Quality and safety improvement of blood component products in blood transfusion by using statistical methods and control charts in screening test results

Saleh Nasiri (Ph.D.)
IBTO-Research Center
What basic statistics must we know to monitor QC results

- Mean
- Standard deviation (SD) (precision)
- Bias
- Random error
- Systematic error
- Total error
- Gaussian distribution
The QC Process

1. QC Sample
2. Determine Control Limits
3. Include in all test runs
4. Data Collection
5. Data Analysis
6. Monitor variation
7. If variation identified, investigate
Accuracy and Precision

A. Accurate and Precise

B. Accurate But not Precise

C. Not Accurate but Precise

D. Neither Accurate nor Precise
What is “normal” Random Error?

- Inherent in system
- Always present
- Data to fall above or below mean
  - Gaussian distribution
  - Predict likelihood of spread
  - Basis for quality control analysis

- Increase SD and Coefficient of Variation
Gaussian Distribution: Standard Deviation and Probability

For a set of data with a normal distribution, a value will fall within a range of:

- ± 1 SD 68.2% of the time
- ± 2 SD 95.5% of the time
- ± 3 SD 99.7% of the time
What causes increased Random Error?

- When a system experiences inconsistent changes such as:
  - Fluctuations in temperature
  - Fluctuations in volume
  - Inconsistent environmental conditions
  - Electrical interferences
  - Inconsistent handling of materials from operator to operator
How to minimize Random Error?

- Handle reagents, calibrators and controls with extreme care
- Review reagent preparation instructions
- Check expiration dates on reagents/calibrators
- Check reconstitution date of reagents and calibrators
- Use volumetric pipette to measure control and reagent diluent (change pipette frequently)
- Make fresh reagent frequently, pour fresh reagent each day, and store unused portions properly
How to minimize Random Error?

- Bring reagents to room temperature prior to use and return to the refrigerator immediately after use
- Calibrate tests more frequently
- Perform cleaning procedures more frequently
- Clean internal reservoir frequently
How does the SD measure Random Error?

- Increased random error causes increased variation about the mean and a higher standard deviation. We no longer see 68% of the points within ±1 SD of the mean.
How does the SD measure Random Error?

If the SD increases from 5 to 10, the spread of the data on the Gaussian curve will increase.
Why do we measure Coefficient of Variation?

- Coefficient of Variation (CV)
- \( \frac{SD}{Mean} = CV \)
- \( \frac{SD}{Mean} \times 100 = CV\% \)

- Measure of precision
- Useful in comparing methods
- Inter-laboratory comparisons
Why do we measure Coefficient of Variation?

The CV% allows us to compare precision in methods with different means.

<table>
<thead>
<tr>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>5</td>
</tr>
<tr>
<td>80</td>
<td>8</td>
</tr>
<tr>
<td>200</td>
<td>12</td>
</tr>
</tbody>
</table>
What is systematic Error?

<table>
<thead>
<tr>
<th>Target Value</th>
<th>Measured Mean</th>
<th>Bias</th>
<th>Absolute of Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>105</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>100</td>
<td>95</td>
<td>-5</td>
<td>5</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Bias is the difference between the measured mean value and the target value
What causes increased Systematic Error?

Common causes of Systematic Errors include:
- Changes in reagent lot numbers
- Changes in calibration
- Inconsistent environmental conditions
- Consistent changes in the analytical process
- Changes to instrumentation
What causes increased Systematic Error?

A systematic change causes all results to be consistently higher or lower than before.
Quality control terms associated with systematic error include:

- a change in accuracy
- a shift in the mean value
- consistent changes in the analytical system
- a change in bias
How does the mean monitor Systematic Error?

Systematic errors usually create two populations of data with different mean values. Each has the same SD.
If we mix two different populations of data, the calculated SD will be incorrect for each individual data set.
Bias is the variation between the measured value and the target or “true” value.
What is Total Error?

- Systematic error associated with change in accuracy
- Random error is associated with change in precision
- Total Error combines random and systematic error to show the total variation from the target value
What is Total Error?

- Total Error (TE)
  - Combines random error (imprecision)
  - SD
  - Systematic error (inaccuracy)
  - Bias

- TE = |Bias| + 2SD
- %TE = |%Bias| + 2CV%
What is Total Error?

Total Error combines random and systematic error to show the total variation from the target value.
What causes increased Total Error?

The factors that affect random and systematic error combine to affect Total Error.
Levey-Jennings Chart

- A graphical method for displaying control results and evaluating whether a procedure is in-control or out-of-control
- Control values are plotted versus time
- Lines are drawn from point to point to accent any trends, shifts, or random variations
Results of testing QC sample T7:s2058:PS040421 in the Abbott PRISM HIV O Plus ChLIA with Instrument the period of 05.09.2005 to 16.10.2005.
One, two or three level QCs

Laboratories may test:

- A single control
- A single control in duplicate
- Two controls at different levels
- Three controls at different levels

If more than one QC sample is tested, or QC sample tested twice, plot ALL results
Calculate Control Limits

To establish control limits to assist in monitoring variation:

- Test sample in 20-30 test runs using ~3 reagent batches
- While establishing limits use cumulative mean and control limits
- Following 20-30 runs, fix mean and control limits
Recording and monitoring the data

Paper and Pen are fine!
Appropriate Control Limits are Critical

- Calculate accurate control limits is critical to an effective QC system
- Control limits too wide
  - Problems not detected
  - False accept
- Control limits too narrow
  - Acceptable results flagged
  - False reject
- QC flags occur when method accuracy and precision changes
Each data point on the QC chart may be either a true or false accept or a true or false reject.
Best QC System

- QC rules that allows for:
  - maximum error detection
  - minimize false rejection
  - treat every QC flag as a significant change,
  - know how to react appropriately to that significant change