through the shoulders
* SHOULDER PRV
  + Create a PRV structure for each shoulder by extending the humeral heads superiorly.
  + Max mean dose constraints for the PRVs
* SHOULDER PROTECT
  + Instead of max mean dose constraints, use the Protect function on the shoulder PRVs to prevent dose from entering inside the PRVs.
* SKIP ARCS
  + Avoid arc segments around shoulders
  + Only 2 patients, not all 10
* SHIFTED-ISO
  + Shift the iso superiorly (to the top of the target instead of the center) to avoid beam divergence at the shoulders
  + Only 2 patients, not all 10
* COUCH-KICKS
  + Rotate the couch 10–15 degrees to avoid shoulder-target overlap
  + Use partial arcs to avoid collisions
  + Only 2 patients, not all 10

As expected, the shoulders were better spared using either PRV strategy than using the base plan:

The PRV strategies also yield more robust target coverage as measured by an eval PTV 3cm thick at shoulder level.

##### Audience Questions

1. Did you try combining the two PRV approaches?

No, but we should.

#### Adaptive Ablative Radiation Therapy to Restrain Everything Safety Treatable (ARREST)

The researcher presented his “new paradigm” (building on the CE-7 and COMET projects) for treating multiple simple targets across a large volume instead of just one or a few complex, more localized volumes, specifically for palliative polymetastatic CNS tumors with SABR. There are existing phase 2 studies for 10 lesions, but this study looked at >10. The five patients in the sample had from 24 to 50 (!) lesions.

The SABR plans used several consecutive regions, each with the adjacent region as background dose. It evaluated OAR dose as composite, but still ensured that each target in the region got the full dose planned for that region.

The island effect causes MLC modulation to be small.

They used beam set dependency (as in brain SRS), RayStation’s Treat functionality, and co-optimized beams/regions. (Note: Their version of RayStation supports only two co-optimized items at a time.)

A single fraction was sometimes split over multiple days because setup took 45–50 total minutes due to tasks such as 4DCT imaging and changing the iso in the middle of the tx.

#### Robust Optimization with Multiple CTs to Account for DIBH Variation in Pancreas SBRT

A retrospective study compared robust optimization to PTV-based planning for pancreas SBRT.

It used 33 Gy × 5 fx. Four DIBH CTs were taken at sim because the free breathing difference for pancreas is much too high for SBRT.

PTV-based planning addresses systemic uncertainty while robustness addresses random uncertainty as well. This is especially important in the IS direction.

PTV-based planning is problematic for pancreas:

* The CTV is not guaranteed to be contained inside the PTV.
* The PTV margins add OAR dose. The OAR proximity in the abdomen makes this more likely.
* The plan is rarely conformal to the PTV or uniform around the CTV.

Robust optimization balances target coverage robustness and OAR sparing by accounting for setup uncertainty, organ motion, and density errors.

The dose was perturbed 2 mm all directions and on all four DIBH CTs. These optimized plans were compared to PTV-based plans, via clinical goals.

There were more obvious differences for the robust evaluation. Even simply copying the beams to the other CTs and not using perturbation, robust is still better:

# Saturday, Dec. 11

## New Functionalities in RayStation

These presentations were on new functionalities in v11B.

### Synthetic CT

I missed the beginning of this staff presentation, but it was a detailed look at the synthetic CT functionality introduced Friday morning.

A new image type, converted image, was introduced in RayStation. This image type is non clinical, so you can only calculate *approximate* dose. To make the image clinical, you must approve the deformable it is based on, the ROIs it depends on, and the image itself.

The user must commission each image conversion method in RayPhysics for each anatomical region it will be used on.

Image correction takes around two seconds, and the corrected CBCT looks a lot more “CT like” than the original CBCT!

If you use an FOV, you can replace parts of the corrected CT with parts of the reference if those parts are unavailable in the original CBCT.

A virtual CT requires a corrected CBCT.

The virtual CT tools are similar to the current deformable registration tools. E.g., you can compare the differences (usually just anatomical—i.e., if there *are* anatomical differences between the reference CT and the CBCT).

