Research Article

Study of Quality Control in Clinical Hematology Laboratory by Using Six- Sigma in a Medical College &Tertiary Care Center

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ABSTRACT:

Background: Clinical laboratories' unpredictable and counterfeit results have grave implications for patients. Sigma metrics is a standardized tool for assessing the quality of test results in a laboratory. The goal of quality control in the hematology laboratory is to make sure that reliable test findings are created with the vital precision and accuracy. The quality control system aims to keep record and track the analytic processes, identify investigative errors during the process of analysis, and prevent inaccurate patient values. Six σ is a distinguished quality management approach that employs statistical tool or methods to identify removable flaws and variations of observations .In this immediacy of the research gap, the study was undertaken to evaluate the quality of the analytical performance of clinical hematology in laboratories by calculating sigma metrics.

Materials & Methods: The study was conducted at Central Clinical Laboratory, NKP SIMS RC & LMH Nagpur. Internal quality control (IQC) datasets of 5 analytes were analyzed retrospectively in 2 months from May 2023 to June 2023 by using Advia -2120 - 5 Part Cell Counter. The analytics were assessed for red blood cell (RBC), hemoglobin (Hb), hematocrit (HCT), platelet (PLT) and white blood cell (WBC) etc.

Results: The highest coefficient of variation percentage (CV %) value was 8.7% for platelet and the lowest was 0.93 % for Hb. The highest Bias percentage value was 6.5% in Hb and the lowest was 1.70 % for WBC. In case of IQC, Hb, WBC, RBC, HCT, PLT the criteria sigma value for world class performance was seen in Hb & HCT, good to excellent performance in RBC &WBC, poor performance for PLT.

Conclusion: The Advia -2120 - 5 Part Cell Counter would be excellent, with an expressive range of 5 to > 6 sigma values. The accuracy performance is more suitable for routine examination of research intervention, because of its accuracy and reproducibility, the imprecision is within acceptable levels. However, the low sigma expression is an indication for Vigorous monitoring and Corrective and Preventive Action (CAPA) will be implemented by advice.

KEY WORDS: IQC, analytical errors, hematological parameters, six sigma

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INTRODUCTION:

Quality is defined as conformance to the requirements of the end users [1,2]. Quality Control (QC) aims at immediate detection of an error by monitoring the accuracy and precision of the analytical processes. Implementation of QC is a continuous dynamic process to ensure that test results produced by the laboratory are reliable. Sigma in statistics is used to represent the Standard deviation (SD), which is an indicator of the degree of variation in a set of processes. Sigma measures how far a given process deviates from perfection and it is a popular quality management system tool employed for process improvement. Evaluation of errors in terms of sigma metrics is more meaningful than number of defects alone. For analytical process of laboratory system, sigma metric analysis identifies the errors in quality indicators of the process and provides correction of errors on the basis of results[3].The clinical laboratories serve as critical responsibility in helping and saving the lives of patients and also to increase patient well-being and efficiency of inpatient care. The right tests must be chosen, and the test results will be trustworthy and we can appropriately interpret the results to enhance efficiency in patient care and improve patient wellbeing. As a result, quality management policies should be applied as a routine aspect of patient care, not just as an analytical need.[4,5]

Hematology is one sort of laboratory investigations. Moreover; the study of morphology of the produced constituents of the blood, as well as the morphology of the bone marrow, spleen, and lymphoid organs is the focus of hematology.[6] Laboratory errors have a major impact on patient care quality.[3] Previous Studies have found that there is a 2.7%–13% chance of an adverse event occurring as a result of a laboratory errors.[7,8] Automated techniques are being used in many laboratories, techniques are more exact than manual or semi-automated approaches, but their precision is dependent on the proper calibration and the use of reagents that are usually unique to the analyzer.[9] However, the QC should be applied to all examination techniques.[6] Autovalidation and auto reporting are becoming increasingly important.[10]

The laboratory's ultimate evaluation will be based on its quality. Advanced and aesthetically pleasing software should be used to help improve the quality.[11] The selection of appropriate Internal quality control (IQC) material is critical to the success of a QC method.[11] First, to minimize matrix effects on analytes measurement, IQC material should strongly match the makeup of patient samples.[8] 3-Sigma performance is considered the minimum in any industrial process. The typical performance of a business or industry process is considered to be around 4- Sigma.

