AAMD American Association of Medical Dosimetrists

MAKING MOLEHILLS OUT OF MOUNTAINS: COMPLEXITY IN RADIATION ONCOLOGY

Kiernan McCullough, MS, DABR
Colorado Associates in Medical Physics
Penrose Cancer Center

AAMD Regional Meeting
Denver, April 21, 2018

Centura Health.

Colorado Associates IN MEDICAL PHYSICS

Declarations

No research agreements to declare.

Colorado Associates IN MEDICAL PHYSICS

Why Complexity?

Complexity in RadOnc

- Unique in the variety and breadth of tools available to accomplish a similar endpoint.
- Not common that these tools can be integrated together fluidly.
- Large overlap of vendors providing similar services with various degrees of quality.
- Technology can be misused.
- Hard to filter unnecessary, conflicting, or even inaccurate data.

Colorado Associates
IN MEDICAL PHYSICS

Agenda

- Discuss the concept of complexity and how it applies to radiation oncology.
- Analyze sources of complexity and how they may differ between clinics.
- Look at strategies to mitigate sources of complexity.

Colorado Associates IN MEDICAL PHYSICS

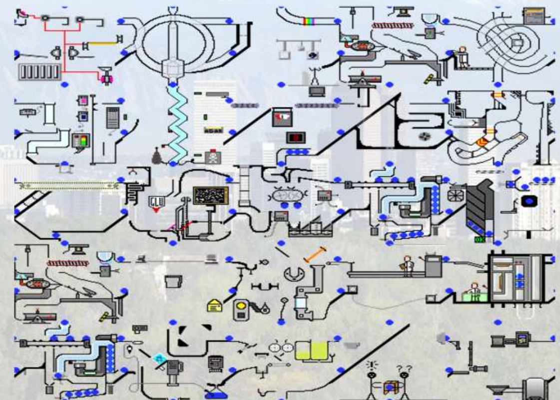
Complexity Defined

- Merriam-Webster
  - The state of being complex
- Wikipedia
  - Generally used to characterize something with many parts where those parts interact with each other in multiple ways, culminating in a higher order of emergence greater than the sum of its parts.
  - The only consensus among researchers is that there is no agreement about the specific definition of complexity.

Colorado Associates IN MEDICAL PHYSICS

Complexity Defined

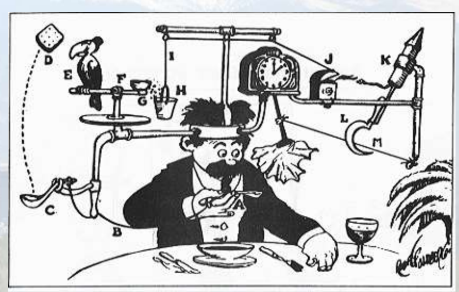
System – a set of connected things forming a complex whole



Colorado Associates
IN MEDICAL PHYSICS

Complexity Defined

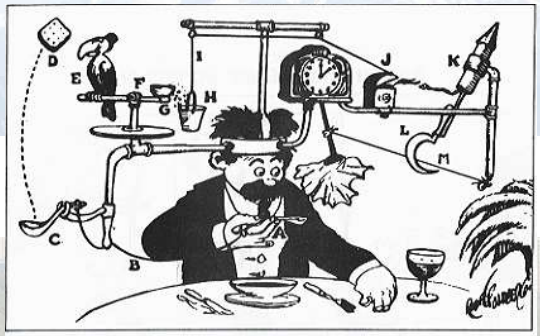
- Many simple devices acting in a system to achieve an equally simple result.
  - Deliberately complex
- What makes a system complex?
  - Number of devices
- More devices > Chance of error



Professor Butts and the Self-Operating Napkin (1931)

Colorado Associates
IN MEDICAL PHYSICS

More Devices = More Complex = Less Success



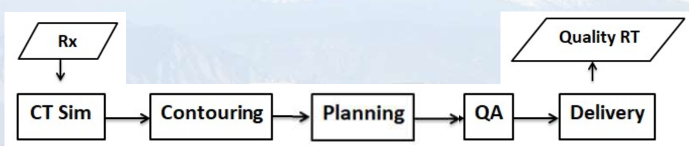
Professor Butts and the Self-Operating Napkin (1931)

