Challenge Maintaining Safety in Radiation Oncology

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University of North Carolina at Chapel Hill, NC
Conflicts of Interest

- NIH, Lance Armstrong, IMPAC, DOD
- Dept: Research support Siemens, Government (NCI, etc)
- Faculty affiliations:
  - Sicel Technologies (Dosimeter)
  - Morphormics (software)
  - IMPAC (Mosaiq)
  - XinRay (nanotechnology)
Summary

• Confluence of events increasing hazards
  • Within Radiation Oncology
  • Broadly in Oncology/Medicine
  • Societal issue
• Technology: challenges & solutions
• Human-mediated solutions
  • Human Factors Engineering
  • Lean Health Care
  • Hierarchy of Effectiveness
  • Safety Culture
• Physician leadership
Adopted from Timothy Williams, ASTRO Chairman of the Board, Lynn Cancer Center, Florida. Miami Safety Meeting June 2010
After 39 Gy in 3 fractions
• Confluence of events increasing hazards
  • Within Radiation Oncology
  • Broadly in Oncology/Medicine
  • Societal issue

• Technology: challenges & solutions

• Human-mediated solutions
  • Human Factors Engineering
  • Lean Health Care
  • Hierarchy of Effectiveness
  • Safety Culture

• Physician leadership
Major reasons cited for IMRT adoption

- normal tissue sparing 88%
- dose escalation 85%
- economic competition 62%

2002 and 2004 data from Mell LK, Mehrotra AK, Mundt AJ. Cancer, 104:1296, 2005
<table>
<thead>
<tr>
<th>Author</th>
<th>Deviation Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per tx</td>
</tr>
<tr>
<td>Marks 2007</td>
<td>0.1%</td>
</tr>
<tr>
<td>French, 2006</td>
<td>0.3%</td>
</tr>
<tr>
<td>Huang, 2005</td>
<td></td>
</tr>
<tr>
<td>Yeung, 2005</td>
<td></td>
</tr>
<tr>
<td>Patton, 2003</td>
<td>0.2%</td>
</tr>
<tr>
<td>Barthelemt-Brichant, 1999</td>
<td></td>
</tr>
<tr>
<td>Fraass, 1998</td>
<td>0.4%</td>
</tr>
<tr>
<td>Macklis, 1998</td>
<td></td>
</tr>
</tbody>
</table>

Population-based studies find much lower rates; e.g. 3/100,000. “Reporting threshold”
Deviation Rate %

Low Tech = No MLC
High Tech = MLC

Learning Curve

Deviations ≈ 0.1 "high" & "low" tech
QA Initiatives and Deviation Rates

Duke; IJROBP 72 (supp):S143, ASTRO 2008

Pre-RT Checklist
Pre-RT verbal timeout: 2 therapists
Pre-RT Timeout: 1 therapist
Standardized physicist pre-RT chart check
Color-coded field marks
Dosimetry calculation time-outs

Overall Deviation Rate

QA measures appear effective
Increased Complexity (Obvious)

Beyond the obvious

Over-simplification of complex
Traditional schedules/work-habits?

Misconceptions

Over-reliance, unforeseen dangers
Over-Reliance on Imaging

QuickTime™ and a decompressor are needed to see this picture.
Certainty of Gross Anatomy

Field Margins

- Physically or biologically necessary margin
- More conservative approach
- Too fancy: marginal miss
# Prostate: Too Fancy?

<table>
<thead>
<tr>
<th>Method</th>
<th>Margins (mm)</th>
<th>Biochemical Disease Free Survival (5yrs)</th>
<th>P- Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implanted Seeds for Localization (N = 25)</td>
<td>3-5</td>
<td>58%</td>
<td>0.02</td>
</tr>
<tr>
<td>No Implanted Seeds (N = 213)</td>
<td>6-10</td>
<td>91%</td>
<td></td>
</tr>
</tbody>
</table>

Engels, IJROBP 74:388, 2009
Too Fancy? Orbital Lymphoma

Method

GTV + Margin (12)

Whole Orbit (12)

Local Control

67%

100%

Grade ≥2 Toxicity

25%

33%

From Pfeffer et al., IJROBP 2004
I can’t see the tumor
The tumor moves
The patient is breathing
The patient is fidgety

