

Evaluation of clinical biochemistry laboratory performance using sigma metrics

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Abstract

Producing a reliable, reproducible, accurate, timely, and correctly interpreted test results by clinical laboratory is very important, since physicians' decisions mostly depends on it for screening, diagnosis and monitoring diseases. To provide quality report, routinely in all clinical laboratories internal quality control (IQC) and external quality assessment (EQA) programs are done which helps to evaluate and continuously improve analytical quality. Recently new quality assessment (QA) systems, six-sigma became more popular because it offers a different approach to problems. Sigma metrics allow comparison of different processes with each other and thus improving the quality of testing processes. This study was done to evaluate clinical chemistry laboratory performance using sigma metrics.

Keywords: Internal quality control, External quality assessment programs, Laboratory, Sigma metrics, Six-sigma.

Introduction

Clinical laboratories are backbone of health care system, since physicians' decisions mostly depends on laboratory results for screening, diagnosis and monitoring diseases.¹ Thus it is important that clinical laboratory produce a reliable, reproducible, accurate, timely, and correctly interpreted test results. To achieve this goal, laboratories must establish and maintain quality in all laboratory processes, while focusing on cost-effectiveness.²

It is difficult to determine the quality of a laboratory since most laboratories are not clear about the analytical quality required by their tests. Many laboratories don't bother, till, they get direct complaints about testing quality, and, many other laboratories assume that the quality of laboratory testing, they are providing, is adequate. Most laboratories assume that the manufacturer provides with excellent quality instrument and reagents and thus following manufacturer's instructions is enough to maintain the quality of test. It is important for us to know that, a manufacturer provides directions, and, does not guarantee that the directions are adequate. It is the responsibility of laboratory to keep professional standards and maintain the quality of procedures.

Defining quality specifications for a laboratory is a difficult thing and CLIA (Clinical Laboratory Improvement Amendments) so far has defined quality requirements for around 80 analytes. Other than this there are proficiency testing programs, external quality assurance programs, etc.³ Routinely in all clinical laboratories internal quality control (IQC) and external quality assessment (EQA) programs are done which helps to evaluate and continuously improve analytical quality. IQC is run for all parameters and both normal and abnormal level. It helps in continuous and immediate monitoring of the various test and the emergent results

and helps in deciding whether the results are reliable enough to be released to the physician. On the other hand, EQA is by an independent external agency. It is done every month end and tells about the accuracy or bias in the systems and methods of respective lab.⁴

In clinical laboratory, recently new quality assessment (QA) systems six sigma became more popular because it offers a different approach to problems. Six sigma (σ) is the mathematical symbol for standard deviation (SD). Motorola Company has developed six sigma methodology as part of the quality measurement and improvement program in the early 1980s since then it has been applied widely in business and industry to reduce the cost of products, eliminate defects and decrease variability in processing. Define, measure, analyze, improve and control (DMAIC) are the five steps for improving quality by sigma metric.¹ Nevalainen's did an innovative work in Sigma assessment in the clinical lab and analyzed the performance of common laboratory processes. He found that many were sadly of inadequate quality.⁵

Sigma metrics evaluate the process by counting defects, then converting it into Defects per million opportunities (DPM, or DPMO) rate. 1 sigma (σ) represents 6,90,000 errors/million reports, 2 sigma represents 3,08,000 errors/million reports, 3 sigma represents 66,800 errors/million reports, 4 sigma represents 6,210 errors/million reports, 5 sigma corresponds to 230 errors/million reports and 6 sigma represents 3.4 errors/million reports.⁶ If a process exceeds six sigma, it implies that variability is very low and thus the defect rate. 3 Sigma is the minimal acceptable performance for a process, especially for industries outside of healthcare. When performance falls below 3 sigma, the process is considered as unstable and unacceptable and should not be used for routine test purposes.^{3,5,7}

In the laboratories too, counting defects is the usual six sigma metric technique. It is difficult to determine and detect defects and to know the true value of a test result, even if it is run multiple times. However, measuring variation provides an alternative method for calculating sigma metric of a process. In all laboratories, variation is measured routinely using controls. Standard deviation of a testing process can be calculated from the control results which are run daily, and, then the coefficient of variation (% CV) can be calculated. Inaccuracy (bias) of an analytical testing process can be calculated by comparing results between the testing method and a reference method, or by analyzing the results of the testing method in proficiency testing, peer group, or some other form of external quality assurance program.³

With the aid of six sigma principles and metrics, it is possible to ensure that the desired quality is achieved.⁸ Therefore we have applied sigma metrics to evaluate the performance of 14 routine parameters run in DM WIMS biochemistry laboratory, Wayanad, Kerala.

