Error Analysis & Reduction
Philosophy and Theory

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Outline

- Error reduction and quality control
- The ‘system view’ and variation
- Tools for error reduction
- Summary and future directions
Definition of Medical Errors

• The failure of a planned action to be completed as intended or the use of a wrong plan to achieve an aim

• A factor contributing to errors is the fragmented nature of the health care delivery system – or ‘nonsystem’

Definition of Quality

- The quality of a product or service is the loss that product or service causes to the patient after it is used for treatment.

- What is the meaning of loss?
  - Loss caused by variability of function
  - Loss caused by harmful side effects

- Quality can not be viewed as a value.

Error Reduction and Quality

• Both are concerned with reducing the two types of losses that may be caused to the patient after treatment
  – Variability of function
  – Harmful side effects
Health Care Progress

• During the past half-century, progress in health care has been made by medical science and technology breakthroughs

• The quality revolution taking place in medicine will provide new remarkable opportunities to improve health care

Taguchi Loss Function (TLF)

\[ E[L(x)] = \int_{all \ x} L(x)f(x)\,dx \]

Average loss per unit of production
TLF Applied to Radiotherapy

\[ F = 1 - \left[ TCP \cdot (1 - NTCP) \right] \]

![Graph showing RT Failure Function (F), Quality Distribution, and Expected Failures E<\(F\).](image)

**Figure 2**
TLF Applied to Radiotherapy

Figure 3
Summary Thus Far

• Error reduction and quality control are intimately related

• Improving quality will reduce errors

• Improving quality may increase survival and decrease complications
The System View and Variation

• Appreciation of a system
  • A network of interdependent components that work together to try to accomplish the aim of the system

• Knowledge of variation
  – Every system (or process) displays variation
  – Variation can be predictable or unpredictable

Patient Treatment Viewed As A System

System View

• Every system or process creates data

• Every data set contains noise
  – To detect a signal, first filter out the noise

• Data do not have meaning apart from their context
  – The order in any sequence of observed results helps physical interpretation

Knowledge of Variation

• It is easy to appreciate variation in your personal life
  – What about variation in the workplace?

• Failing to appreciate variation in processes can lead to obvious and not so obvious problems

Without an Understanding of Variation…

- Difficult to understand past performance
  - No ability to predict the future and make improvements in a process

- Blame or give credit to others for things over which they have little control

- You see trends where none exist

Importance of Time-Ordered Data

Chamber Readings - Time Ordered
Tools For QC & Error Reduction

- Idea Creation (4)
- Cause analysis (3)
- Evaluation and decision-making (2)
- Process analysis (3)
- Project planning and implementation (2)
- Data collection and analysis (7)
- Management and planning tools (7)

Idea Creation

• Nominal group technique
  – Structured brainstorming session that encourages contributions from everyone

• Affinity diagram
  – Organize a large number of ideas into their natural relationship
Nominal Group Technique

• When to use
  – Ideas are coming slowly
  – Some members are more vocal than others

• General method
  – 10 minutes of individual idea generation
  – Each person states one idea aloud per round
  – Facilitator records each idea on a flipchart
  – After all ideas are out – then discuss each
  – Prioritize the ideas using multi-voting
Affinity Diagram

• When to use
  – Many facts or ideas that seem unrelated
  – Issues seem too complex

• General method
  – Generate ideas – one per notecard
  – Spread all notecards on large surface
  – Group the notecards that are related
  – Discuss patterns of groups – changes are ok
  – Choose a title that captures each group
Cause Analysis

• Cause-and-effect (fishbone) diagram
  – Identifies many possible causes for an effect or problem

• Pareto chart
  – Visual depiction of most significant components or situations

• Root cause analysis
  – Study of the original reason for nonconformance with a process
Cause-and-Effect Diagram

• When to use
  – To identify possible causes of a problem
  – Team thinking is in a rut

• General method
  – Describe the problem
  – List categories for causes of the problem
  – List possible causes of the problem
  – Continue to ask, “Why does this happen?” to uncover sub-causes
Responsibility of physicist

- Patient’s CT for planning is complete
  - QA not done
  - Fusion not done
  - Treatment plan not ready on time

Responsibility of dosimetrist

- Plan not finished
  - Overworked
  - Post-approval work not done

Responsibility of physician

- No MR scan
  - Contours not drawn
    - Rx not communicated
      - Dosi not notified
        - Plan not approved
          - No good plans
            - Rx change
              - New patient info

- Treatment plan not ready on time
Pareto Chart

• When to use
  – To analyze the frequency of problems
  – To focus on the most significant problems

• General method
  – Decide on categories, measurements, and period of time
  – Subtotal the measurements for each category
  – Plot as a bar graph from largest to smallest
Pareto Chart

- Contours not done
- Plan not reviewed
- Waiting for other info
- Rx change
- QA not done
- No acceptable plans
- Other
Root Cause Analysis (RCA)

• When to use
  – To identify what, how and why something has happened to prevent recurrence

• General method
  – Data collection
  – Causal factor charting
  – Root cause identification
  – Recommendation and implementation

Evaluation and Decision Making

• Decision matrix
  – Evaluates and prioritizes a list of options
  – Uses pre-determined weighted criteria