The first goal of a Six Sigma project in business and industry is usually to improve from 4-Sigma to 5-Sigma. This is a very significant improvement: a 100-fold reduction in defects in short term. Some processes never reach 6-Sigma. But reaching 5-Sigma may be good enough. A sigma score of six indicates that the assay performance is optimal and thus efforts to further improvement in the quality are unwarranted. In some cases, the process can be re-engineered to achieve 6-Sigma performance.[8,12] Six sigma provides an easy way to talk about different process by using a common mathematical framework.[9] In this propinquity of the research gap, the present study aims to correlate the sigma metrics of clinical chemistry analytes and plan the QC strategy.

Further, we determine the total permissible error in clinical laboratory and correlate the findings by the use of CLIA guidelines (thereby evaluate the functioning of the instrument as well as the adequacy of the methodology being followed).

MATERIALS & METHODS:

The study was conducted at Central Clinical Laboratory, NKP SIMS RC & LMH Nagpur. IQC datasets of 5 analytes were analyzed retrospectively in 2 months from May 2023 to June 2023 by using Advia - 2120 - 5 Part Cell Counter. The analytics were assessed for red blood cell (RBC), hemoglobin (Hb), hematocrit (HCT), platelet (PLT) and white blood cell (WBC) etc. QC material Level-1, Level-2 & Level-3 were assayed before analyzing patient's samples every day. E- check QC material belonged to R&D systems (CBC-3D) and QC values were obtained based on the standard reference method. The instrument was calibrated and maintained regularly. IQC datasets were obtained from the IQC document laboratory. If erring (Violating Westgard Rule) values arose from the sample of control, the values were eliminated and rectified by control.

The study was approved by institutional ethical clearance.

IMPRECISION:

Imprecision (random error) is determined from a replication experiment during method validation studies or SQC data collected during routine operation. The Labs performed verified replication experiments, the precision was cross checked and then monitor ongoing performance from SQC data collected under the conditions of routine operation (Westgard & Westgard, 2006). An imprecision expressed routine operation (Westgard & Westgard, 2006). An

imprecision expressed values was modeled as coefficient of variation (% CV), it was determined from the calculated mean and standard deviation evaluated from the IQC data. The CV is the ratio of SD to the actual mean obtained from the data set.

CV % = (SD/mean) x100

BIAS: Bias was calculated as the percentage difference of the average of observed results on each analytes from the target values which was provided from the control package inserts. Percent bias values in each test was determined separately between May2023- June 2023.This can be summarized by the following formula

% BIAS = [(our laboratory mean of IQC data-target mean of IQC data)/target mean of IQC data] ×100.

TOTAL ALLOWABLE ERROR:

In 1974, Westgard was the first to propose the concept of total error (TE). A single measure of the uncertainty of a test result was created by combining analytical imprecision and bias i.e., systematic error (SE).[13] Total allowable error (TEa) is the total allowable difference from the accepted reference value seen in the deviation of a single measurement from the target value. Standardized TEa values of various parameters were taken from Clinical Laboratories Improvement Act (CLIA) guidelines.

TEa observed in this assay was calculated using the formula –

TEa observed = bias + % CV* 2. Thus, observed TEa was compared with CLIA guidelines.

SIGMA:

Sigma (s) value was used to determine the analytical performance characteristic of sigma value tested by using CV (obtained from IQC data), Bias %, and TEa values. Sigma value is calculated using the standard equation: Sigma (σ)= (TEa-Bias) / CV.