Materials and Methods

The study was conducted in the clinical biochemistry laboratory of DM WIMS, Wayanad, Kerala. Our hospital is NABH accredited tertiary care centre. Daily internal quality control (QC) is run for both level I (normal level) and level II (abnormal level) and every month our laboratory participates in Biorad-EQUAS (external quality assessment scheme). For the present study, 12 months (July 2016 to June 2017) internal quality control and Bio-Rad EQUAS data was collected retrospectively for 14 parameters- albumin, total protein, ALP, ALT, AST, Total bilirubin, cholesterol, LDL, HDL, triglyceride, urea, creatinine, glucose and uric acid. These parameters are measured in Cobas Integra 400 plus fully automated chemistry analyzers.

Sigma metrics (σ) was calculated for all parameters from CV%, bias%, and TEa using the formula:

$$\Sigma (\sigma) = (\text{TEa}\% - \text{bias}\%) / \text{CV}\%$$

Bias% for each parameter was calculated from Bio-Rad EQUAS using the formula:

$\text{Bias} (\%) = (\text{Mean of all laboratories using same instrument and method} - \text{Our mean}) * 100 / \text{Mean of all laboratories using same instrument and method.}$

Coefficient of variance (CV %) for each parameter will be calculated from internal QC data using the formula:

$\text{CV}\% = (\text{Standard deviation} * 100) / \text{our laboratory mean.}$

Total allowable error (TEa) is the total allowable difference from accepted reference value seen in the deviation of single measurement from the target value. TEa values of various parameters were taken from Clinical Laboratories Improvement Act (CLIA) guidelines.

Excel 2013 was used for all statistical analysis. The study protocol was approved by the institutional human ethics committee.

Results

Table 1 and table 2 shows average CV%, average Bias %, TEa % and sigma for each parameter, Level I and Level II. CV % was calculated from internal QC data for each parameter, and then average was taken. Bias was calculated from EQUAS data and then average was taken. TEa was taken from CLIA guidelines. Sigma metrics was calculated using the formula mentioned using TEa, average CV% and average bias% calculated.

Out of 14 parameters assessed for sigma performance, 8 parameters (ALP, ALT, AST, bilirubin total, HDL, LDL, triglyceride and uric acid) showed sigma value > 6 in level I QC. 5 parameters (glucose, albumin, cholesterol, total protein and creatinine) showed sigma value between 3-6. 1 parameter (urea) showed sigma value of <3. (Fig. 1)

In level II QC, 7 parameters (ALP, ALT, AST, bilirubin total, HDL, triglyceride and uric acid) showed sigma value >6, 6 parameters (LDL, glucose, albumin, cholesterol, total protein and creatinine) showed sigma value 3-6, and, 1 parameter (urea) showed sigma value of <3. (Fig. 2)

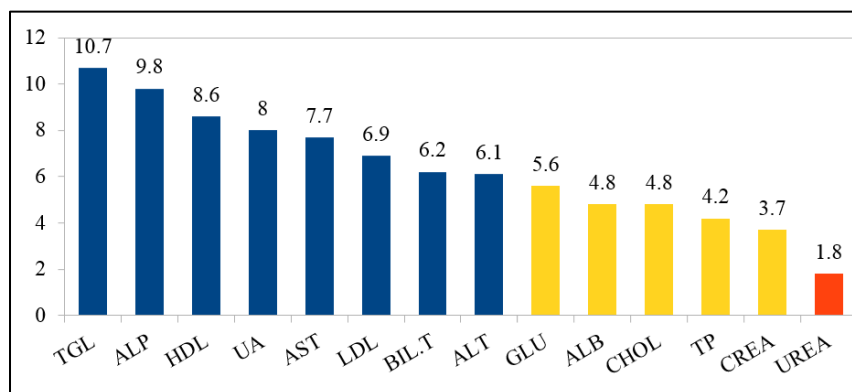


Fig. 1: Graph showing sigma-metrics level I (July 2016 to June 2017)

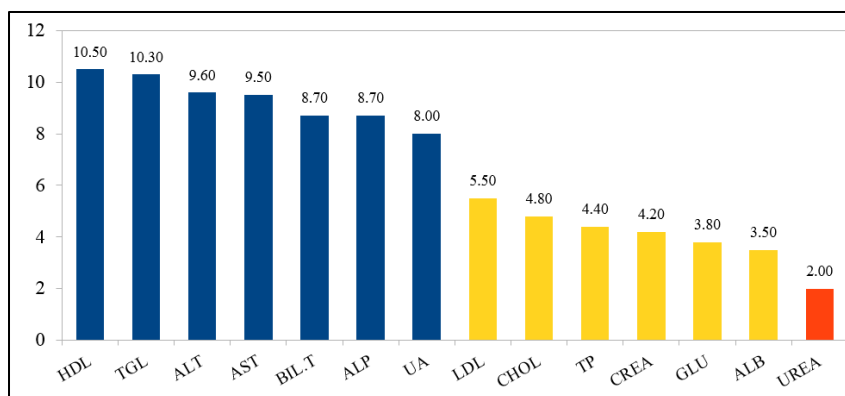


Fig. 2: Graph showing sigma-metrics level II (July 2016 to June 2017)