$P_{napkin} = P_{spoon} * P_{brea\ \ tapult} * P_{parrot} * P_{bucket} * P_{\ \ ch} * P_{rocket} * P_{scythe}$

Colorado Associates IN MEDICAL PHYSICS

The RadOnc System

- System – Design and Deliver Therapeutic Radiation



Colorado Associates IN MEDICAL PHYSICS

Plan Documentation

- Time consuming
- Many simple steps with many variables
  - Typically 'binary' in quality – right or wrong
- Crucial to plan communication and execution

- Solution: Automation
  - Reduce steps, save time
  - Increase probability of success

Colorado Associates
IN MEDICAL PHYSICS

Printing and Automation

- Screenshots
  - Isocenter
  - Multiple planes to show coverage
  - Alignment images
  - Beam ports
- DVHs
- Contour overlays, colors, fill settings
- Isodose settings
- Secondary Image Studies

Colorado Associates
IN MEDICAL PHYSICS

Printing and Automation

Colorado Associates
IN MEDICAL PHYSICS

Printing and Automation

$$P_{printing} = P_{DVH} * P_{display} * P_{isodose} * P_{ports} * P_{DRRs} = 1$$

$$P_{printing} = 0.999$$

Colorado Associates
IN MEDICAL PHYSICS

AAMD
American Association of Medical Dosimetrists

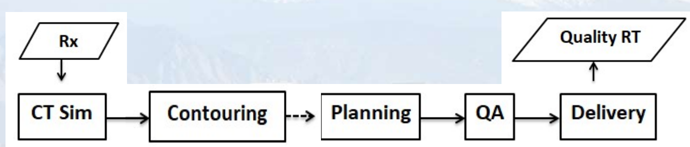
Step Reduction by Automation

- Easy means of reducing system complexity
- Particularly useful when replacing simple processes and decisions.

Colorado Associates IN MEDICAL PHYSICS

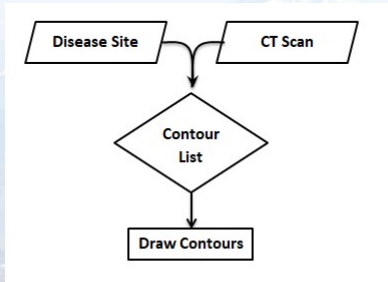
The RadOnc System

- System – Design and Deliver Therapeutic Radiation



Colorado Associates IN MEDICAL PHYSICS

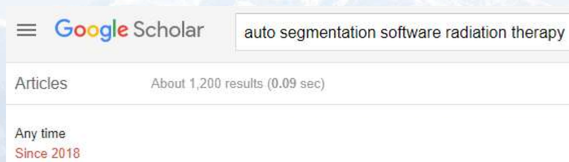
Contouring: Simplified

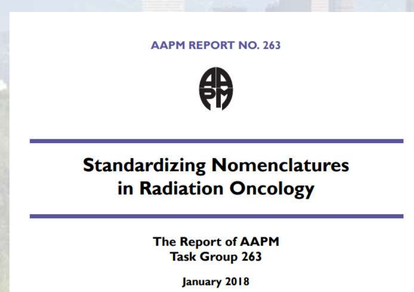


- Atlas and model based segmentation tools can create contours for organs at risk with little or no user input.
- Autosegmentation tools focus on anatomic regions and contain many structures pertinent to plan quality.

