Analyzing Operational Decision-Making of Radiotherapy with STPA

Lawrence Wong, PhD
Todd Pawlicki, PhD

UC San Diego Health

RETHINKING MEDICAL PHYSICS
Radiotherapy

- Radiation kills malignant cells
- Targeting and dosing are critical to minimize collateral damage

Conventional radiotherapy workflow

- Imaging for planning
- Treatment planning
- Treatment delivery

- Anatomical changes at cancer sites can make targeting difficult

Åström et al., 2022
Online adaptive radiotherapy: Opportunities and challenges

- New radiotherapy system enables plan adaption

- New decisions at the treatment console in real-time

Great opportunity for STPA
TU-115-lePD-F7-2 - Operational Decision-Making of Cone Beam Computed Tomography-Based Online Adaptive Radiotherapy
### Step 1: STPA purpose

<table>
<thead>
<tr>
<th>Foci</th>
<th>Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Radiation is delivered in the wrong dose (amount, location, or timing) or to the wrong patient</td>
</tr>
<tr>
<td>Efficiency</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
</tbody>
</table>
Step 2: Control structure

Frontline care delivery

Patient assessment & planning

Define and provide treatment plan

Treatment delivery

Treatment delivery staff (Radiation Therapists, Medical Physicists, Radiation Oncologists)

Mode up adaptive session
Capture radiographic image
Delineate anatomical structures
Choose plan

Radiographic image
Dosimetry plans
Adaptive plan QA result
...

Linear accelerator (linac)

Identity
...

Patient

Management
Manage frontline operations

UC San Diego Health
Highlights from Step 4: Causal scenarios

Causal scenario 1: an inaccurate estimation of the change in patient anatomy

- only the session radiographic image is shown but not also the image from original plan
- software-estimated anatomic changes is not displayed

UCA: mode up adaptive session when patient anatomy has changed significantly and a CT cannot be satisfactorily generated

Treatment delivery staff

Control action generation
- If change in patient anatomy can be accommodated by linac, mode up adaptive session

Mental model
- (Change in) patient anatomy
- Capability of linac

Linear accelerator (linac)

Patient anatomy
Applying STPA in the radiotherapy community

- Collaboration between 4 centers
  - Different disease site applications
  - Different staffing models

- First STPA for 3 of 4 centers
Collaboration/analysis team

STPA facilitator
- Systems engineer
- STAMP/STPA expert
- Familiarity with previous STPAs on the topic
- Basic knowledge of radiotherapy

Co-STPA facilitator
- Medical physicist
- Experienced STPA user
- Radiotherapy expert

Co-analysts
- Medical physicists, other radiotherapy practitioners
- Radiotherapy experts
- Basic knowledge of STPA
Collaboration/analysis workflow

Pre-STPA

- Collaboration formation
- STPA familiarization

STPA

1. Define purpose of analysis
2. Model control structure
3. Identify unsafe control action
4. Identify causal scenario
STPA familiarization

- 5-min video
  - Control loop and control structure
  - Examples in radiotherapy
  - Model of human decision-making
  - STPA analysis process
- Short written description of methods
- Reference STPA Handbook

Comments welcome
lmwong@health.ucsd.edu
Results generation

- Geographic, timezone differences
- Contributor-integrator approach
- Input solicitation through Excel worksheets
- Results harmonization
STPA facilitating

• Comprehensibility is key
  • translate between STPA-speak and medical (physics) speak
  • solicit comment on comprehensibility always
  • top-down analysis, so provide examples especially when descriptions are general

• Apply STAMP-thinking
  • prompt for feedback, process model flaws

• *If pre-requisite met*, expedite the analysis
  • UCAs addressed by previous STPA
  • Be careful of probabilistic thinking – *do not* disregard UCAs based on *perceived* likelihood of occurrence
Acknowledgement

- Trent Aland, PhD
- Mikel Byrne, MSc
- Erik van Dieren, PhD
- Joseph Harms, PhD
- Xenia Ray, PhD
- Dennis Stanley, PhD
- Lisanne Zwart, MSc
- Varian Medical Systems
Lawrence Wong
Department of Radiation Medicine and Applied Sciences
lmwong@health.ucsd.edu