Table 1: TEa%, Bias%, CV% and sigma value for different parameters for Level I (July 2016 to June 2017)

| Parameters | TEa% | Bias% | CV% | Sigma |
|-----------------|------|-------|------|-------|
| Albumin | 10 | 0.29 | 2.04 | 4.8 |
| ALP | 30 | 0.47 | 3 | 9.8 |
| ALT | 20 | 0.92 | 3.15 | 6.1 |
| AST | 20 | 0.14 | 2.58 | 7.7 |
| Bilirubin total | 20 | 0.24 | 3.18 | 6.2 |
| Cholesterol | 10 | 0.06 | 2.07 | 4.8 |
| Creatinine | 15 | 3.13 | 3.17 | 3.7 |
| Glucose | 10 | 0.15 | 1.76 | 5.6 |
| HDL | 30 | 0.87 | 3.39 | 8.6 |
| Total protein | 10 | 0.78 | 2.18 | 4.2 |
| Triglyceride | 25 | 0.90 | 2.25 | 10.7 |
| Uric acid | 17 | 0.19 | 2.10 | 8 |
| Urea | 9 | 1.93 | 4 | 1.8 |
| LDL | 20 | 0.91 | 2.77 | 6.9 |

Table 2: TEa%, Bias%, CV% and sigma value for different parameters for level II (July 2016 to June 2017)

| Parameters | TEa | Bias | CV | Sigma |
|-----------------|-----|------|------|-------|
| Albumin | 10 | 0.29 | 2.78 | 3.5 |
| ALP | 30 | 0.47 | 3.38 | 8.7 |
| ALT | 20 | 0.92 | 1.99 | 9.6 |
| AST | 20 | 0.14 | 2.09 | 9.5 |
| Bilirubin total | 20 | 0.24 | 2.28 | 8.7 |
| Cholesterol | 10 | 0.06 | 2.07 | 4.80 |
| Creatinine | 15 | 3.13 | 2.84 | 4.2 |
| Glucose | 10 | 0.15 | 2.62 | 3.8 |
| HDL | 30 | 0.87 | 2.77 | 10.5 |
| Total protein | 10 | 0.78 | 2.11 | 4.4 |
| Triglyceride | 25 | 0.9 | 2.35 | 10.3 |
| Uric acid | 17 | 0.19 | 2.11 | 8 |
| Urea | 9 | 1.93 | 3.57 | 2 |
| LDL | 20 | 0.91 | 3.49 | 5.5 |

Discussion

Six sigma helps in evaluating the laboratory performance. Based on the sigma values and with the help of westgard operational specifications chart (OPSpecs chart), Schoenmaker et al specified importance of sigma metrics application and its use in

designing QC.⁹ Six sigma aims at monitoring a process to 6 SDs, representing 3.4 DPM opportunities.^{10,11}

In the present study, performance of 14 parameters of clinical chemistry were assessed with sigma scale for both level QC (normal and abnormal). 8 parameters in level I QC and 7 parameters in level II QC showed sigma value more than 6, whereas, 1 parameter showed sigma

value less than 3, for both level I and II QC. The highest value for sigma was found for triglyceride 10.7 (in level I QC) and HDL 10.5 (in level II QC). Urea showed lowest sigma value at both level QC (1.8 level I and 2.0 level II respectively).

In the present study, ALP, ALT, AST, bilirubin total, HDL, LDL, triglyceride and uric acid showed sigma value more than 6. Thus, no strict IQC rules are required for these parameters. Since urea showed sigma value less than 3 in both level QC, therefore, appropriate scrutiny is required for monitoring the performance of this parameter, to provide quality test results.¹¹ Glucose, albumin, cholesterol, total protein and creatinine showed sigma values between 3-5, signifying satisfactory performance with a scope of improvisation.