Colorado Associates IN MEDICAL PHYSICS

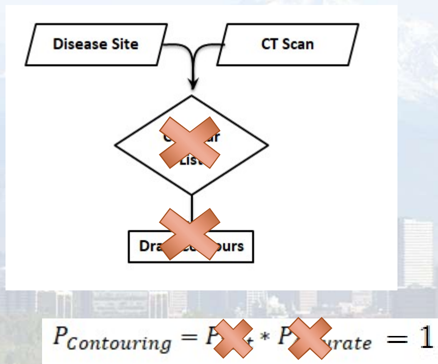
Contouring: Simplified





Colorado Associates IN MEDICAL PHYSICS

Contouring: Simplified

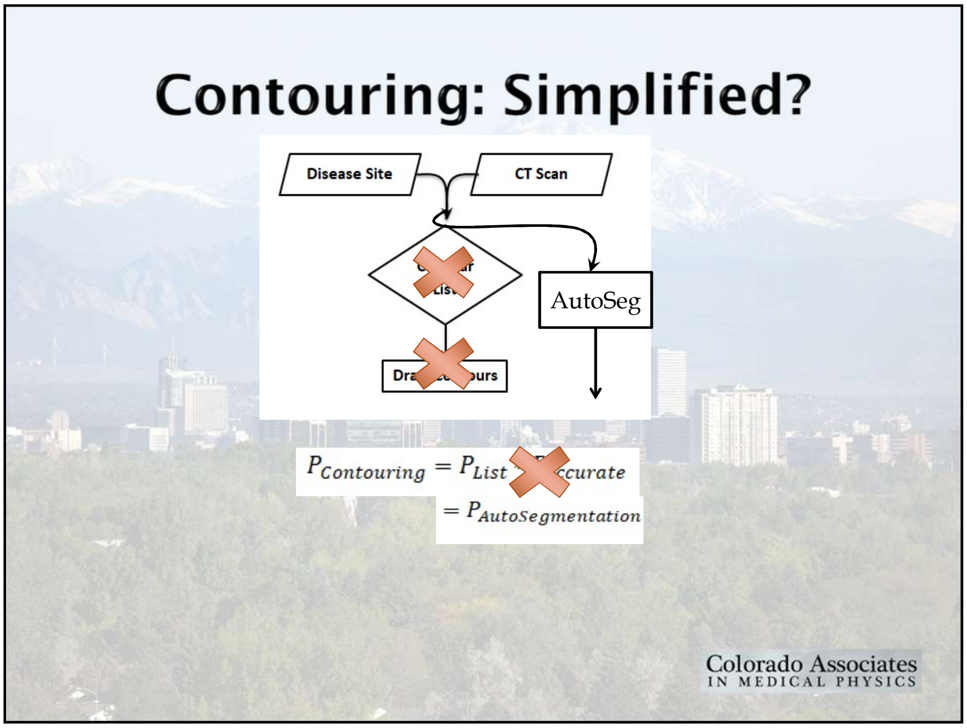


Colorado Associates IN MEDICAL PHYSICS

Contouring: Male Pelvis

- Bladder, Rectum, Prostate, Femoral Heads
- Data Management System
  - Atlas segmentation — **Poor Bladder Quality**
  - Autosegmentation — **Doesn't work if scan is short**
- TPS 1
  - Autosegementation — **Needs an MR to function**
- TPS 2
  - Autosegmentation — **Won't contour prostate**
  - Model based segmentation — **Choice Overload**

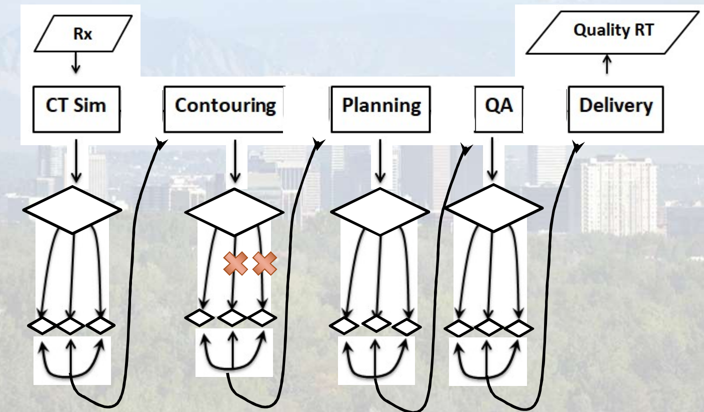
Colorado Associates IN MEDICAL PHYSICS


Contouring: Simplified?
Disease Site
CT Scan
AutoSeg
$P_{Contouring} = P_{List}$
$= P_{AutoSegmentation}$
Colorado Associates
IN MEDICAL PHYSICS