A sigma score of 6 indicates that, the assay's performance is ideal and further improvements are unlikely. Assays with a sigma value of 4–6 are considered adequate and have reasonable level of quality and accuracy, while those with a sigma score of 3–4 are considered unsatisfactory.

For an assay with a sigma metric of less than 3, no amount of IQC provides adequate error detection rates; therefore efforts should be focused on enhancing the test's quality. We should improve the precision of the assay, duplicate or triplicate analysis may be used.[8]

RESULTS:

Descriptive statistics like mean, SD, CV, and Sigma Value IQC data of 5 analytes were analyzed retrospectively in 2 months (May and June 2023) by using quality control data result with Advia 2120i hematology Analyser. The mean, SD, CV (%), bias, and sigma values for all 5 analytes were calculated. Results are presented in the (Table 1,2,3,4) and (Graph1). A sigma level<3 is an indication of a poor performance procedure (i.e. Non acceptable, No amount of IQC provided appropriate errors detection rate), sigma level 3- 4 is an indication of marginal performance (i.e. Unsatisfactory), sigma level 4 – 6 is an indication good to excellent performance (i.e. Adequate) and above six sigma level is a world-class performance (i.e. Ideal).[8]

DISCUSSION:

QC is used to evaluate the examination (analytic) phase of testing as part of the quality management system. Before patient results are presented, the purpose of QC is to detect, assess, and fix errors caused by test system malfunction, environmental circumstances, or operator performance etc.[14] Internal and external quality controls are investigated at various levels to determine the precision and accuracy of laboratory tests of clinical laboratories. When evaluating internal quality, Westgard standards are applied. Analytical procedures' performance is monitored using quality control materials.[6] The role of quality control in clinical laboratories is well-established.[15] IQC practice, on the other hand, differs greatly between laboratories. Standardization of procedures to IQC material selection, target and range assignment, statistical rule application, IQC review, and troubleshooting will improve the quality of results and ease pathology service standardization.[8]

The analytical phase accounts for 7%–13% of all errors in the entire testing process. IQC procedures are critical for discovering errors in the analytical phase and thus enhancing patient care quality.[16] Commutability, correctness of analytes concentration, stability, vial-to-vial & lot-to-lot verification variability should all be considered when choosing an IQC material. Ideal QC material should have long stability and matrix same as patient sample.[17] Target values and ranges should be assigned locally. Material for IQC should come from a third- party resource and not be the same as that utilized for calibration. IQC samples should be treated in the same way as patient samples are.[8]

The sigma values <3 i.e. for PLT, HCT, upgraded analyzers and better methodologies may help in achieving sigma values. This was in comparison with the other studies done by Usha Adiga et. al where the sigma score was very less for few parameters.[18] For

Table1:Descriptive Statistics of P.Q.C. May. 23

SN	Parameter	Target	Mean	SD%	CV%	Bias%	TEa%	Sigma
1	Hb	13.80	12.90	00.12	00.93	06.50	07.10	05.37
2	WBC	08.04	08.20	0198	02.41	01.70	15.00	05.50
3	RBC	04.71	04.60	00.04	00.86	04.40	06.00	01.86
4	HCT	40.30	42.80	00.70	01.75	04.70	06.00	07.40
5	PLT	258.0	03.72	00.30	08.70	04.40	25.00	02.80

Table 2: Descriptive Statistics of P.Q.C. June. 23

SN	Parameter	Target	Mean	SD%	CV%	Bias%	TEa%	Sigma
1	Hb	13.70	13.20	00.46	03.50	04.30	07.1 0	08.00
2	WBC	08.05	07.50	112.0	14.90	06.60	15.00	05.60
3	RBC	04.71	04.90	00.06	01.20	01.90	06.00	03.40
4	HCT	40.30	43.90	00.96	02.00	09.10	06.00	02.70
5	PLT	02.59	02.60	00.35	13.50	07.00	25.00	01.80

Table 3: Six Sigma distribution & Internal Quality Control Performance Quality Control for May: 23

