

# Optimizing Radiation Therapy Process in Small Community Hospital Environment

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## Outline:

- Treatment goal
  - ◆ What is the Study Subject
  - ◆ Treatment Goal --- "Value"
  - ◆ Reality facing
    - ◆ Human Performance Mode
    - ◆ Swiss Cheese model
  - ◆ Tools available
    - ◆ FMEA
    - ◆ Lean Six Sigma
    - ◆ Incident report system
    - ◆ Root Cause Analysis
- Influence of upstream and downstream operations
  - ◆ Simulation variation
  - ◆ Check list for simulation variations
  - ◆ Treatment delivery variation
  - ◆ Check list for treatment planning
  - ◆ Collision detection
- Optimizing process to reduce event
  - ◆ Event examples
  - ◆ Root cause analysis
  - ◆ Process change discussion

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## What is the Study Subject

- Clinical Environment like community hospital
  - ◆ 3 linac, 2 CTsim, 1 HDR; 3 Physicists
  - ◆ Routine clinical service mainly, min unusual treatment
  - ◆ Favor more towards efficiency
  - ◆ Work assignment change, like dosimetrist contour OAR
  - ◆ Min physics support, commissioning done by 3<sup>rd</sup> party
- Paperless environment with EMR
  - ◆ data in digital format with image, plan, treatment record, RT image, etc.

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## Treatment Goal --- "Value"

- High Efficient
  - ◆ Benchmarked by turn around time
  - ◆ Real working time and dead time
- High Quality
  - ◆ Benchmarked by cure rate
  - ◆ Imaging rejection rate and delivery error
- High Reliability
  - ◆ Benchmarked by mistakes, incident and near-miss
  - ◆ Error rate and severity

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## How Accident Occur

Humans Work in Three Modes

- Knowledge-Based Performance – 50% error rate
  - ◆ "Figuring It Out Mode" – Stop and ask expert
  - ◆ IMRT QA, **learn** to operate the equipment, delivery, documentation
  - ◆ Policy and Procedure, protocol
  - ◆ Graduate program practicum/lab
- Rule-Based Performance – 1% error rate
  - ◆ "If-Then Response Mode" – Education, Reduce burden, increase risk awareness, improve coaching
  - ◆ IMRT QA, accumulate **experience** on trouble shooting if something happens
  - ◆ Checklist, cheat sheet
  - ◆ Resident training IMRT QA rotation
- Skill-Based Performance - 0.1% error rate
  - ◆ "Auto-Pilot Mode" - Stop and think before acting
  - ◆ IMRT QA, after tens of repeat, it become **natural operation** and/or even **habit**
  - ◆ Resident completed rotation/Full time clinical practice every day




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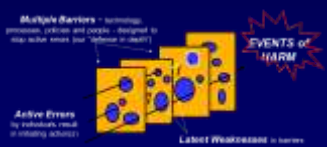
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## How Accident Occur

- Swiss Chees Model
  - ◆ Holes in cheese highlight role of errors within individual layer in global system failure.
  - ◆ Potential error need to go through a series holes to reach patient to become accident
- Feta Chees Model
  - ◆ Nested block of Cheese
  - ◆ **Stresses** applied to any portion of the block can cause the block to fracture in an unpredictable manner




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**How Accident Occur**

- Radiation Oncology Treatment process is **moderately coupled complex system**, accident occur when
  - ◆ Component failure
  - ◆ External disturbances
  - ◆ Dysfunctional interactions among system components are not adequately controlled
- ◆ Reliable/robust components do not guarantee overall system reliability
- ◆ **Too much focus on sub-unit reliability have negative impact to whole system**
- ◆ Each improvement introduce additional opportunities for unforeseen interactions
- ◆ Adding layers of quality assurance/safety steps to existing practices may be detrimental

References: Lawrence Marks, Lukasz Mazur; Engineering Patient Safety in Radiation Oncology

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**Tools available**

- TG-100 Risk Analysis for quality/safety
  - ◆ Process Map
  - ◆ FMEA (Failure mode and effects analysis)
  - ◆ Fault Tree
- Lean Six Sigma for consistency/efficiency
- Incident report system
- Root Cause Analysis