Fewer Steps = Less Complex?
Colorado Associates
IN MEDICAL PHYSICS

Step Reduction

- System – Design and Deliver Therapeutic Radiation



Colorado Associates IN MEDICAL PHYSICS

Contouring: Male Pelvis

- Bladder, Rectum, Prostate, Femoral Heads
- Data Management System
  - Atlas segmentation — Poor Bladder Quality
  - Autosegmentation — ~~Doesn't work if scan is short~~
- TPS 1
  - Autosegmentation — ~~Needs an MR to function~~
- TPS 2
  - Autosegmentation — ~~Won't contour prostate~~
  - Model based segmentation — ~~Choice Overload~~

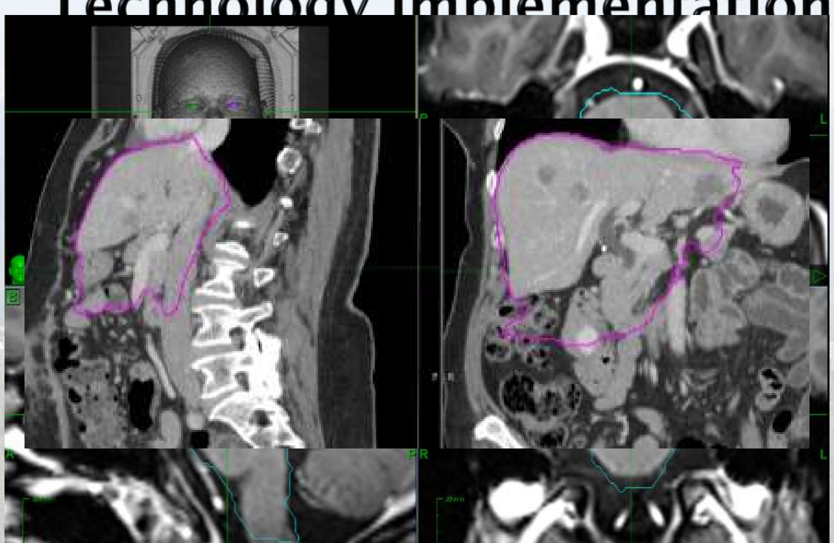
Colorado Associates IN MEDICAL PHYSICS

Step Reduction by Automation

- Easy means of reducing system complexity.
- Particularly useful when replacing simple processes and decisions.
- Total impact on system complexity may not be straightforward.
  - Especially true when quality of process is variable
  - Requires more scrutiny

Colorado Associates IN MEDICAL PHYSICS

Technology Implementation



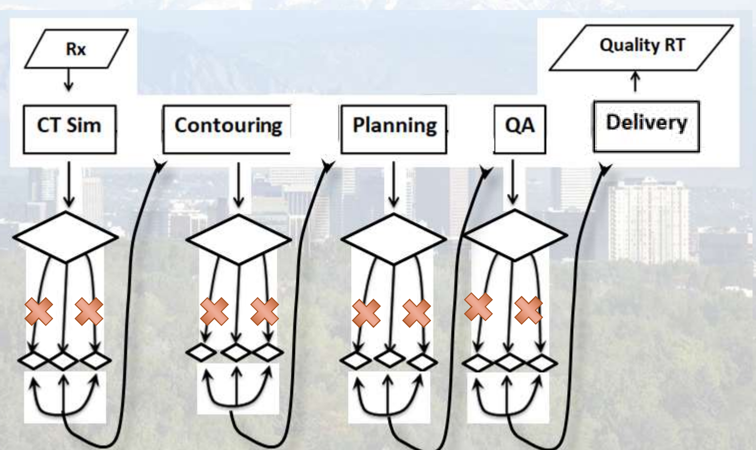
Colorado Associates IN MEDICAL PHYSICS

Decision Reduction through Uniformity

- Clinic should agree on method of implementation
  - At least educate on technology limitations
- Reducing variation in decisions perhaps more important than reduction of steps
  - Poor decisions lead to unsuccessful clinical pathways