Circa 1985

Add margin
Add margin
Add margin

Circa 1985
Used to lump them together: 1.5-2.0 cm margins routinely

Gross Tumor Volume (GTV) + Microscopic Spread + Internal Motion + Set-up Errors
Used to lump them together: 1.5-2.0 cm margins routinely

- Gross Tumor Volume (GTV)
- Microscopic Spread
- Internal Motion
- Set-up Errors

**Clinical Target Volume (CTV)**

**Internal Target Volume (ITV)**

**Planning Target Volume (PTV)** - treated volume
Addressing physical uncertainties unmasked biological ignorance

- Imaging - CT, PET
- Gross Tumor Volume (GTV)
- Microscopic Spread
- Internal Motion
- Set-up Errors
- Respiratory gating
- On board imaging

- Clinical Target Volume (CTV)
- Internal Target Volume (ITV)

- Planning Target Volume (PTV) - treated volume

Addressing physical uncertainties unmasked biological ignorance
I can’t see the tumor
The tumor moves
The patient is breathing
The patient is fidgety

PET, CT..
4D CT..
Gating..
Calypso..

Circa 2011
I can’t see the tumor
The tumor moves
The patient is breathing
The patient is fidgety

Call physics
Call physics
....

Circa 2011
IMRT ≠ IGRT

紧致边缘 ≠ 快速剂量梯度

不否定微观扩散
IMRT
IMRT: Misconceptions

• “… even with IMRT, … ‘perfect’ plan that creates completely homogeneous coverage of the target volume and zero or small dose to the adjacent organs at risk is not always obtained.” (my emphasis)

IMRT: Misconceptions

• “… even with IMRT, … ‘perfect’ plan that creates completely homogeneous coverage of the target volume and zero or small dose to the adjacent organs at risk is not always obtained.” (my emphasis)

**Integral Dose**

- Total energy deposited in patient
  Units: gram-rad
  \[(\text{gram}) \times (\text{energy/gram}) = \text{energy}\]
- Hypothesis: Integral dose is largely *constant* for IMRT vs. 3D

**IMRT redistributes dose**

Symmetric: orientation irrelevant (a la Mike Goiten)
Brain Tumor: 2 to 6 Beams
## Data from scans of patients with brain tumors

<table>
<thead>
<tr>
<th>Patient</th>
<th>2-Beam</th>
<th>3-Beam</th>
<th>4-Beam</th>
<th>5-Beam</th>
<th>6-Beam</th>
<th>Average</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 1</td>
<td>2516</td>
<td>2649</td>
<td>3011</td>
<td>3097</td>
<td>3074</td>
<td>2870</td>
<td>268 (± 9.3%)</td>
</tr>
<tr>
<td>Patient 2</td>
<td>3507</td>
<td>3551</td>
<td>3610</td>
<td>3739</td>
<td>3708</td>
<td>3623</td>
<td>100 (± 2.8%)</td>
</tr>
<tr>
<td>Patient 3</td>
<td>4315</td>
<td>4420</td>
<td>4723</td>
<td>4617</td>
<td>4628</td>
<td>4541</td>
<td>168 (± 3.7%)</td>
</tr>
<tr>
<td>Patient 4</td>
<td>1581</td>
<td>1632</td>
<td>1814</td>
<td>1780</td>
<td>1770</td>
<td>1716</td>
<td>102 (± 5.9%)</td>
</tr>
<tr>
<td>Patient 5</td>
<td>4913</td>
<td>4980</td>
<td>4998</td>
<td>4952</td>
<td>4952</td>
<td>4959</td>
<td>32 (± 0.6%)</td>
</tr>
</tbody>
</table>

Curle and Das, Duke

- Integral Dose
- Average
- Std. Dev.
- Non-coplanar beam arrangements
- Standard Deviations <10%
- Laterals
whole internal shell

Integral dose constant = Integral dose constant = Integral dose constant
Dosimetric Limitation of IMRT

- Integral dose to each shell is $\approx$ constant
- Ability to move dose around is somewhat limited
- "Average" dose gradient $\approx$ constant!!
“Don’t worry, IMRT will solve it”

