Statistical Process Control
for Analysis of Routine Machine QC

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Background

- Recent publications have stressed the need for managing QA systems.
  - Sentinel Event Alert #47 (2011)
    - “Implement a system for centralized quality and safety performance monitoring of inventoried equipment under the supervision of a qualified medical physicist”
  - AAPM Task Group 142 (2009)
    - “A sudden and significant deviation from the expected value should be called to the attention of the MP, even if the measurement itself does not exceed the table tolerance value.”
Background

- ACR Accreditation
  - Therapy accreditation inspecting to TG142 standards (as of 2011)
- State legislation (TG142 – Ohio??)
- RTOG
  - November 2011 – updated its requirement and is testing to TG142 standards rather than TG40
Definition of “Quality”

- Minimizing process variation
- Understanding source of fluctuations
  - And how/when to fix it

Quality Control
- Is the process “in control” or “out of control”?
- Consistency in measurements.

Quality Assurance
- Predictability in measurements.
- Opposite of the “rear-view mirror approach”.

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Principles for Understanding Data

- “No data have meaning apart from their context.”
- “Every data set contains noise, and some data sets contain signals. Therefore, before you can detect a signal, you must first filter out the noise.”

Conventional QA

Begin

Determine Specifications

Perform the Test

Result

Document

End


- No understanding of variation inside specifications
- No understanding of trends in data
The Source of (Some) Specifications

- Without any context for the data, specification may give an incomplete picture.

Specifications vs. Context

- Is the measurement on day 14 a signal?
- Is it something to be concerned about?
Possible Failures

- Whenever a system attempts to detect a “signal”, there are 2 possible failures:
  - 1: Failure to separate the signal from the background noise
  - 2: Incorrect identification of noise as signal

- Both result in lost time (looking for source of error, or making up for missed error)
- How do we minimize both?
Process Behavior Charts

- Developed by Shewhart in 1930’s
- Used mostly in manufacturing
- Recently been adopted into radiotherapy and diagnostic radiology

- Designed to separate the two types of variation in any process
  - Routine variation
  - Exceptional variation

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Process Behavior Charts

- Set of numerical data is acquired
  \[ x_1, x_2, x_3, \ldots x_N \]

- Subgroups are created from the set
  - Size chosen to ensure subgroup homogeneity
    - Same quantity is measured in same way
      \[ x_1, x_2, x_3, \ldots x_n, \quad n < N \]

- For each subgroup, the average \( \bar{x} \) and range \( R \) are calculated

- Two charts are created: average chart, and range chart
Process Behavior Charts

- The average chart has thresholds \( A_{\pm} \) and a centerline \( A_c \) defined by:

\[
A_{\pm} = \bar{x} \pm 3 \frac{\bar{R}}{d_2 \sqrt{n}} , A_c = \bar{x}
\]

- The range chart has thresholds \( R_{\pm} \) and a centerline \( R_c \) defined by:

\[
R_{\pm} = \bar{R} \left( 1 \pm 3 \frac{d_3}{d_2} \right) , R_c = \bar{R}
\]

- The quantities \( d_3 \) and \( d_2 \) depend on the size of the subgroup.
Clinical Example

- Daily Flat/Sym Output
  - Red dash = SPC limits
  - Dotted line = $1\sigma$
  - Clinical specification limits 3% (Action 1) and 5% (Action 2)
  - Limits calculated from first 10 measurements
  - First “signal” at point 9 in process behavior chart

Pawlicki, Whitaker, and Boyer “SPC in Radiotherapy” *Med Phys* 32(9) (2005)
Clinical Example

- Introduction of “systematic errors” clearly indicated in process chart.
  - Change of output factor for ion chambers
  - Change of SSD in setup

- Process Behavior Chart re-evaluated after systematic error was corrected.
Clinical Example

- Daily Flat/Sym Output
  - Limits calculated from subsequent measurements (9-19)
  - First “signal” at point 21
    - Incorrect SSD (setup to buildup not surface of ion chamber)
    - Corrected for next measurement
  - Second “signal” at point 32
    - Same mistake (on therapist part)
    - Immediately caught and corrected (measurement 33)
Clinical Example

- At no point were any measurements outside $1\sigma$
- At no point were any measurements outside clinical specification action limits (3%, 5%)
- Systematic changes quickly caught
- Immediate indication of whether or not process is “in control”
Assume process of routine QA displays a predictable behavior

Calculate process behavior limits (averages and ranges)

Compare observed average and range values with process behavior limits

If routine QA readings are within process behavior limits, then process *may be stable.*

“Proof” of stable process is continued routine QA readings within process behavior limits.

If routine QA readings are outside process behavior limits, then process *is definitely unstable.*

Take action to identify and remove systematic errors in the process

Continue charting routine QA readings to confirm removal of systematic errors
Practical Guidelines

- PBC should never supersede clinical requirements.
  - i.e. If process is outside clinical requirements, action should be taken regardless of whether or not process is “in control”

- Limits can be calculated with little data, and revised as more data becomes available
  - Increases the sensitivity of the chart

- If a deliberate change is made to the process, limits should be recalculated
Multi-Source Data Manager

The Multi-Source Data Manager is a tool designed to manage and track data from various sources in a comprehensive manner. It allows users to configure and perform different procedures, such as X-ray flatness change, X-ray symmetry change, and others, each with specific types and values provided. The interface is user-friendly, allowing for easy data input and management, ensuring that all relevant parameters are accurately recorded and monitored.
Automated Routines For:

- MLC Picket Fence
Automated Routines For:

- Beam Profile Measurements
- Star / Spoke Shot
- Stereotactic (Winston-Lutz)
- Asymmetric Beam
- Radiation-Light Field

Use your EPID
Planar kV Imaging

PTW Normi4 FLU

Leeds TOR18 FG

DISC Plus

IBA PrimusL
Planar MV Imaging

PTW EPID QC

QC3

Las Vegas

RIT EPID
CBCT
ISO-Cube
The New (And Improved!) RIT Family
Appendix
We’ve got you covered

- Ongoing help
- New recommendations
- This is a process / transition

- Regular
  - Updates
  - Online training sessions
  - Classes
  - Tech Support

- Come see us at booth #10087