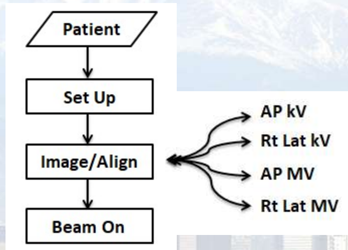
Colorado Associates IN MEDICAL PHYSICS

Fewer Decisions = Less Complex



Colorado Associates IN MEDICAL PHYSICS

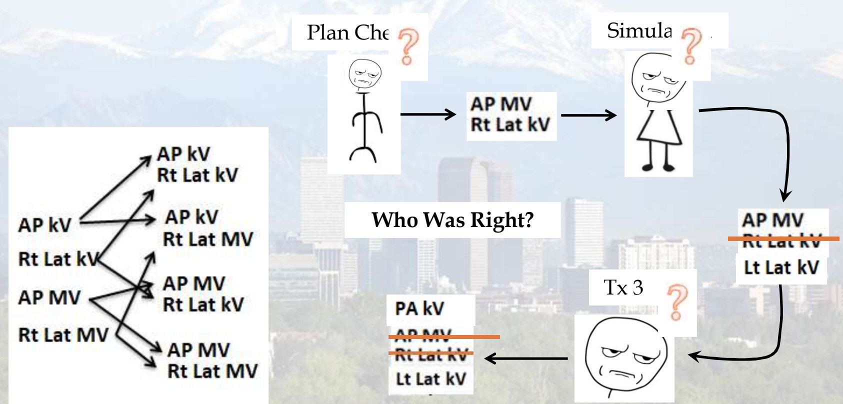
Complexity in Delivery



- Most important area to increase uniformity.
- Documentation and communication on simulation day can have critical impact on patient treatment.
  - Tends to propagate through treatment.

Colorado Associates IN MEDICAL PHYSICS

Decision Uniformity

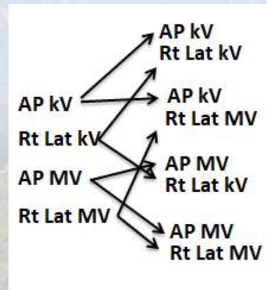


Colorado Associates IN MEDICAL PHYSICS

AAMD American Association of Medical Dosimetrists

Decision Uniformity

- Who was right?
- No one!



- You never determined what was right.
- Hindsight may reveal a more efficient combination
  - Not helpful in guiding practical decision making

Colorado Associates IN MEDICAL PHYSICS

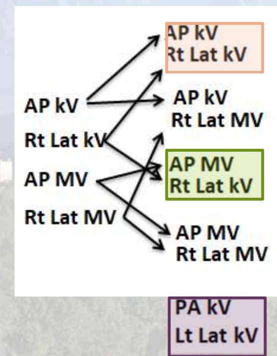
Decision Uniformity

- Important in all aspects of plan execution and plan documentation.
- Imaging technique
- Beam naming conventions
- Treatment accessory description
- Order of operations

Colorado Associates IN MEDICAL PHYSICS

Decision Uniformity

- Who was right?



- Machine 1
  - Most patients
  - Alignment with fiducials
- Machine 2
  - Central and left sided
  - Right Sided

Colorado Associates IN MEDICAL PHYSICS

Decision Uniformity

- Well vetted strategies discussed with all members of the RadOnc team can account for most scenarios
  - Additionally, limit number of clinical decisions
- Documentation and accessibility to standards prevent treatment deviations
- Most of these processes run through dosimetry.