There are numerous studies done on sigma-metrics and different values were reported. Afrifa et al.,¹² in their study, reported sigma value for urea < 2, Bhawna Singh et al.,¹¹ in another study reported sigma values for urea <3 for both levels of QC. Similar findings were found in our study for urea. Sigma value for glucose was reported between 2.9-3.3 by James O Westgard et al.,¹³ < 2 by Afrifa et al.,¹² between 0.5 – 3.2 by Alneil et al.¹⁴ Our sigma value for glucose was much higher between 3-6. Sigma value for cholesterol in our study was 4.8 (both level QC). Other studies have reported sigma value for cholesterol between 2-3.^{13,15} Sigma value for triglyceride, HDL, AST, ALT was reported as more than 6, in a study by Bhawna Singh et al.¹¹ These values were similar to those in our study. In our study, the sigma metrics value for Creatinine was found to be 3.1, in contrast to that reported by Carl Garber (sigma value for creatinine 6).¹⁶ The discrepancy in sigma metrics by various study compared can be attributed to difference in method of analysis, different IQC material, difference in bias calculated due to different proficiency testing bodies.¹

Conclusion

The main role of a laboratory is to produce accurate test results. Six sigma helps in assessing and comparing the performance of various tests using IQC, peer comparison and proficiency testing in the form of EQAS. Therefore, it is easy to apply and helps in streamlining the routine test procedures. With routine six sigma practice, the 2s QC practices can be replaced with appropriate control limits and control measurements.³ Applying six sigma prevents us from applying stringent criteria in a laboratory and thus reducing false rejections.

References

1. Chauhan KP, Patel JD, Trivedi A. Six sigma in clinical biochemistry: It matters, measure it. *International Journal of Clinical Biochemistry and Research*. 2017;4(3):270-4.
2. Inal TC, Goruroglu Ozturk O, Kibar F, Cetiner S, Matyar S, Daglioglu G, Yaman A. Lean six sigma methodologies improve clinical laboratory efficiency and reduce

- turnaround times. *Journal of clinical laboratory analysis*. 2018;32(1):e22180.
3. Westgard S, Westgard QC. Six Sigma metric analysis for analytical testing processes. *Abbott MS*. 2009;9:04.
4. Yadav R, Bhartiya JP, Verma SK, Nandkeoliar MK. External quality assessment scheme (EQAS): Our experience as a participating laboratory. *IJRRMS*. 2013;3(4):1-4.
5. Nevalainen D, Berte L, Kraft C, Leigh E, Picaso L, Morgan T. Evaluating laboratory performance on quality indicators with the six sigma scale. *Archives of Pathology & Laboratory Medicine*. 2000;124(4):516-9.
6. Westgard JO, Westgard SA. The quality of laboratory testing today: an assessment of σ metrics for analytic quality using performance data from proficiency testing surveys and the CLIA criteria for acceptable performance. *American Journal of Clinical Pathology*. 2006;125(3):343-54.
7. Westgard JO. Quality control. How labs can apply six sigma principles to quality control planning. *Clin Lab News*. 2006;32:10-2.
8. Huysal K, Budak YU. Application of sigma metrics for the assessment of quality assurance using the MQ-2000 PT HbA1c analyzer. *Biochemia Medica: Biochemia Medica*. 2015;25(3):416-20.
9. Schoenmakers CH, Naus AJ, Vermeer HJ, van Loon D, Steen G. Practical application of Sigma Metrics QC procedures in clinical chemistry. *Clinical Chemistry and Laboratory Medicine*. 2011;49(11):1837-43.
10. Revere L, Black K. Integrating Six Sigma with total quality management: a case example for measuring medication errors. *Journal of Healthcare Management*. 2003;48(6):377.
11. Singh B, Goswami B, Gupta VK, Chawla R, Mallika V. Application of sigma metrics for the assessment of quality assurance in clinical biochemistry laboratory in India: a pilot study. *Indian Journal of Clinical Biochemistry*. 2011;26(2):131-5.
12. Afrifa J, Gyekye SA, Owiredu WK, Ephraim RK, Essien-Baidoo S, Amoah S, Simpong DL, Arthur AR. Application of sigma metrics for the assessment of quality control in clinical chemistry laboratory in Ghana: A pilot study. *Nigerian Medical Journal: Journal of the Nigeria Medical Association*. 2015 Jan;56(1):54.
13. Westgard JO, Westgard SA. An assessment of σ metrics for analytic quality using performance data from proficiency testing surveys and the CLIA criteria for acceptable performance. *Am J Clin Pathol*. 2006;125(3):343-54.
14. Hamza AA, Mohamed AI. Application of Sigma Metrics for the assessment of analytical quality in clinical biochemistry laboratories in Sudan: A Pilot Study. *International Journal*. 2015;3(11):714-9.
15. Nanda SK, Ray L. Quantitative application of sigma metrics in medical biochemistry. *Journal of Clinical and Diagnostic Research: JCDR*. 2013;7(12):2689.
16. Garber C. Six Sigma: its role in the clinical laboratory. *Clin Lab News*. 2004;4:10-4.

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