• KISS: Lost in the Modern Era
  • Positioning
    • E.g. Belly boards, decubital position
  • Reducing skin folds
  • Barium in bowel

Applicable in Modern Era!
Down-stream
‘peer-review’
Swiss cheese model of Errors

Down-stream errors maybe getting harder to detect

James Reason. Image modified from John French, BC Cancer Agency
Vancouver, Miami Safety Meeting June 2010
Assess doses and beam orientation & aperture

Apply prior knowledge

Beam orientations, “apertures,” intensity maps not intuitive.
Physics QA: planned vs. delivered dose?
I see what I am treating
Quest for better dose distributions

- Complex solutions; e.g. IMRT
- Workload increased
- Safety concerns

Time = Money, Fun
• Anatomy
• Physiology
• Surgery

• Exportability
• Applicability
  • IMRT vs. 3D
• Fractionation
• Segmentation

DVH-Based Models
Increased Complexity (Obvious)
Beyond the obvious
  Over-simplification of complex
  Traditional schedules/work-habits?
Misconceptions
  Over-reliance, unforeseen dangers
Radiation Oncology

Sicker patients
Electronic medical record
Billing & insurance

Broadly Oncology & Health Care
FDA Approved Drugs for Oncology by Year

Number of Drugs Approved by FDA for Oncology

from centerwatch.com 3/6/2012
Percent of patients with advanced lung cancer receiving chemotherapy

41%  58%

1996  2003-2005

SEER Patterns of Care Study, Stage IV disease  CanCORS, Stage IIIB and IV disease

Nausea controlled. Patient well. She is scheduled for CT scan on 10/21/08. Also to see Dr. Heathcote. She will stop by the clinic of pigs.


10/5/06: Rights.

Skin do not seem clear. (by people) regular check up.

All after 15 weeks.
2/6/09
e-Boost
demar

Patch
Moisture
SKW DJ

Scar
Boost

3cm macropigment near skin DJ in axilla

Picture = 1,000 words
Paper: easily edited, annotated, corrected, highlighted, emphasis

The patient will come back for treatment simulation confirmation in about a week.

LOOSE ENDS: Baseline PFTs, baseline laboratories.

FEV1 1.3 L
Patient is a 56 year old man with a T5 N0 left breast cancer. He initially presented with a rapidly enlarging mass.....

Electronic record is NOT easily edited- Propagation of errors

Context!
**Dx:** Female Breast, NOS (excludes Skin of breast T-173.5)

<table>
<thead>
<tr>
<th>Site</th>
<th>Technique</th>
<th>Modality</th>
<th>Fractions</th>
<th>Rx Dose</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right SC/Neck</td>
<td>AP/PA</td>
<td>06/15 MVX</td>
<td>5</td>
<td>1,000 cGy</td>
<td>1,000 cGy</td>
</tr>
<tr>
<td>Lt SC/Neck</td>
<td>AP/PA</td>
<td>06/15 MVX</td>
<td>5</td>
<td>1,000 cGy</td>
<td>1,000 cGy</td>
</tr>
<tr>
<td>Lt Chestwall</td>
<td>Tangents w/FiF(s)</td>
<td>06/15 MVX</td>
<td>8</td>
<td>1,600 cGy</td>
<td>1,600 cGy</td>
</tr>
<tr>
<td>Both 3D Lt Chestwall</td>
<td>Tangents w/FiF(s)</td>
<td>06/15 MVX</td>
<td>8</td>
<td>1,600 cGy</td>
<td>1,600 cGy</td>
</tr>
<tr>
<td>Right Supravcl/Neck</td>
<td>AP/PA</td>
<td>06/15 MVX</td>
<td>16</td>
<td>3,200 cGy</td>
<td>3,200 cGy</td>
</tr>
</tbody>
</table>

**Rx Site:** Lt Chestwall  
**Status:** Pending

**Technique:** Tangents w/FiF(s)  
**Modality:** 06/15 MVX  
**Dose Spec:** Isodose

- **Rx Dose:** 1,600 cGy  
- **Fractional Dose:** 200 cGy  
- **Number of Fractions:** 8  
- **Fractionation Pattern:** Every Other Day  
- **Status:** Fractions Treated