Colorado Associates IN MEDICAL PHYSICS

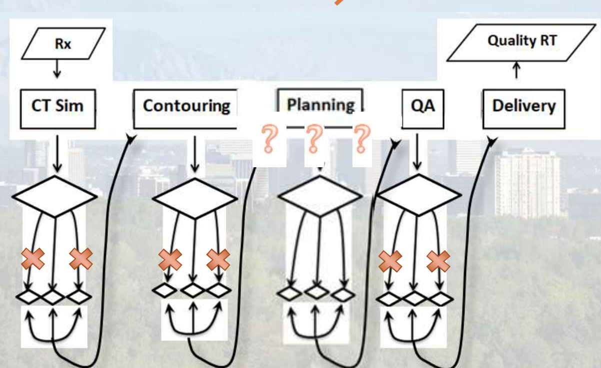
Complexity: Getting Better

- Step Reduction: Automation
  - Automating simple processes increases efficiency and uniformity.
  - Automation of variable quality for crucial system steps may introduce additional complexity and decrease probability of system success.
- Decision Reduction: Uniformity
  - Formalized clinical stances on performance of 'time-saving' tools and their implementation significantly reduces scenarios that lead to system failure.
  - Establishing well-defined clinical strategies improves system uniformity and ability for team members to coordinate

Colorado Associates IN MEDICAL PHYSICS

Step and Choice Reduction

$$P_{printing} = P_{DVH} * P_{display} * P_{isodose} * P_{ports} * P_{DRRs} = 1$$



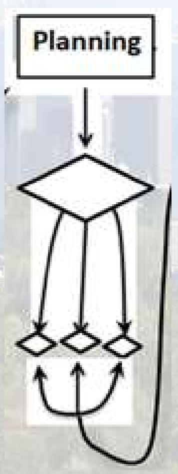
Colorado Associates IN MEDICAL PHYSICS

Making Clear Decisions

- Judging plan quality can be difficult, not necessarily straightforward
- Creating plan evaluation metrics is time consuming and can be miscalculated
- Knowing how these plan metrics compare to similar plans not always easy to assess

Colorado Associates IN MEDICAL PHYSICS

Adding Tools to Remove Complexity



- Comparing plans versus historical and national data easiest way to gauge relative plan quality
- More metrics that can be analyzed, less likely that plans of poor quality are treated

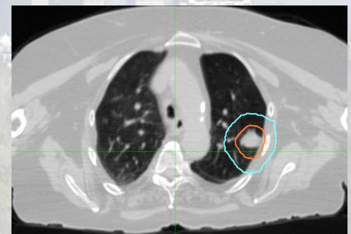
$$P_{GoodPlan} = P_{intuition} * P_{experience} * P_{Tool}$$

- $P_{Tool} < 1$ but additional workflows can enhance ability to evaluate more metrics and compare large amounts of data
  - Increases value of $P_{intuition} * P_{experience}$

Colorado Associates IN MEDICAL PHYSICS

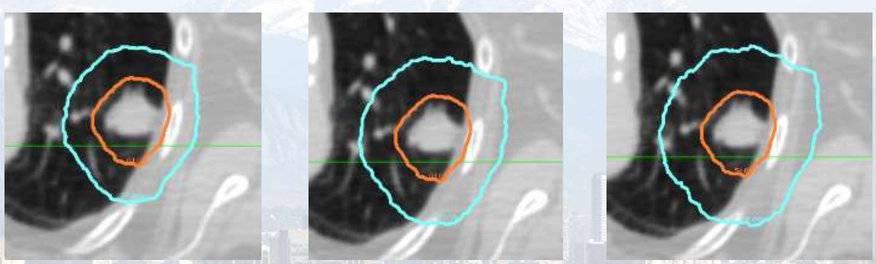
SBRT Gradient Index and Quality

- Dose gradient index: (50% Rx Volume)/(Target Volume)
  - Evaluates how quickly radiation dose falls off away from the target
  - An important metric to determine plan quality that is hard to appreciate visually
- Orange – Rx Dose
- Blue – 50% Rx



