Challenges in implementing industrial engineering tools in radiation oncology clinics

Tools * People * Culture

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Systems Thinking

• An approach to problem solving, by viewing "problems" as parts of an overall system, rather than reacting to specific part, outcomes or events and potentially contributing to further development of unintended consequences.

It is a conversation

• Our efforts
• Systems thinking – What and Why?
• Industrial Engineering Tools – WashU Experience
  – Lean+ Six Sigma, Organizational learning and automation
• Challenges in radiation oncology clinics
  – Culture
  – Power distance
• Other thoughts

Modern Radiation Therapy Process

Current Challenges

<table>
<thead>
<tr>
<th>Data Informatics</th>
<th>Automation</th>
<th>Patient Safety</th>
<th>Process Management</th>
<th>Compliance &amp; Standardization &amp; Benchmarking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lots of Data</td>
<td>Diverse format</td>
<td>Various sources</td>
<td>Random Analyzed</td>
</tr>
</tbody>
</table>
### Current Challenges

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<tbody>
<tr>
<td>Repetitive</td>
<td>Variability in practice</td>
<td>Variety of equipment</td>
<td>Variability of process</td>
<td>Variability in interpreting results</td>
</tr>
<tr>
<td>Quality assurance paradigm rather than a quality control paradigm</td>
<td>Scientific approach seldom used</td>
<td>Ad-hoc approach optimizing workflow, scheduling of tasks and monitoring of status</td>
<td>Process Management</td>
<td>Compliance, Standardization &amp; Benchmarking</td>
</tr>
</tbody>
</table>

### Vision

- To develop infrastructure, process and techniques to perform digital, automatic, intelligent, process-oriented, and patient safety-oriented quality control in radiation oncology.
  - Nurture systems thinking and use lean & six sigma principles
  - Should make use of advanced information processing techniques
  - Should facilitate transparency of processes, status and results
  - Should facilitate data sharing, standardization and benchmarking

- Formed in January 2008

### Our Story

- **2005** – Realized need for robust clear and effective communication
- **2007** – Organizational Learning campaign
  - Error Reporting System
- **2008-2009** – Several reactive tools
  - SPC, FMEA, Value stream analysis, process mapping etc
- **2010-2011** – Systems thinking & integration of tools
Organizational Learning

Quantifying Failures and Identifying Areas for Improvement

- A voluntary web-based reporting and analysis system
- Potential and actual errors (events) tracked
- Track explicit and random errors
- Use the data to feed design of clinical processes and tools

MD Simulation/Treatment Planning Orders

- During 19 months - ~500 Events submitted for MD Simulation/Treatment Planning Orders
- ~70% of reported events related directly to the order entry process (MS Word template in MOSAIQ)
  - 28% Incorrect/incomplete simulation instructions
  - 33% Incorrect/incomplete treatment planning orders
  - 6% Scheduling issues
- Solution – Web-based order entry system with business logic and error checking

Electronic MD Orders - Results

- 4 Physicians in the pilot group
  - 203 events in 19 months with the old system
  - New system
    - 22 events in 4 months
    - 3 events in month 4
- Fully deployed in April 2010
  - Drastic reduction in incomplete/incorrect orders

