Research article

A comparative evaluation of six sigma metrics and quality goal index ratio 3 months prior to first lockdown due to COVID-19 pandemic and 3 months during lockdown in a NABL accredited central laboratory

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ABSTRACT

Introduction and Aim: Sigma represents Standard Deviation (SD) which indicates the degree of variation in a process, where the higher sigma value implies that less likely the laboratory reports false test results. Using a newer parameter called Quality Goal Index (QGI) we can find the reason behind the lower sigma value. Our study aimed to compare the six-sigma metric and QGI ratio 3 months prior to first lockdown due to COVID-19 pandemic and 3 months during the first lockdown.

Methodology: A retrospective study was used to compare the six-sigma metric and QGI ratio 3 months prior to first lockdown due to COVID-19 pandemic and 3 months during the first lockdown for the selected ten analytes from 1st of January 2020 to 30th of June 2020 from the clinical biochemistry section of Yenepoya Medical College Hospital, Deralakatte, Mangalore.

Results: The sigma metrics from January to March (level 1) indicated that urea, TSH, beta-HCG fell short of meeting Six Sigma quality performance and from April to June, glucose, creatinine, urea and ALT had metrics less than 3 at both the Internal Quality Control levels. QGI ratio indicated that from January to March, the problem was imprecision for urea, TSH and beta-HCG (QGI < 0.8). From April to June, urea and creatinine showed imprecision, glucose and ALT showed inaccuracy, urea and ALT showed both imprecision and inaccuracy.

Conclusion: This study highlights the necessity for stringent Internal Quality Control and External Quality Assurance monitoring even during the lockdown period of the pandemic. By implementing six sigma and finding QGI ratio, quality of laboratory services can be improved immensely.

Keywords: Imprecision; inaccuracy; quality goal index; six sigma metrics.

INTRODUCTION

Clinical laboratories are the foundation of any healthcare system since they give the results that doctors use to make all their choices regarding the patients (1). A clinical biochemistry laboratory carries out over 60 % of the tests, therefore plays an important role in diagnosing and managing diseases (2). There should be a proper quality management system to provide an accurate and reliable test report (2). Bill Smith, a Motorola engineer who suggested, later introduced the Six Sigma management approach in China in the late 1990s, and after 1999, it began to be used in hospital administration. The five processes of the Six Sigma management paradigm are defined, measure, analyze, improve, and control (DMAIC). By reducing flaws, sigma metrics helps to increase process quality (2). In statistics, sigma is used to represent SD, which shows how variable a process is. One sigma is equivalent to 6,90,000 errors or defects per million reports, two sigma is equivalent to 3,08,000 defects per million reports, three sigma is equivalent to 66,800 defects per million reports, four sigma is equivalent to 6,210 defects per million reports, five sigma is equivalent to 230 defects per million reports, and six sigma is equivalent to 3.4 defects per million reports (3). Performance at the 3-sigma level is considered the minimum acceptable quality for a production process (4). If an analyte fails to meet the minimum acceptable limit for sigma i.e., 3 sigma level, it could be either due to inaccuracy, imprecision or a combination of both. Therefore, using a newer parameter called Quality Goal Index (QGI) we can find the reason behind the lower sigma value (2). Thus, this study is aimed to compare the six-sigma metrics and quality goal index ratio 3 months prior to lockdown due to COVID-19 pandemic and 3 months during the lockdown period.

METHODOLOGY

The study was conducted in the clinical biochemistry laboratory of Yenepoya Medical College Hospital, Deralakatte, Mangalore, which provides various modalities of treatment facility in both broad specialty and super specialty services to a maximum number of patients. We analyzed sigma metrics of 10 parameters with the automated chemical analyzer, VITROS 5600. The study protocol was approved by the institutional human ethics committee- Yenepoya ethics committee 2 with protocol ID YEC2/801. Internal quality control (IQC) data of 10 analytes were analyzed retrospectively over 6 months i.e., 3 months (January 2020-March 2020) prior to lockdown due to COVID 19 pandemic and 3 months (April 2020-June 2020) during the lockdown with VITROS 5600.

A normal control product contains normal levels for the analyte being tested (L1).

An abnormal control product (L2) has an analyte concentration that is either above or below the analyte's normal range. Before starting to report on the patient samples each day, the QC materials' normal (L1) and abnormal (L2) levels were analyzed. Equipment maintenance protocol as per instructions for use from the manufacturer is followed. The analytes assessed were Glucose, creatinine, urea, total cholesterol, aspartate transaminase, alanine transaminase, alkaline phosphatase, thyroid-stimulating hormone (TSH), β-HCG, dTIBC (Total Iron Binding Capacity).

Sigma value was calculated with the following formula:
Sigma = (TEa − Bias)/CV
Where, TEa is total allowable error, and bias and CV are the indicators of systematic and random errors, respectively.