The following functionality is only in the research phase:

* DL image conversion (e.g., CT to MR)
* DL img painting to remove artefacts and other non-anatomical features that hamper other algorithms’ performance

#### Audience Questions

1. Can I use a Tomo MVCT for image conversion?

The clinical implementation currently only supports CBCT, so if you can tag the MVCT as a CBCT, then you should be able to create a corrected or virtual CT from it.

### Optimization Improvement/Fine Tuning with Clinical Goals

The presenter is the creator of robust optimization in RayStation.

Some new robust optimization features in v11B:

* Increased speed
* Decreased memory usage
* Fixed certain failing cases
  + He didn’t mention any related to Elekta
* Setback jaws
  + Common ER
  + In RayPhysics, define distance from jaws to MLC opening

New features for VMAT:

* Reverse, or copy and reverse, beam direction
* Speed up Treat
* Dec memory usage for segment MU optimization
* Speed up Agility (!) with constraints (which we know are slower than objectivess)

New features for Tomo:

* Jaws for multi-target plans
  + Reduce the island problem
    - Can irradiate the targets separately and quickly move between targets
  + Close the leaves when between targets, even without a string Protect objective
* Fix a bug that made it hard to target the target is certain entrance Protect ROIs are set
* Fix MCO that failed due to violation of machine parameter constraints

New features for brachy optimization

Fine Tuning is a new tool in the Plan Optimization module.

Fine tuning is useful when you have a good plan but want to push just a little harder on a few clinical goals. It preserves the DVH and spatial dose distribution while focusing on these few goals.

Methodology (the algorithm under the hood): Objective functions attempt to maintain the dose distribution. Other Clinical Goal-esque functions push the DVH just one point at a time. When the fine tuning finishes, the optimization is changed back to the original user-set optimization, and dose is computed.

#### Audience Questions

1. Can I fine tune an MCO plan?

It doesn’t matter where the plan to fine tune comes from. If you want to use an MCO plan, you’ll have to make it an actual plan.

1. Can I fine tune a proton plan?

Fine tuning can be used for all modalities and tx techniques that can be optimized. But fine tuning does not support robustness, so you may not want to use it for protons.

1. What exactly does the fine algorithm optimize?

By default, optimizes machine parameters for MLC positions and segment weights, but you can change this to only use segment weights.

1. Does fine tuning improve the selected clinical goals at the expense of non-selected goals?

The whole point of fine tuning is to keep everything else as constant as possible except the selected goals, but of course some tradeoff is inevitable.

### EqD2 and Brachytherapy

The presenter is the functionality owner of the Brachytherapy module in RayStation.

Tg-143 which doesn’t take heterogeneities (not calc dose to water) into acct, but rsrch project

Some updates to the Brachytherapy module in v11A and v11B (2021 versions):

* Channel reconstruction:
  + Smart draw
    - Useful for interstitial implants
  + Edit channel geometries after they are smart drawn or fully automatically generated
  + Flip channels
    - Allows you to start reconstruction from the connector side instead of the pip side
  + Delete channels
* Applicator structure templates:
  + Create the applicator model from template and then rotate and translate
  + You can script an import from the Elekta applicator library
  + Include points
* Image fusion:
  + *Very* common in brachy because CT shows applicator well while MR shows organs well
* Planning:
  + Create and move POIs
  + Copy dwell time distribution between plans (e.g., from one fx to another)
  + Lock dwell times during optimization
* EqD2:
  + Linear-quadratic formula
  + Also for photons!
  + “Replace Excel sheets” (was that actually a RayStation feature?)
  + EqDQ distribution by voxel to account for dose variation within an ROI
  + Facilitates comparison between fractions for brachy and external beam
  + Deform and accumulate EqD2
  + Choose α/β for each ROI/POI
  + Set α/β priorities because structures can overlap
  + EqD2 is computed and summed in Plan Evaluation
  + Sum EqD2 dose distributions (but not physical dose distributions) for brachy and external beam and evaluate clinical goals on the sum
* Common ER: Put POIs at a certain distance from applicator

#### Audience Questions

1. Can you use EqD2 optimization objectives?

No, you can’t optimize using EqD2.