**Pattern:** “DIBH” Alternates with 1.0 cm bolus tang flds ev. other day

**Comment:** Pt ID’d by photo/verbal/ID (2) prior to each tx
Physics QA (“Chart Checks”)

Paper chart
Solution existed
Served us well
Doable and Trackable
Evolved over decades

Electronic Medical Record
Much harder to do
Not trackable (e.g. no annotation)
Billing guidelines; complex, distracting
Broadly Oncology & Health Care

Radiation Oncology

Society
Societal Expectations

- Specialization and increased cost
- Wars, Civil rights movement, affluence
- Government funding

- Increased patient expectation
- As we do more, more opportunities to harm, more harm done

Leape: Harvard School of Public Health
Lean
• increase capacity
• decrease demand
- Standardization
- Human factors
Dunscombe (Univ Calgary): Human Factors implicated 60% of errors

Joe Cafazzo (PMH): Foolish-try to change someone’s behavior
Need better tools to give people
Timothy Williams, Lynn Cancer Center, Florida. Miami Safety Meeting June 2010
Therapist: Same issue for MD, dosimetrist, etc  UNC
QuickTime™ and a decompressor are needed to see this picture.

“Its 3 and 2”
<table>
<thead>
<tr>
<th>Site</th>
<th>Technique</th>
<th># Fractions</th>
<th>Total Dose</th>
<th>Dose/fraction</th>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lt Breast DIBH</td>
<td>Tangents w/FF(s)</td>
<td>16</td>
<td>267 cGy</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Lt Brst Bed Boost</td>
<td>Electron boost</td>
<td>5</td>
<td>200 cGy</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

**Site, Technique, # Fractions, Total Dose, Dose/fraction, Technique**

**Total Dose, Dose/fraction, # Fractions**

**Site, # Fractions, Total Dose, Dose/fraction, Technique**
<table>
<thead>
<tr>
<th>Site</th>
<th># Fractions</th>
<th>Total Dose</th>
<th>Dose/fraction</th>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lt Breast DIBH</td>
<td>21</td>
<td>4,272 cGy</td>
<td>267 cGy</td>
<td>Tangents w/Fif(s)</td>
</tr>
<tr>
<td>Lt Breast Bed Boost</td>
<td>6</td>
<td>1,000 cGy/1,000 cGy</td>
<td>200 cGy</td>
<td>Electron boost</td>
</tr>
<tr>
<td>Sec: Total Tumor Bed</td>
<td>28</td>
<td>5,272 cGy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Physician’s Unique Role/Responsibility

- Acknowledge problem
  - Speak openly: staff, administrators, patients
- Advocate automation, standardization, Lean
- Judicious use of technology
  - patient advocate & trusted societal servant
- Empower and celebrate others’ QA activities
- Embrace safety initiatives
  - Broad areas; e.g. training programs
- Safety culture
  - Facilitator, champion, leader
## Most Trusted Professions (Gallup Poll)

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
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<tbody>
<tr>
<td>1</td>
<td>Nurses</td>
<td>Nurses</td>
<td>Nurses</td>
<td>Nurses</td>
<td>Nurses</td>
</tr>
<tr>
<td>2</td>
<td>Druggists / Pharmacists</td>
<td>Druggists / Pharmacists</td>
<td>Grade-school teachers</td>
<td>Druggists / Pharmacists</td>
<td>Druggists / Pharmacists</td>
</tr>
<tr>
<td>3</td>
<td>Medical doctors</td>
<td>Veterinarians</td>
<td>Druggists / Pharmacists</td>
<td>High school teachers</td>
<td>Medical doctors</td>
</tr>
<tr>
<td>4</td>
<td>High school teachers</td>
<td>Medical doctors</td>
<td>Military officers</td>
<td>Medical doctors</td>
<td>Police officers</td>
</tr>
<tr>
<td>5</td>
<td>Policemen</td>
<td>Dentists</td>
<td>Medical doctors</td>
<td>Policemen</td>
<td>Engineers</td>
</tr>
</tbody>
</table>
Physician’s decision to apply advanced technologies