RO-ILS RADIATION ONCOLOGY INCIDENT LEARNING SYSTEM  
Sponsored by RTRD and AOPM

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**Tools available**

- Error prevention tool:
  - ◆ Forcing functions and constraints (most efficient)
  - ◆ Automation and computerization
- ◆ protocols and standard
- ◆ Independent double-check systems
- ◆ rules and policies

References: Matthew Grissinger, Institute for Safe Medication Practices, Medication error prevention "toolbox". Medication Safety Alert, June 2, 1999. WE-CISAM-BRG-1 Quality Management Systems in Radiotherapy: Making Treatments Safer - E. Ford (2011)

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**Influence of upstream operations**

- Check list for Simulation Variations
  - ◆ Patient SI coverage not enough
  - ◆ Target AP and LR centering
  - ◆ Metal artifact: like prosthesis, breast expander, dental filling
  - ◆ Dose limiting: pacemaker/ICD, fetus, gonad
  - ◆ Electron: small field, large oblique angle, extended SSD, backscatter for keloid
  - ◆ Breast: Flash, breast expander
  - ◆ Nose/extremities: water, rice, bolus
  - ◆ Simulation mistake: arm in beam, non-bladder control, excessive gas in rectum, object on patient, accessory/setup error
  - ◆ Indexer, respiration belt clipper
  - ◆ Recon cutoff like heavy patient
  - ◆ Collision detection
  - ◆ Patient identification
  - ◆ Patient orientation

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**Treatment Error**

- Collision
  - ◆ Bent Screw from Gantry head
  - ◆ Collision could cause
    - ◆ Collimator rotation chain pop-out, service/calibration needed, cancel patients for the rest of the day.
    - ◆ Scratch or damage of gantry head cover
    - ◆ Scratch or damage of couch




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**Treatment Error**

- Collision
  - Not only a mistake of therapist
  - Potential risk from sim/planning, detect and correct early
  - Lung case: Couch 0, collision with couch, due to shift wrong direction in simulation;

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**Treatment Error**

- Collision
  - Breast case: PAB field collide with couch.
  - Exact Couch in Trilogy has less clearance than IGRT couch in Truebeam

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**Influence of downstream operations**

- Treatment delivery Variation
  - Gantry clearance, especially with couch kick
  - CBCT clearance
  - Electron cone clearance
    - Schedule linac simple sim in additional to CT sim
  - In-consistent setup
    - Same immobilization device between sim and treatment
  - Couch kick minimization
    - Larger PTV margin for couch kick
  - Treatment MU/Time
    - Non-SRS mode has max 999 MU limit for Trilogy and 1999 MU for Truebeam
    - Tx time is not enough for breast FinF patient
  - Exact Couch side rail/bar
    - Rail-in affect AP/PA KV imaging
    - Rail-in give more room for rail-free arc
  - Gantry angle sorting
    - Sort KV setup fields/CBCT, 90 deg difference
    - Sort MV treatment fields
    - 179.9 or 180.1 instead of 180.0

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## Influence of downstream operations

- Treatment delivery Variation
  - ◆ Collision
  - ◆ Bolus
    - ◆ Skin cancer, fall off
    - ◆ Breast cancer, mess out on/off schedule due to tx break
  - ◆ Partial Tx
    - ◆ Machine down
    - ◆ Collision
    - ◆ Plan scheduling left out
  - ◆ Shift wrong
    - ◆ Wrong direction
    - ◆ Wrong target
  - ◆ Course delivery not complete
    - ◆ Rx changed
      - ◆ Tx calendar update after Tx break
  - ◆ Cone down or plan revision
    - ◆ Fraction number matching
    - ◆ Setup instruction update

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## Planning/Imaging Error

- Image dataset error
  - ◆ Different patient
  - ◆ Previous simulation dataset
  - ◆ Non-optimal dataset
  - ◆ Orientation error
- Process change
  - ◆ Check patient name and ID during import
  - ◆ Clean DICOM import directory regularly and automatically
  - ◆ Verify imaging scanning date from DICOM tag
  - ◆ Note optimal CT series to use in QCL/task
  - ◆ Check **patient and imaging orientation**

