The Phenomenon of the Ethos AI-Driven Adaptive TPS

# Presenter

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# Overview

The presenter gave an overview of the adaptive planning workflow in the Varian Ethos system. Ethos is not a TPS, but a self-contained, comprehensive treatment planning solution, from pre-planning to post-treatment monitoring. Its claim to fame is AI-driven daily adaptives.

# Ethos Overview

We humans can accurately and precisely create and deliver dose distributions based on a single planning CT. But patient anatomy of the day differs volumetrically, geometrically, and positionally from the anatomy on the planning CT. IMRT helps reduce the effects of volumetric differences by producing more conformal dose distributions that better spare OARs and deliver high dose to the target. IGRT quickly and accurately reduces positional differences. But Ethos delivers dose to individual structures independent of other structures. Every fraction should be just as dynamic as the patient’s anatomy.

Ethos has three pillars:

1. Initial planning
2. On-couch session (adaptation)
3. Monitoring

This entire process still needs human input! The big picture is that adaotive plans are different from IGRT because they are *recalculated* based on today’s CBCT. But you are free to modify, approve, and do anything else that you would with a plan generated in any other way.

This webinar focused on initial planning.

# Workspaces in Initial Planning

## Planning Directive

Once the patient demographics have been imported into Ethos, the user selects some simple settings that define the Rx: anatomical site, laterality (if applicable), and (optionally) RapidPlan® template. Of course, a plan from template is editable.

A traditional Rx consists of a site and a total dose, often specified by a point dose / reference point. In Ethos, the Rx also includes clinical goals for volume, dose, and variation. Each goal has required priority 1 through 4, where 1 is highest, or “report only” if the goal should not be used in optimization. In the Planning Directive workspace, goals are sorted by structure. Clinical goals are visible in Planning Directive, Contours, and Dose Preview workspaces.

A course is made up of phases. Each phase has its own Rx(s) and fractionation. Each phase uses either daily adaptives (creates additional plans while the patient is on the couch) or standard IGRT (CBCT, align, and adjust patient before treating). The total Rx is always shown.

The Sigma tool creates derived structures, including margins, walls, unions, and intersections, and is available in both the Planning Directive and Contours workspaces. In the Planning Directive workspace, Sigma creates dynamic structures: the derivation is contoured at the daily adaptive.

# Contours

The user chooses the planning image (e.g., CT) and the supporting images (e.g., MR, PET).

Ethos uses the TG-132 (Image Fusion and Registration) protocol for automatic image registration of the supporting images to the planning image: the user chooses the registration uncertainty on a scale from 0 (fully aligned) to 4 (not acceptable).

Contours can be drawn on supporting images but live on the planning image.

Contours can be imported from other systems as long as the exams are in the same FoR.

Ethos automatically contours certain anatomical and non-anatomical structures based on the body site in the Planning Directive. Of note are technical structures, small (<0.01 cc), high-density (>2800 HU) regions, which are contoured with a 2mm margin and help avoid streaking. The sim iso is automatically placed in the center of the bounding box that encompasses all targets, and two isos (on the same couch plane) are placed if the z-dimension of the bounding box exceeds 26 cm. Of course, any auto-contours may also be manually edited.

The Sigma tool in the Contours workspace creates static structures: the structure does not change for the daily adaptives.

Ethos provides alerts of contouring mistakes, such as stray contours and overlapping OARs. Click the Focus button to automatically navigate to the problem area.

## Dose Preview

Dose Preview is a totally new feature in Ethos; it is not in the Eclipse TPS.

Dose Preview allows you to evaluate whether your goals are even attainable and to change priority levels and sublevels accordingly. Unlike in the Planning Directive workspace, in the Dose Preview workspace, goals are organized by priority level. Relative priority (priority “sublevel”) is maintained inside each level.

Dose Preview’s calculation is very rough. It computes a fluence-based dose optimized distribution with fixed gantry angle, nine equally spaced fields, and no control points or MU.

# Plan Generation

The AI-generated plan relies on three algorithms: photon optimizer (PO), intelligent optimization engine (IOE), and Fourier transform dose calculation (FTDC).