### Proton Arc

The presenter is the head of physics and development and the functionality owner for protons. The features discussed in the presentation will debut in v12B, but evaluations versions are available. Though there is no research supporting PBS arcs over IMPT, PBS has been much requested.

PBS arc is opposed to the conventional proton tx technique IMPT.

You can manually place points or let the optimizer do it.

An MSc thesis written at RaySearch showed that PBC arc reduces NTCP compared to either VMAT or IMPT. This is more for many (20 in the study) static beams than for dynamic beams.

Work with IBA shows that PBS arc has very slow optimization and delivery times.

Switching the energy layer up is slower than switching it down. Dead time occurs during tuning and burst load. To speed up, try just a single energy layer per gantry angle and minimize the number of upward jumps. If you need multiple energy layers, use dual arcs.

The new optimization framework analyzes the target from all directions and determines the energy layer for each direction. The energy layers are continually sorted in descending order as optimization proceeds. GPU MC is fast: for simple two-arc prostate plans without robustness, both optimization and delivery times are less than five minutes. Compared to IMPT, target dose is the same, but OAR doses are lower, as seen in the LET distribution (another new feature).

PBS arc plans in RayStation create the “PBS arc flower” distribution.

## Robustness Optimization and Future Improvements

Why robustness? Account for uncertainty! We traditionally do this using margins:

CTV = GTV + microscopic disease

ITV = CTV + internal motion

PTV = ITV + setup error

But a RaySearch PhD thesis by a now RaySearch employee RS pioneered robust optimization in commercial TPSs.

Robustness first became popular with ions, then with photons. According to the thesis, robust planning yields robust CTV dose and lower OAR doses.

Is robustness really necessary? PTV-based planning assumes a static dose cloud, so while it sometimes works well, the fact remains that dose distributions don’t move like that.

Robust optimization in RayStation uses minimax optimization: minimize the worst case.

Optimize with respect to setup, range uncertainties (for ions), anatomical uncertainties (real, or simulated using 4DCT).

Based on a 1999 paper by the RaySearch CEO, v10B added intra-fraction and inter-fraction in addition to systematic.

Two types of uncertainties:

* Systematic
  + - Density
    - Patient setup
    - Patient geometry
    - In 3D or 4D
    - Overly conservative because it assumes the same error across all fractions
      * Target dose is lower
      * OAR doses are higher
    - Essential for protons because margins don’t work
* Random:
  + - Inter-fraction
      * Patient setup
      * Patient geometry
    - Intra-fraction
      * Patient geometry
      * E.g., breathing motion for lung
      * 4D only, not 3D

Robust optimization works by building multiple scenarios. The user sets the number of scenarios. The scenario dose is the sum of the fraction doses in that scenario, so the optimization is performed on this sum.

Note the dose horns.

Of course, robust optimization is not a magic bullet. It doesn’t resolve the problem of conflicting objectives and constraints. And some situations are too computationally complex for robust optimization. Some situations don’t really *need* such large uncertainties. It also doesn’t replace margin-based planning; it must work with margin-based planning, after all.

Robust optimization is evaluated using DVH clusters, clinical goals, and aggregate dose distributions.

Robust optimization will help the transition from PTV- to CTV-based planning, as discussed in many papers right now.

Future robust optimization features:

* Organ motion uncertainty in robust
* Independent beams
* Random inter-fraction errors
* Intra-fraction interplay effects
  + Should be available clinically in 2022, but evaluation versions are available.
* Rotations
  + In Plan Evaluation

Important: Simple plan evaluation is unchanged. The only difference is that now you can *also* simulate complex error scenarios.

Robust optimization is a license.

### Audience Questions

1. Can we quantify benefits more than “50% of the robust plans pass”? As you alluded to, that isn’t sufficient evidence in favor of robust optimization.

I agree that more research is needed. We started with a grandiose plan and kind of got aheade of ourselves before doing the proper research.

1. Referencing the horns at the edge of the PTV in inter-fraction motion, isn’t it true that what you gain in robustness, you lose in LET?