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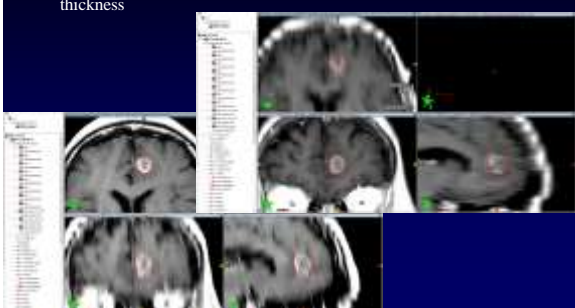
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## Planning/Imaging Error

Brain Imaging Data Set error

- Contour of brain met GTV/CTV is unusual shape
- Compare T1 axial post with T1 Cro post, both with 6mm slice thickness




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**Planning/Imaging Error**

Brain Imaging Data Set error

- Compare T1 axial post with FSPGR post **1mm slice thickness**
- Partial volume effect** due to 6mm slice thickness
- CTV/GTV is much larger than needed, could result in extra dose/brain damage
- Wrong data set Used for contour

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**Planning/Imaging Error**

Left/Right error

- Symptom
  - Right cerebellar lesion need to be treated
  - MRI scan with neurological convention instead of usual radiological convention
  - Only Left and Right fiducial indicator plate used
  - Patient planned and treated to left cerebellar

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**Planning/Imaging Error**

Left/Right error

- RCA
  - HFS vs FFS
  - Viewing direction
    - neurological convention  
View from head to foot direction, patient right on image right
    - radiological convention  
View from foot to head direction, patient left on image right

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**Planning/Imaging Error**

- Left/Right error
  - Process change or checklist
    - Stop and think before patient's position indicator
    - Display image annotation if possible
    - Match anatomical lesion with patient pathology/radiology report
    - Trying to use 3<sup>rd</sup> optional anterior fiducial indicator plate (able to indicate left/right), or additional marker needed
    - Check matching of image skin with skull-scaling device measurement




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**Treatment Error**

- Left/Right error
  - prone breast patient, while most patients supine
  - In the middle of course, patient told nurse after treatment, that treatment was not same as usual
  - Wrong side of breast was treated by mistake, due to mind set with supine and not changed with prone
- RCA
  - Prone is deviation from typical supine
- Correction
  - Stop and thinking
  - Reminder/alert of prone patient
  - Even patient do not want to have tattoo, mark on skin for setup with ink marker
  - Label breast board about left/right
  - Double check by second therapist
  - Verify with IGRT




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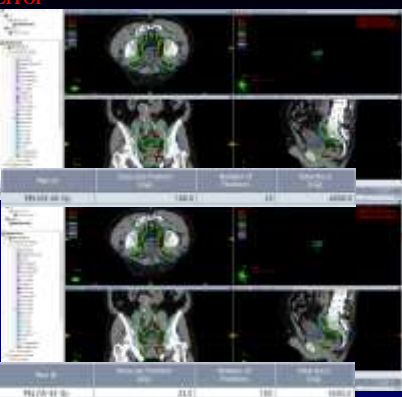
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**Planning Error**

- Wrong Rx
  - Fractional dose and Fraction number reversed
  - Plan isodose, DVH and dose constraint are all the same




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### Planning Error

- Scenario
  - Paper Rx (Prostate 180cGy\*25Fx) and IMRT dose constraint sheet
  - Dose per fraction and fractional dose reversed in Eclipse planning Rx
  - Dosimetrist **tried very hard to meet all constraints**
  - Radcalc secondary check match within 3%
  - IMRT QA pass rate just above 90% with 3mm 3% using Mapcheck, much lower than typical 95% and above, re-measure confirmed setup, record reviewed by director.
  - Reference point dose match Eclipse Rx
  - Treatment scheduled 180 times, match with Eclipse Rx
  - Treated multiple fractions, detected by physicist weekly chart check
- RCA
  - IMRT QA low pass rate should be investigated further
  - Too much focus on sub-unit (planning) have negative impact to whole system**
  - Reliable/robust components do not guarantee overall system reliability**
- Process change
  - Encourage vendor to add a warning to unusual plan fraction number
  - Paper Rx should be checked to match Eclipse Rx
  - Utilize Aria Rx, and Aria Rx to Plan, check reference point dose against Rx dose