Evolution of IMRT Process – case study

Let us go over few tools

- Are they any worth
Catching Errors Using Dynalogs

Wrong beam deleted from Mosaiq

Improper MLC Segment

Highly Modulated DMLC Plan

MLC Position Error

Therapist accidentally changed Jaws
Errors Detected

<table>
<thead>
<tr>
<th>Site</th>
<th>No. of patient</th>
<th>No. of errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head and Neck</td>
<td>216</td>
<td>3</td>
</tr>
<tr>
<td>Prostate</td>
<td>198</td>
<td>1</td>
</tr>
<tr>
<td>Brain</td>
<td>127</td>
<td>1</td>
</tr>
<tr>
<td>Pelvis</td>
<td>78</td>
<td>1</td>
</tr>
<tr>
<td>Lung</td>
<td>74</td>
<td>0</td>
</tr>
<tr>
<td>Breast</td>
<td>74</td>
<td>2</td>
</tr>
<tr>
<td>Rectum</td>
<td>40</td>
<td>2</td>
</tr>
<tr>
<td>Pelvis</td>
<td>78</td>
<td>1</td>
</tr>
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<td>Lung</td>
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<td>0</td>
</tr>
<tr>
<td>Rectum</td>
<td>40</td>
<td>2</td>
</tr>
<tr>
<td>Breast</td>
<td>38</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>151</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>512</td>
<td>13</td>
</tr>
</tbody>
</table>

False Positive and other minor errors

<table>
<thead>
<tr>
<th>Warnings message type</th>
<th>Number</th>
<th>SMLC</th>
<th>IMLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low pass of Errors map</td>
<td>123</td>
<td>85</td>
<td>38</td>
</tr>
<tr>
<td>Carriage A and B</td>
<td>11</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Number of beams more than plan</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number of beams less than plan</td>
<td>14</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Cell mass angle</td>
<td>5</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Mean MLC precision error</td>
<td>24</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Other calculation error</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>174</td>
<td>113</td>
<td>58</td>
</tr>
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Evolution of IMRT Process – case study

ECCK
(Electronic Chart Checking)

Problems of human chart checking

- Initial chart check
  - Zillion numbers
  - Not comprehensive
  - Lack of consistency
- First and sequential weekly chart check
  - Too much dependent on humans
  - Reactive, not proactive
- General problems
  - Very laborious, repetitive, costly

Motivation of ECCK

ECCK Report Generator Program

1. Select a patient from Mosaiq
2. DICOM plan is automatically found and loaded
3. Pinnacle plan is automatically found and loaded
4. On-demand initial chart check
5. Automatic daily/weekly chart check
6. DynalogQA report viewer
7. Mosaiq document viewer
What are checked?

- Initial chart check
  - Matching among Pinnacle, DICOM and Mosaiq
  - Beam parameters
  - Patient site setup
  - Images rejection and DRR attachments
  - Required documents
  - Prescriptions and treatment calendar
  - Notes

- Daily/weekly chart check
  - Beam delivery records versus planned beam parameters
  - Couch table position and trend
  - Documents
  - Rejections of beam portal images
  - Plot of different assessment data

ECCK Reports

- In dynamic HTML format
- Stored on physics G drive
- Can be viewed
  - In web browsers
  - Using ECCK report viewer program
  - Online via OCF web server (in the near future)

ADQ (Automatic Dynalog QA)

To QA IMRT patient beam deliveries

- Dynalog files
  - Dynalog = Varian LINAC MLC dynamic log
  - Recorded for all patient IMRT deliveries on LINAC MLC controller computer for TX3, TX4, TX8 and TX9
  - Automatically copied to Eclipse server
- ADQ programs automatically
  - Analyze the dynalog files
  - Compare to treatment plans
  - Create reports
- Physicists
  - Use ADQ report viewer program to check the reports daily

ADQ reports

- In HTML format
- Improved layout
- Summary, followed by detailed report for each beam
- Fluence map comparison
- Color-coded error display
- User instruction and explanation of rules
- Searching by patients, by machine or by date

Other pain points – System thinking

- Machine QA – Documentation, Compliance benchmarking and auditing
- Commissioning of Truebeam
- Commissioning of Viewray
- Commissioning of Still River Proton therapy
- Management of multiple clinics with standardized lean operation
QAIS

Centralized Web-Based QA Information System

- Patient Specific QA Data
- Machine and Equipment Performance Logs
- Equipment/Event/Event Log Data
- Just Before, Just After, Pipeline Status, Warning and Alerts
- Patients, QA Statistics, and Status
- Machine and Equipment Performance Logs
- Workflow Manager and Monitor