- Competitive Pressures
- Financial Incentives
- Macho “fun”
- Patient Pressures
Promoting safety culture at UNC

Automation
Lean / Standardization
Peer Review
Visibility
Celebrate successes
Hierarchy of Effectiveness

Forcing function & constraints

Automation/computerization

Simplification/standardization

Reminders, checklists, double checks

Rules & policies

Training & education

Adopted from Joseph Cafazzo. Miami Safety Meeting June 2010
Hierarchy of Effectiveness

Forcing function & constraints
- Automation/computerization
- Simplification/standardization
- Reminders, checklists, double checks
- Rules & policies
- Training & education

Technology
Focused
More Effective

People
Focused
Easy, Cheap
Less Effective
Most Often Used

Adopted from Joseph Cafazzo. Miami Safety Meeting June 2010
Hierarchy of Effectiveness to Prevent Error

Forcing function & constraints

Automation/computerization

Simplification/standardization

Reminders, checklists, double checks

Rules & policies

Training & education

Technology

Focused

More Effective

People

Focused

Easy, Cheap

Less Effective

Most Often Used

Automatic naming within planning system

Reminder signs on walls

“You must do this”

“We should do this”

Adopted from Joseph Cafazzo. Miami Safety Meeting June 2010
The fact that the plan has multiple isocenters is automatically noted in the name.

Beams are automatically named, as is the presence of bolus.

The user is alerted that the isocenter has been shifted relative to the isocenter at CT.
**IMRT Goal Sheet**

**HEAD AND NECK IMRT DOSE GOAL SHEET**

<table>
<thead>
<tr>
<th>Pat Last Name:</th>
<th>Doe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pat First Name:</td>
<td>John</td>
</tr>
<tr>
<td>Site:</td>
<td>Head &amp; Neck</td>
</tr>
<tr>
<td>Plan Name:</td>
<td>09/21/10_1142MVK_composite_6480</td>
</tr>
</tbody>
</table>

**PTV_ER Dose Specification: PTV_SR**

| Does 95% of PTV_ER receive 100% of Rx (4560 cGy)? | 95.0% Yes |
| Does 99% of PTV_ER receive 93% of Rx (4241 cGy)? | 99.0% Yes |
| Does <20% of PTV_ER receive 110% of Rx (5016 cGy)? | 0.0% No |
| Does <1% of Non-Sp receive 110% of Rx (5106 cGy)? | 0.0% No |

Non-Specified tissue: Skin min SR

| # of fields: | 8 |
| # of segments: | 86 |
| Mean Dose: | 4713 cGy |
| Max Dose to 0.1cc vol: | 4965 cGy |

**PTV_NR Dose Specification: PTV_NR**

| Does 95% of PTV_NR receive 100% of Rx (1920 cGy)? | 95.8% Yes |
| Does 99% of PTV_NR receive 93% of Rx (1786 cGy)? | 99.9% Yes |
| Does <20% of PTV_NR receive 110% of Rx (2112 cGy)? | 0.0% No |
| Does <1% of Non-Sp receive 110% of Rx (2112 cGy)? | 0.0% No |

Non-Specified tissue: Skin min NR

| # of fields: | 8 |
| # of segments: | 80 |
| Mean Dose: | 1976 cGy |
| Max Dose to 0.1cc vol: | 2085 cGy |

**Composite Dose Specification**

**PTV_SR in Composite Plan**

| Does 95% of PTV_SR receive 100% of Rx (4560 cGy)? | 100.0% Yes |
| Does 99% of PTV_SR receive 93% of Rx (4241 cGy)? | 100.0% Yes |

**PTV_NR in Composite Plan**

| Does 95% of PTV_NR receive 100% of Rx (6480 cGy)? | 98.0% Yes |
| Does 99% of PTV_NR receive 93% of Rx (6026 cGy)? | 100.0% Yes |
| Does <1% of Non-Sp receive 110% of Rx (7128 cGy)? | 0.0% No |

Non-Specified tissue: Skin min NR

**HEAD AND NECK IMRT CRITICAL STRUCTURE GOAL SHEET**

| Name: | Doe |
| Site: | Head & Neck |
| Plan Name: | 09/21/10_1142MVK_composite_6480 |