Maybe, if you don’t use LET optimization. That’d be an interesting study.

## Proton Updates and LET/RBE/FLASH

#### Updates

* MC was migrated to GPU. This applies to all modalities but is most important for photons, whose optimization time was decreased to within five seconds. For comparison, other TPSs take minutes.
* Robust optimization for inter- and intra-fraction motion
* RayOcular
  + First commercial ocular TPS based on ion image (CT/MR)
  + Can also use for photons and photons

#### LET

The main new photon feature in v11B is LET.

Linear energy transfer (LET): density of electronic excitations along particle track. LET dose should be low in OARs, high in the center of the target.

RayStation is the first commercial TPS with LET.

Why use LET instead of just RBE?

* RBE (biological) model (e.g., RBE 1.1) is too simple
* LET is highly correlated with RBE
* LET can be input into RBE

Proton (primary and secondary only), helium, and carbon LET is dose averaged.

You can view 2D dose and LET dose in the same window.

LVH (LET volume histogram)

LET dose statistics

LET color table now has a dose threshold, a useful feature because since LET does not scale with dose, it’s nice to be able to hide the high LET levels that can come with even very low doses.

Patient rotations in perturbed dose calculation

Coming soon: Patient rotation in robust evaluation

Broad beam proton planning:

* Radial fluence correction
  + For anything without flat fluence: single scattering, double scattering, uniform scattering

User-defined materials

* Useful for but not specific to protons
* Global or patient specific
* Fully user-defined, or from template

Water-equivalent depth (WED) to beam DSP (BDSP)

* WED to iso for MU scaling broad beam plans
* WED to movable DSP as WET ruler from source to point

Collision check

* Only implemented at one clinic (MedAustron), but investigating potential usefulness for others
* Models of machine, patient (registered to external), and fixation devices)
* Check collisions for nominal setup, setup errors using 6D setup margin scenarios
* Potentially useful for VMAT photons

Future features:

* LET optimization in addition to evaluation
* LET for proton arc
* Improved robustness evaluation
* Interplay evaluation
* Proton dose calculation on CBCT
* ML proton planning, including robustness
  + Finished but not FDA approved
* Faster optimization
* More support for dual-energy CT
* Proton RBE models for evaluation and optimization
* Online adaptive
* FLASH planning

#### Plan Creation & Plan Evaluation for PBS FLASH Delivery in RayStation

Presenter is a senior search scientist at RaySearch.

Presenter thinks we’re entering a “new era” that involves closer collaboration among TPS and machine vendors, especially for proton arc.

FLASH is defined as >4 Gy/fx and >40 Gy/sec. FLASH is less toxic than traditional proton therapy.

FLASH is advancing so fast that there is no consistent terminology for or understanding of its biology.

Photon beam delivery time = beam-on time + spot move time + spot dead time + energy layer shift time

FLASH by proton PBS delivery:

* Transmission-style irradiation with many high-energy beams
* SOBP-style irradiation with few beams
  + Single energy layer vs. IMPT with many (e.g., 32) layers
  + Hedgehog: energy compensator/modulator in the beam in the synchrotron/cyclotron
    - Goes behind range shifter
    - 3D-printed
    - Geometry is optimized using objective functions for dose, RBE/LET, robust, etc.
    - MC for optimization and final dose calculation
* Case studies:
  + Peripheral lung 20 Gy × 3; liver metastasis
  + FLASH plans not inferior in any way
* Energy deposition (Gy/sec) as a function of time traces time per voxel per beam. It is used to predict FLASH dose. Using a 100 ms sliding window, 76 percent of dose is delivered at or above what 100 Gy/sec.

The IonPG research version of RayStation includes FLASH planning.

FLASH shows promise in microRayStation, the RaySearch TPS used in preclinical/small animal research.

##### Audience Questions

1. What are the target and field size limitations of FLASH?

The field size limitations primarily relate to the delivery machine. Smaller fields are easier; I’d say a good rule of thumb is 8 × 8 cm maximum.