SN	Parameter	CV%	Bias%	TEa%	Sigma	Note
1	Hb	00.93	06.50	07.10	05.37	Good to Excellent Performance
2	WBC	02.41	01.70	15.00	05.50	Good to Excellent Performance
3	RBC	00.86	04.40	06.00	01.86	Poor Performance
4	HCT	01.75	04.70	06.00	07.40	Good to Excellent Performance
5	PLT	08.70	04.40	25.00	02.80	Poor Performance

Table 4: Six Sigma distribution & Internal Quality Control Performance Quality Control for June: 23

SN	Parameter	CV%	Bias%	TEa%	Sigma	Note
1	Hb	03.50	04.30	07.1 0	08.00	Good to Excellent performance
2	WBC	14.90	06.60	15.00	05.60	Good to Excellent performance
3	RBC	01.20	01.90	06.00	03.40	Good to Excellent performance
4	HCT	02.00	09.10	06.00	02.70	Poor Performance
5	PLT	13.50	07.00	25.00	01.80	Poor performance

less than 3 sigma, method performance must be improved before the method can be used for routine production. A method with a sigma of less than 3 necessitates method modification as the test's quality improves even after multiple QC runs, assurance cannot be guaranteed. As a result, sigma metrics values can be useful in a variety of situations establishing IQC acceptance criteria.[18] The six sigma scale is evaluated between 0-6 and may exceed more than 6 in case of low variability. In the result obtained from the observation study the parameter HB, WBC, RBC are showing good to excellent performance, hence two levels of QC per day has been run following 1;2.5s rule. HCT has marginal performance and use of a combination of rules with two levels (Westgard rules) of QC twice per day has been run, however, PLT has

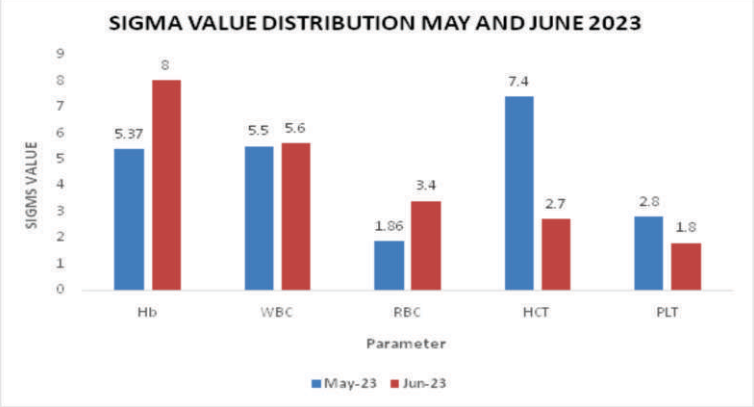

Figure : Six Sigma distribution for May &June: 23

poor performance as per six sigma, hence low six sigma calls for more vigorous monitoring and CAPA.[12]

According to Cooper et al, 3s (problems), should be corrected with maximum QC, which is run three levels, three times a day and considers testing specimens in duplicate. 3s–4s (poor performers) should use a combination of rules with two levels of QC twice per day. 4s–6s (suited for purpose) should be evaluated with two levels of QC per day and the 1:2.5 s rules. 6s (excellent tests) should be evaluated with one QC per day (alternating levels between days) and follow 1:3.5 s rule.[7]

CONCLUSION:

Grading laboratory errors according to their severity should aid in identifying quality improvement priorities and encourage a focus on corrective/ preventive efforts. It's crucial to examine, not only the actual patient injury but also the worst-case scenario if an error happens. Sigma metrics help us to assess analytical methodologies and augment laboratory performance. It acts as a guide for planning a quality control strategy. It can be a self-assessment tool regarding the functioning of a clinical laboratory. Specific limitations of the study is that this is only a pilot project to understand the significance of the six Sigma metrics application for total quality management of the laboratory. Further, these studies involve a wide range of parameters over an extended period which is being recommended for a significant conclusion.

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Conflicts of Interest

There are no conflicts of interest.

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