MAKING MOLEHILLS OUT OF MOUNTAINS: COMPLEXITY IN RADIATION ONCOLOGY

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Declarations

No research agreements to declare.
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.
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.
Why is Complexity Bad?

AGGREGATE REPORT CARD – Q1 2016
January 1, 2016 – March 31, 2016

DATA ANALYSIS: OCCURRENCE AND DISCOVERY OF ERRORS WITHIN THE WORKFLOW PROCESS

Of the 1632 events in the database through Q1 2016, 70 percent (1146/1632) had both the data elements for occurrence and discovery filled out. It is of particular interest to look at the number of cases in which the event occurred early in the process, i.e., in Treatment Planning or earlier, but the event was not discovered until Treatment Delivery or later (i.e., “early occurrence, late discovery”). These are the cases that passed through QA steps that—in principle—should have found the problem. Table 1 and Figure 2 highlights this subset of events.
Why is Complexity Bad?

**ANALYSIS & COMMENTARY | continued**

**FIGURE 2. “EARLY OCCURRENCE, LATE DISCOVERY”**

Overall Event Occurrence

- Occurred AFTER Treatment Planning 41.4% (474 events)
- Occurred DURING Treatment Planning or Earlier 58.6% (672 events)

Discovery of Events that Occurred During "Treatment Planning" or Earlier

- Discovered in Pre-Treatment Review and Verification 42.4% (285 events)
- Discovered in Treatment Planning or Earlier 28.3% (190 events)
- Discovered in Treatment Delivery or Later 29.3% (197 events)
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.
Complexity Defined

System – a set of connected things forming a complex whole
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
More Devices = More Complex = Less Success

Professor Butts and the Self-Operating Napkin (1931)

\[ P_{\text{napkin}} = P_{\text{spoon}} \times P_{\text{bread}} \times P_{\text{tapult}} \times P_{\text{parrot}} \times P_{\text{bucket}} \times P_{\text{pitch}} \times P_{\text{rocket}} \times P_{\text{scythe}} \]
The RadOnc System

- System – Design and Deliver Therapeutic Radiation

Diagram:

- Rx → CT Sim → Contouring → Planning → QA → Delivery → Quality RT
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
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
Printing and Automation
Printing and Automation

\[ P_{\text{printing}} = P_{\text{DVH}} \times P_{\text{display}} \times P_{\text{isodose}} \times P_{\text{ports}} \times P_{\text{DRRs}} = 1 \]

\[ P_{\text{printing}} = 0.999 \]
Step Reduction by Automation

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

- System – Design and Deliver Therapeutic Radiation
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.
Contouring: Simplified

AAPM REPORT NO. 263

Standardizing Nomenclatures in Radiation Oncology

The Report of AAPM Task Group 263
January 2018
Contouring: Simplified

\[ P_{\text{Contouring}} = P_{\text{Accurate}} \times P_{\text{Contour}} = 1 \]
Contouring: Male Pelvis

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

\[ P_{\text{Contouring}} = P_{\text{List / Accurate}} = P_{\text{AutoSegmentation}} \]
Fewer Steps = Less Complex?
Step Reduction

- System – Design and Deliver Therapeutic Radiation
Contouring: Male Pelvis

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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.
Important to know the limitations of systems.

Impact of inaccuracy is case specific
- benign to catastrophic

Carefully document behavior of automation when first implementing clinically

Clinic should agree on method of implementation
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
Fewer Decisions = Less Complex
Most important area to increase uniformity.

Documentation and communication on simulation day can have critical impact on patient treatment.

- Tends to propagate through treatment.
Decision Uniformity

Who Was Right?
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
Decision Uniformity

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

- Who was right?
- Machine 1
  - Most patients
  - Alignment with fiducials
- Machine 2
  - Central and left sided
  - Right Sided
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.
Why is Complexity Bad?

Discovery of Events that Occurred During "Treatment Planning" or Earlier

- Discovered in Pre-Treatment Review and Verification: 42.4% (285 events)
- Discovered in Treatment Planning or Earlier: 28.3% (190 events)
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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
Step and Choice Reduction

\[ P_{\text{printing}} = P_{DVH} \times P_{\text{display}} \times P_{\text{isodose}} \times P_{\text{ports}} \times P_{\text{DRRs}} = 1 \]
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
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

\[ P_{\text{GoodPlan}} = P_{\text{intuition}} \times P_{\text{experience}} \times P_{\text{Tool}} \]

- \( P_{\text{Tool}} < 1 \) but additional workflows can enhance ability to evaluate more metrics and compare large amounts of data

- Increases value of \( P_{\text{intuition}} \times P_{\text{experience}} \)
SBRT Gradient Index and Quality

- Dose gradient index: \( \frac{(50\% \text{ Rx Volume})}{(\text{Target Volume})} \)
  - 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
**Stereotactic Plan Evaluation: New Challenges**

<table>
<thead>
<tr>
<th>Volume</th>
<th>Percentage</th>
<th>Dose Gradient – Ratio of 50% Rx Volume/Target Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>118.9 cc</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>153.6 cc</td>
<td>62%</td>
<td></td>
</tr>
<tr>
<td>192.3 cc</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Stereotactic Lung: Dose Gradients
Stereotactic Lung: Dose Gradients

Gradient Index Post Data Collection: Lung

- Penrose Lung Old
- SMC Lung Old
- Parker Lung Old
- Longmont Lung Old
- Durango Lung Old
- RTOG No Deviation
- RTOG Minor Deviation
- Penrose Lung New
- SMC Lung New
- Littleton Lung New

PTV Volume (cc) vs. Gradient Index
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
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
Thank You!