• Multi-voting
  – Narrows a large list of possibilities to a final selection
  – Allows an item that is favored by all, but not the top choice of any, to be selected
Decision Matrix

• When to use
  – A list of options must be narrowed to one
  – The decision is made on the basis of several criteria

• General method
  – Determine the evaluation criteria
  – Assign a relative weight to each criterion
  – Create a matrix that give a final highest weight to one criterion
## Decision Matrix

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<th>Criteria</th>
<th>Weight</th>
<th>3DCRT</th>
<th>IMRT 1</th>
<th>IMRT 2</th>
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</table>
Process Analysis

• FMEA
  – Systematic method of analyzing and ranking the risks associated with various modes of failure

• Mistake-proofing
  – A method that either makes it impossible for an error to occur or makes the error immediately obvious once it occurs
Failure Modes & Effects Analysis
FMEA – TG100

• When to use
  – When a process or equipment is being applied in a new way
  – When a process or equipment is being designed or redesigned
  – When analyzing failures of an existing process or use of equipment

• General method
  – Please visit Medical Errors II
  – Wednesday, August 2. Rm 230A, 10-Noon.
Mistake-Proofing

• When to use
  – At a hand-off step in a process
  – When the consequences of an error are dangerous

• General method
  – Create flowchart of the process
  – Find source of each potential error
  – Elimination, Replacement, or Facilitation
  – Test it, then implement it (inspection)
Data Collection and Analysis

• Statistical Process Control (SPC)
  – Monitor and control variation in a process or product over time
  – Strikes a balance between two types of mistakes we can make in quality control
    • Looking for problems when they do not exist
    • Not looking for problems when the do
Process Control

• A definition of control
  – A process will be said to be predictable when, through the use of past experience, we can describe, at least within limits, how the process will behave in the future.

• SPC is concerned with practical methods to satisfy this definition

W.A. Shewhart. Economic Control of Quality of Manufactured Product. 1931: ASQ Quality Press Publications.
Process Control

• Every measurable phenomenon or process displays variation

• There are 2 types of causes of variation
  – Exceptional variation
    • Assignable cause(s) exist and once removed will reduce variation
  – Routine variation
    • No readily assignable cause(s) exist
Process Control

- Process behavior charts
  - Use a sequence of data for predictions of what will occur in the future
  - Subgroups from a time-ordered stream of data are used to describe process behavior

- A process is predictable when it is in a state of statistical control
Process Behavior Charts

One chart for the subgroup mean

Average

Sample number or Time

\[ \overline{X} + 3 \frac{\overline{R}}{d_2 \sqrt{n}} \]

\[ \overline{X} - 3 \frac{\overline{R}}{d_2 \sqrt{n}} \]

One chart for the subgroup range

Range

Sample number or Time

\[ \left( 1 + 3 \frac{d_3}{d_2} \right) \overline{R} \]

\[ \left( 1 - 3 \frac{d_3}{d_2} \right) \overline{R} \]
Project Planning/Implementation

• Models to carry out change and continued improvement
  – Plan-do-study-act (PDSA)
  – Define, Measure, Analyze, Improve and Control (DMAIC)

• Design for Six-sigma (DFSS)
  – Answers the question, “How much risk is in my design?”
PDSA

- Plan – Do – Study – Act
- Shewhart cycle for learning and improvement

E. Deming. The New Economics. 1993: MIT, Center for Advanced Engineering Study. Figure 13.
DMAIC

- Define – Measure – Analyze – Improve – Control
- Data-driven strategy for improving processes

Define
What problem to solve?

Measure
What is the process capability?

Analyze
When & where do defects occur?

Improve
Go after root causes.

Control
Control process to sustain gains.

Redesign
Optimization
Design for Six-Sigma (DFSS)

• A process of predicting response variation
  – Calculate variance due to specific noise

• Can answer the question; How much risk is in my design?

• Methods include
  – Deterministic
  – Stochastic
Philosophy Paradigms

• Six-Sigma
  – Disciplined methodology of improving products and processes

• Lean
  – Processes are continually evaluated for waste

• Total Quality Management (TQM), Business Process Reengineering (BPR), etc…
What Have We Omitted

- Cp,k
- Gage R&R
- Fault Tree Analysis
- Scatter Diagram
- Brainstorming
- Arrow Diagram
- Histograms
- PDPC
- Check Sheet
- Relations Diagram
- Hypothesis Testing
- Tree Diagram
- Situational Awareness
- Gnatt Chart
- Matrix Diagram
- Survey
- Benchmarking
- List Reduction
- DCOV
Summary

• Quality/error reduction innovations may not seem technologically significant but are extremely important for our patients.

• Increased efforts should be aimed at reducing errors and chronic sources of defects from clinical processes.
Summary

• Our best efforts are not good enough
  – We can’t do everything we think of
  – We have to assess risk and choose our focus carefully (TG100!)

• Quantitative quality control techniques require training and practice

• Leadership must make quality a priority (AAPM / ASTRO)
Proposals for AAPM

• Physicists should champion error reduction and quality control

• Future AAPM meetings should have a specific research session for error/cost reduction and quality control

• Create a working group/task group charged to understand and describe the vast amount of quality techniques
Some Further Reading


• **Six part series on Quality of Health Care.** The New England Journal of Medicine, 335(12-17), 1996.