The PO optimizes fluence maps, and the IOE uses the PO plus the prioritized goals and optionally the DVH Estimation model. The IOE automatically converts the clinical goals into objectives and adds objectives (which are thankfully not added to the goals) for helper structures, such as rings, NTO, 98%, and 100%. Say goodbye to manual entering objectives and constraints and adjusted their numeric weightings! Ultimately, each goal belongs to one of three categories. In order of importance:

1. Min goal: like Eclipse lower goal for target; for coverage
2. Max goal: like Eclipse upper goal for target; for hotspot reduction
3. OAR: like Eclipse upper goal

Under the hood, the IOE uses a P score to iteratively optimize the plan. The P score is a function of the goal’s quality index (Q) versus its priority. Q measures proximity: how close is the plan to meeting the goal? On each iteration of the optimization algorithm, the IOE chooses the goal with the lowest P score. If an iteration devolves a goal, that goal’s P score is lowered so that subsequent iterations can focus on it. Once a goal reaches a P score of 4, it is ignored until all scores reach 4. Then, scores are pushed beyond 4 (goals are exceeded) as far as possible.

# Plan Review

Up to five plans are generated by the AI. The MD uses goal analytics to choose their favorite plan as the reference plan. The reference plan includes the optimization recipe. (On a side note, I think RayStation deep learning planning can generate many more than five plans.)

QA is performed on the reference plan, which is automatically exported to Mobius3D for second check. You can compare Ethos dose, M3D dose, and measured dose. Measured dose is obtained the same way it’s always been, such as with ArcCHECK® or Delta4, but portal-based QA cannot be used.

# Q&A

**Q:** What is the total treatment time for an adaptive plan after the CBCT is done?

**A:** Based on ~17000 patients treated using Ethos, the average total treatment time is 13 minutes.

**Q:** What if we trust the planning exam more than the CBCT and so want to use a contour from the former in the adaptive plans?

**A:** All original contours live on the planning exam, and they are called static contours when used instead of dynamic contours on the CBCT. But why would you want to use a static contour? The dynamic contour is more accurate because it is based on the anatomy of the day, and it’s not as though the original contours aren’t used to guide the dynamic contours.

**Q:** For standard IGRT (not adaptive), how is Ethos better than Eclipse? Eclipse seems to have more IMRT/VMAT optimization tools.

**A:** You can import an Eclipse plan to use as the reference plan in Ethos.

**Q:** If no Sigma is provided for the PTV at adaptive, dose Ethos use the PTV from Eclipse?

**A:** Well, Ethos generates its own plans, so the reference plan is likely not from Eclipse. But if the PTV is not derived, then the static PTV is used.

**Q:** How do we QA adaptives?

**A:** You don’t. You only QA the reference plan.

**Q:** Does IOE work with TrueBeam?

**A:** Not yet. Ethos is its own self-sufficient world that requires an Ethos unit.

**Q:** Can the MD work with adaptives remotely?

**A:** No, but this is a good time to bring up customer feedback. Contact your Varian sales rep, Varian IT, and/or the presenter with your feedback, including enhancement requests for the engineering team, and the info will be passed to the necessary parties.

**Q:** Do priority groups replace numerical objective weights that contribute to the cost function? If so, how can the user fine tune two strongly compelling objectives in the same priority grp?

**A:** The beauty of AI plan generation like Ethos is that the computer can fine tune the cost function much more efficiently than a human can. But keep in mind that you can use the **Refine Dose** functionality in Dose Preview to change a goal’s priority level or sublevel. You can also drag DVH lines and lock. Essentially, AI planning allows you to specify the desired end result and leaves the tedious maneuvering to the computer.

**Q:** Does the IOE slow down with more goals?

**A:** Well, yeah, but in practice, unless you have hundreds of goals or something, the IOE is so fast that the difference between, say, three and 50 goals isn’t important.

**Q:** Is image registration rigid or deformable? Is it based on the whole image or on an ROI?

**A:** Image registration is rigid, not deformable.

**Q:** Is the IOE available for non-adaptive planning? Is it included in RapidPlan® and MCO?

**A:** IOE is part of Ethos’s own continent; it is not an “optional add-in” to a TPS.

**Q:** Does Ethos have an automatic QA system for structure sets?

**A:** No, it uses Mobius3D to QA the reference plan only.

**Q:** Does Ethos support adaptive frequencies other than daily (e.g., weekly)?

**A:** No, the sys is not designed that way, but custom frequencies are not out of the question. Again, reach out to Varian with your feedback!

**Q:** What if the MD doesn’t like any of the generated plans?

**A:** Re-evaluate the Planning Directives. Are any goals too lax or restrictive?