## Boosting Efficiency in RayStation with RayCare Flow

The presenter is the RayCare manager and a former RaySearch user.

Everyone is confused on what RayCare Flow actually is. It is *not* an entire OIS; that’s RayCare. RayCare Flow is intended as a stepping stone to RayCare but right now should co-exist with your current OIS.

Connect an entire cancer center: machines, modalities, people, …

Goodbye to:

* “Did I QCL this?”
* Tx planning whiteboard
* Email trails as documentation

Customized to your clinic

Fully integrated tx planning workflow process: patient registration through tx plan delivery

Even image management integration using RayCare PACS!

Efficiency really comes with patient synchronization with RayStation. This is even better than Friday’s script solution for DICOM manipulation prior to OIS import of plans.

Tasks always direct the user to where the task can be performed. Opens RayStation to the exact module!

Raycare’s PACS allows all of a patient’s images to be stored with all the patient’s other documents.

*Scripting*! Python, PowerShell, RayCare, and RayStation scripts can call each other.

E.g., If plan is approved, execute script that creates QA plan.

Subscription-based license model

User-configurable workflows come in v5B in Dec 2021.

## RayIntelligence

See RayIntelligence webinar notes for more in-depth info.

Soon, users will be able to define their own metrics for plan analysis in RayIntelligence.

### Audience Questions

1. [My question] I know RaySearch doesn’t have a DQA software, but can RayIntelligence analyze DQA data?

They thought I meant “daily QA”—guess I should’ve said *PSQA* instead of DQA. But they want to connect RayIntelligence to the machine database in addition to the patient database, so we can analyze commissioning data and combine machine data with patient data. Many of the requested RayIntelligence features are just a matter of integrating more data sources.

1. Can RayIntelligence analyze bottlenecks in the workflow? E.g., can we display an average contouring time per MD?

That will come with integration with RayCare. Timestamps will allow you to analyze bottlenecks.

Since RayCare is cloud based, upgrades are automatic if you have a subscription.

## IT Infrastructure

The presenter is the RaySearch IT solutions architect.

Instead of Citrix with application layers, as discussed in a customer presentation on Friday, how about VMWare horizon with Windows 10 VMs?

RayHosted, a hosted version of RaySearch products (RayIntelligence already does this), is in the works. Customers want SaaS!

Aryaka provides data center connectivity through SD-WAN as a service. Equiniz provides the data centers themselves. RaySearch is currently testing using AWS and Azure for their SaaS.

LogicMonitor, a performance, centralizes the logs from multiple servers. This helps RaySearch support troubleshoot issues for sites (like us) with multiple RayStation servers. The tool si very customizable by RaySearch or on-site IT.

A single-GPU Liqid container yields no performance degradation as compared with an internal chassis GPU. The performance improves with a multi-GPU Liqid container. But the real test case, which occurs when there are multiple users, is comparing a multi-GPU Liqid container to a multi-GPU internal chassis.

### Audience Questions

1. Our on-site IT refuses to install a Python IDE, such as PyCharm, onto the RayStation server. Can we have your vendor blessing to do so?

No, because each site’s situation is different. But RaySearch will definitely investigate ways to include an IDE that interfaces seamlessly with RaySearch products on a server. They may collaborate with IDE vendors for this.

## Community Update

RayCommunity is incredibly underutilized.

URL: raysearchlabs.com/community. I tried this URL, and it does not work. The correct URL is raysearchlabs.force.com. I put in a RaySearch ticket about this.

Email [support@raysearchlabs.com](mailto:support@raysearchlabs.com) to create an account. Your account must use a work email.

Pay attention to the Field Safety Notice (FSN) emails from the director of customer support! These FSNs are, of course, also on RayCommunity.

Please submit ERs and support cases via RayCommunity instead of email. There are also other support case types, such as scripting request (I could have used this to request that DICOM filter that makes the MOSAIQ site name match the RayStation plan name).

RayCommunity is also where you can find the release notes to check before you submit an ER.

FAQs, suggestions, articles

Videos:

* Customer presentations from User Meetings
* Tutorials
* Past webinars
  + Available to RaySearch users only, not competitors