Colorado Associates IN MEDICAL PHYSICS

Stereotactic Plan Evaluation: New Challenges



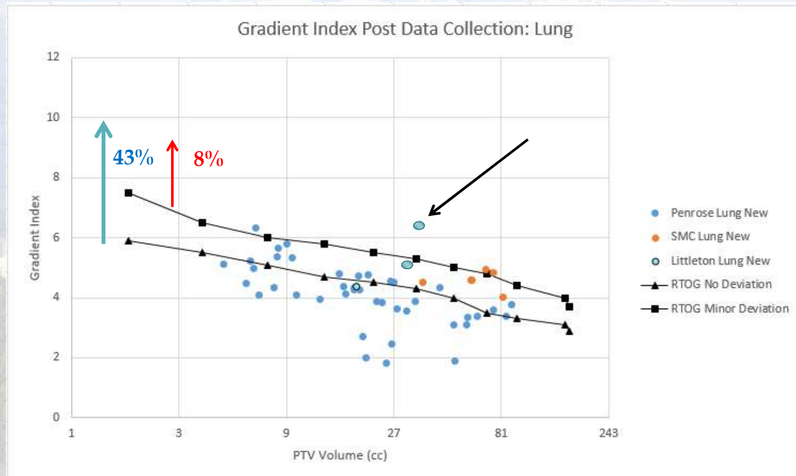
118.9 cc | 153.6 cc | 192.3 cc

29% | 62%

Dose Gradient – Ratio of 50% Rx Volume/Target Volume

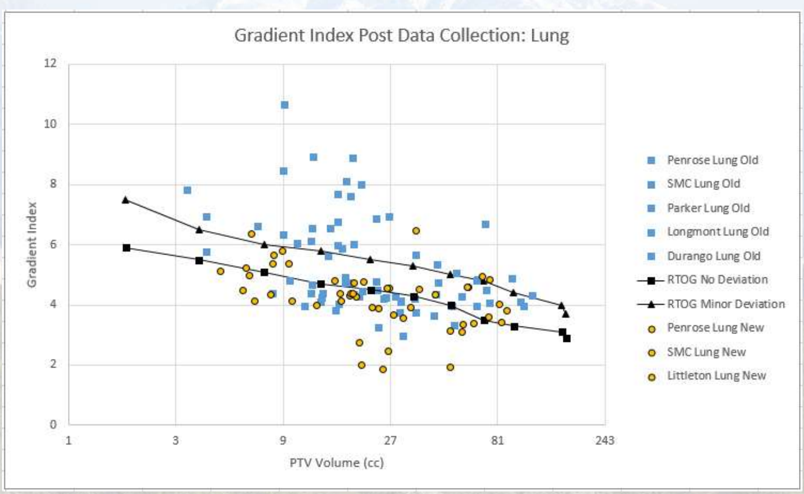
Colorado Associates IN MEDICAL PHYSICS

Stereotactic Lung: Dose Gradients



Colorado Associates
IN MEDICAL PHYSICS

Stereotactic Lung: Dose Gradients



Dose Gradient Implementation

- Possible because of:
  - Automation
  - Uniformity
- Index calculation formalisms not as important as consistency
- The ability to share and implement identical workflows guarantees reliable comparisons
- Effective tool for planning feedback during optimization
- Very important for sites with low stereotactic workload

Colorado Associates IN MEDICAL PHYSICS

Summary

- Radiation Oncology is complex
- Reducing the number of total pathways to plan completion will reduce the complexity of your system
- Reduce steps to limit opportunities for system failure
  - Automation
- Reduce planning decisions to limit opportunities for miscommunication and incorrect treatment paths
  - Uniformity
  - Well described treatment strategies
- Vet new tools thoroughly to evaluate impact on clinical complexity
  - Automation with poor results increases complexity and failure
  - Introduction of tools can increase probability of system success and enhance decision making

Colorado Associates IN MEDICAL PHYSICS


Thank You!
Colorado Associates
IN MEDICAL PHYSICS