Sortable To-Be-Reviewed List

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QAIS – Interface & Feature

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Statistical Process Control (SPC)

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Gamma Knife – Independent dose calculator

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Tomotherapy Sinogram Analysis Tool

Workflow Manager Dosimetry Board-Physics QA Board

Other proactive tools out there
- Process Mapping
- Value stream mapping
- Fault tree analysis
- Failure mode and Effect analysis
- Root cause analysis

FMEA Xoft

FMEA Xoft

WU Rad Onc
Culture in Radiation Therapy

Challenges

- Team building
- Leadership support and understanding
- Knowledge vs execution skills
- Common practice trumps common sense
- Culture in radiation therapy
- Power distance
- Human factors
- Staffing and Resource utilization
- Lack of data

Culture and Radiation Therapy

- 1999: Institute of Medicine
  - To Err is Human: Building a Safer Health System
  - Examine level of safety in US medical institutions
  - Harvard Medical Practice Study and Utah-Colorado Medical Practice Study
  - Medical Errors cause between 44,000 and 98,000
  - More deaths than automobile (43k), breast CA (43k) or AIDS (16k)

Industrial Accidents

- Antecedents to major industrial accidents gained attention
- Consistent organizational factors identified as causes
  - Accidents happen as part of normal operations
  - Consequence of hazardous nature of industry
  - Often no procedures to follow workers developed their own
  - Pressure to get work done as quickly as possible
  - Significant association between safety climate and unsafe behaviors and accidents

High Reliability Organizations

- Potentially catastrophic consequences for failure
- Perform with very low levels of failure under demanding conditions
- Examples
  - Nuclear Power Industry
  - Commercial and Military Aviation
HRO versus Medicine

- Gaba et al (Human Factors 45, 2003)
- Compared naval aviation and medicine
- Survey on safety climate in both systems
- Questionnaires
  - Resources
  - Attitude violations standard operating procedures
  - Attitude of leadership of changing plans
  - Safety in training
  - Leadership’s understanding of risks

Standardization of Processes

- Procedures that work in some countries failed utterly in other countries
  - Why?
  - Cultural differences!
- How about radiation therapy?
  - Are there cultural challenges to improving safety in radiation therapy?
  - Hypothesis: YES!

Cultural Challenges in Radiation Therapy

- Culture
  - Predominating attitudes and behavior that characterize the functioning of a group or organization
- How do we test the hypothesis
- Data
  - We don’t have enough
  - Examine HRO and extrapolate

4 Dimensions of Culture

- Social inequality, including relationship with authority
  - Power distance
- Relationship between individual and group
  - Collectivism versus individualism
- Concepts of masculinity and femininity
  - Femininity versus masculinity
- Ways of dealing with uncertainty, ambiguity, expression of emotion
  - Uncertainty avoidance

Power Distance Index

Beyond QA

- QI dimensions (cont’d)
  - Quality management strategies
    - Principles such as data-driven decisions and evidence-based protocols
    - Six-sigma, FMEA
  - Monitoring
    - Monitor patient care experience, process, outcomes
    - Data collection, analysis, result documentation, review
  - Communication
    - Communicate QI activities, priorities, results
**Challenges**

- Developing safety culture is not as simple as translating work from other industries (e.g. steel factories)
- Medicine has specific and unique challenges
  - Especially with respect to culture
- Some other industries, person that makes error goes down with ship
- Some lack of quantization in medicine and radiation oncology that limits application of hard and fast rules/processes
- Not controlled by organized set of regulators

**Summary**

- Systems thinking is key for improving quality, safety and efficiency on radiation therapy
- Understanding culture is important for safety
- Physician should get basis management education and or six sigma green/black belt certification
- Team building skills and understanding industrial engineering tools are key for radiation therapy practitioners
- More automation and intelligent tools
- Remote and autonomous monitoring

**Summary**

- Trump common practice with common sense
- Compliance to Commitment attitude
- Be a part of the QA revolution