<table>
<thead>
<tr>
<th>Structure</th>
<th>Maxi Mean Dose</th>
<th>Maxi Min Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brainstem</td>
<td>5400 cGy to 0.1 cGy</td>
<td>1320 cGy</td>
</tr>
<tr>
<td>Optic Nerve</td>
<td>5000 cGy to 0.1 cGy</td>
<td>1454 cGy</td>
</tr>
</tbody>
</table>
Daily Morning Huddle (‘Sim Review”)

Agenda:
Pre-tx / planning review intent
image segmentation; IMRT

Machine needs (ports, film/tx)
Simulator schedule

Clinic schedule; Doc of the day
Expected challenges

How was yesterday?
General announcements
Invitation for others to speak

Respectful questioning, building a team, safety culture
Team Effort
"I would make the CTV larger medially"

"Really? Ok, I guess I can"

If you do, no way I can cover it and spare cord
To make it work

Time: Allocated time daily
Routine; daily

Content: Try to keep it useful

Broad participation (mean attendance ≈ 20-30)
NOT just the MDs

Need facilities; screens, computers, connections to planning systems, chairs
Informal peer review: “Hey Patti, look at this.”
Safety Rounds
Good news!
Dept. of Radiation Oncology

Employee of the Month Announcement:
Congratulations to
Doug Allen, Radiation Therapist
May 2011 Recipient

Good Bye and Good Luck to
Mark Foskey!
Thank you for six years of service to the
Dept. of Radiation Oncology
We wish you well as you move on to Morphomics, Inc.

Congratulations to
Yaping Zhang, PhD
Dr. Zhang has been selected for the 2011 National Cancer Institute
Myron L. Battle Distinguished Cancer Research Award

Congratulations!!!
Department of Radiation Oncology
Alumni Association Annual Meeting, June 15-17

Dr. Robert Adam is going to the University of North Carolina School of Medicine
American Association of Medical Scientists Annual Meeting, June 15-17

Congratulations to
Mark Isaacson, RTP
Radiation Therapist
Swiss cheese model of Errors

Radiation Therapists involved ‘all’ tx errors
“How could they do that”
“Why didn’t they pick up on that”

James Reason. From John French, BC Cancer Agency
Vancouver, Miami Safety Meeting June 2010
You don’t really want to do that, do you?
### Survey of Radiation Therapists (n=600)¹

<table>
<thead>
<tr>
<th></th>
<th>Bad</th>
<th>Neutral</th>
<th>Good</th>
<th>Very Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>My communication with my:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>radiation oncologists is...</td>
<td>8%</td>
<td>11%</td>
<td>27%</td>
<td>54%</td>
</tr>
<tr>
<td>physicists is</td>
<td>6%</td>
<td>6%</td>
<td>23%</td>
<td>65%</td>
</tr>
<tr>
<td>departmental administrators is...</td>
<td>19%</td>
<td>13%</td>
<td>30%</td>
<td>38%</td>
</tr>
<tr>
<td>My comfort level reporting errors is...</td>
<td>10%</td>
<td>8%</td>
<td>16%</td>
<td>66%</td>
</tr>
</tbody>
</table>

RTs **personally** reprimanded for reporting errors: **16%**

≈ 18%

¹Random sample from National Certification Board
SAFE PATIENTS, SMART HOSPITALS

How One Doctor's Checklist Can Help Us Change Health Care from the Inside Out

Peter Pronovost, M.D., Ph.D., and Eric Vohr
* e.g. electrical grounding procedures, spark-free hand-tools; movement in horizontal and vertical access zones without crossing designated paths

** e.g. protective gear; housekeeping (e.g., cleaning oil spills appropriately)

Summary

• Confluence of events increasing hazards
  • Within Radiation Oncology
  • Broadly in Oncology/Medicine
  • Societal issue
• Technology: challenges & solutions
• Human-mediated solutions
  • Human Factors Engineering
  • Lean Health Care
  • Hierarchy of Effectiveness
  • Safety Culture
• Physician leadership
Acknowledgments

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