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### Planning Error

- Wrong Rx
  - Fractional dose and Fraction number reversed for TomoPlan
  - Plan isodose and dose constraint are all the same during optimization
  - Plan quality degrade dramatically after final dose calculation

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### Planning Error

- Spine planning and treatment error
  - Patient recurrent at contour "T9 gtv", and need to re-treat
  - Overlay with previous contour "T9" and "T8-T10", mismatch by one vertebral body

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**Planning Error**

- Spine treatment error
- Confirmed previous contour "T9" (actually T8) was planned and treated
- mismatch by one vertebral body, it explained the recurrent as well

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**Planning Error**

- HN Planning error
- Cord got uniform dose
- MLC open larger than target

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**Planning Error**

- HN Planning error
- Cord DVH showed uniform dose

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### Planning Error

- HN Planning error
  - Cord+5mm
  - Lower Objective


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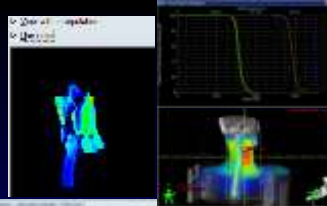
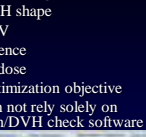
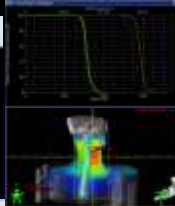
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### Planning Error

- HN Planning error
  - DVH shape
  - BEV
  - Fluence
  - Isodose
  - Optimization objective
  - Can not rely solely on plan/DVH check software


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### Treatment Error

- Wrong patients
  - Prostate patients were treated in a row
  - When treating one prostate patient, RVS showed treated already.
    - Time out procedure
    - Patient identification
      - Two ID,
        - what kind of two ID?
        - is face photo reliable?
        - Ask patient what question instead of yes/no question
      - ID card or ID waist band
      - RFID Tracking
      - Biometric system like palm vein scanner, finger scanner


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**Treatment Error**

- Accidental shift
  - ◆ Plan Pelvis 3D and Plan RP LNs RA share same isocenter
  - ◆ On fx 16, the couch large shift between two plans

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**Treatment Error**

- Accidental shift
  - ◆ Plan Pelvis 3D and Plan RP LNs RA share same isocenter
  - ◆ imaging once and treat both plans without shift in between

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**Treatment Error**

- Scenario
  - ◆ After treated RP LNs, forgot two plans share same isocenter; went to room and press "auto + enter" button, couch automatically moved to last captured position
- RCA
  - ◆ Improper use of "auto + enter" function
  - ◆ Couch position day to day change  
As large as 4cm.
- Solution
  - ◆ Disable "auto + enter" function
  - ◆ Combine fields from two plans to single plan to treat
  - ◆ More consistent setup

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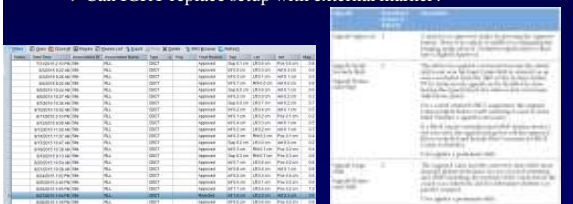
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### Treatment Error

Lung CBCT registration error

- RCA
  - ◆ CBCT shift was large, Inf 1.6cm, Lt 2.2cm, Ant 2.3cm
  - ◆ Policy shift > 1cm, need MD approval, not followed
- Process change
  - ◆ Registration in large scale first, re-training therapist
  - ◆ Forcing sign-off by MD if larger than 1cm shift
  - ◆ Can IGRT replace setup with external marker?




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### Tx Process Optimization

- Forcing function and automation itself can **NOT** adapt to unpredicted issues
- Human **DO** make mistakes even in skill based performance
- **Combination could be more efficient and reliable to detect errors**

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### Acknowledgement

- Vendor
  - ◆ Varian
  - ◆ Elekta
- Physicist
  - ◆ Jian Liang
  - ◆ Yuwei Chi
  - ◆ Fan Zhang
  - ◆ Hao Sha
- Facilities
  - ◆ Wayne State U
  - ◆ DMC/KCI
  - ◆ William Beaumont
  - ◆ Columbia
  - ◆ Bayhealth
  - ◆ RWJBH/SBMC

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