Coefficient of Variance (CV) will be calculated from internal QC for these parameters.
Percentage bias for these parameters will be calculated from the EQAS.
Total allowable error will be followed as per Clinical Laboratory Improvement Amendments (CLIA) guidelines.
The coefficient of variation (CV) is expressed as a percentage and is a measure of the variability of an assay.
The formula for the computation of the coefficients of variation is,
CV = (SD/Mean) × (100)

Bias

Bias is the systematic difference between the expected results obtained by the laboratory test method and the results that would be obtained from an accepted reference method.

$$\text{Bias}(\%) = \frac{\text{Mean of all laboratories using same instrument and method} - \text{our mean}}{\text{Mean of all laboratories using same instrument and method}} \times 100$$

TEa (Total Allowable Error)

In healthcare laboratories, the idea of TEa is widely used as a model that combines a method's bias and imprecision to determine the method's overall impact on a test result. An estimate of how much combined imprecision and inaccuracy in the test result can be accepted without significantly affecting patient care based on that result's interpretation is the term "allowable total error." The following formula will be used to get the total error (TE) of parameters:

TE = Bias + 1.65 × CVTest or Analyte	Acceptable performance
Alanine aminotransferase	Target value ± 20%
Alkaline phosphatase	Target value ± 30%
Aspartate aminotransferase	Target value ± 20%
Cholesterol, total	Target value ± 10%
Creatinine	Target value ± 0.3 mg/dl or ± 15%(greater)
Glucose	Target value ± 6 mg/dl or 10%(greater)
Total Iron Binding Capacity (TIBC)	Target value ± 20%
Urea	Target value ± 9%
Thyroid Stimulating Hormone	Target value ± 20%
βHCG	Target value ± 32%

Quality goal index

It is important to remember that six sigma quality management is a means for bringing a process' current error rate down to a very low error rate as well as a tool for defining process performance. Understanding the test-specific causes of automated analytic tests' quality flaws, such as excessive bias, excessive imprecision, or both, is crucial to achieving quality improvement where it is needed. To help with this, performance data is evaluated by applying the following formula to the quality goal index (QGI):

QGI = Bias / 1.5 CVQGI	Problem
<0.8	Imprecision
0.8 - 1.2	Imprecision & Inaccuracy
>1.2	Inaccuracy

Statistical analysis

The above formulas were used to calculate the bias, CV, QGI, and sigma metrics. CV and bias were displayed as percentages.

RESULTS

Tables 1 and 2 summarize the CV % of level 1 and level 2 IQC and the bias % obtained from EQAS (Biorad), for 10 biochemical parameters from January 2020 to March 2020 and April to June 2020 respectively, along with their average values. Table 3 summarizes the QGI ratio of analytes with lower sigma values (< 3). Fig. 1and 2 represent the sigma metrics graphically for the month January to March and April to June 2020 respectively.

Table 1: CV% and Bias of 10 analytes from January to March 2020 and their average VITROS 5600 (1373)

S. No	Parameter	January			February			March			Average		
		CV%		Bias	CV%		Bias	CV%		Bias	CV%		Bias
		L1	L2		L1	L2		L1	L2		L1	L2	
1	Glucose	1.7	2.6	0.836	0.9	1	2.94	1.5	1.5	0.341	1.36	1.7	1.37
2	TC	1.4	0.9	5.78	1.2	1.1	5.23	1.2	1.6	2.64	1.26	1.2	4.55
3	Creatinine	1.8	1.8	1.92	2.4	1.1	3.7	2.4	1.9	0.575	2.2	1.6	2.065
4	Urea	3.9	1.9	0.164	3.6	1.5	0.205	4.4	1.5	0.933	3.96	1.63	0.434
5	AST	1.8	2	1.71	1.3	2.2	0.416	2.6	3.2	0.219	1.9	2.46	0.78
6	ALP	4.4	3.4	3.01	3.1	3.1	2.49	2.4	2.4	5.42	3.3	2.96	3.64
7	ALT	3.5	2.6	1.92	1.8	1.3	5.27	4.8	3.0	1.44	3.4	2.3	2.87
8	TIBC	2.2	2.3	3.5	2.0	2.3	0.5	2.4	2.0	2.59	2.2	2.2	2.19
9	TSH	5.1	3.3	3.22	3.3	3.5	3.34	7.4	5	7.71	5.26	3.93	4.75
10	β-HCG	5.9	4.6	4.15	16.6	3.5	0.23	5.1	5.1	9.79	9.2	4.4	4.72

CV- Coefficient of Variation, TC- Total Cholesterol, AST- Alanine Transaminase, ALP- Alkaline Phosphatase, ALT- Alanine Transaminase, TIBC- Total Iron Binding Capacity, TSH- Thyroid Stimulating Hormone, β-HCG- Human Chorionic Gonadotropin.

Table 2: CV% and Bias of 10 analytes from April to June 2020 and their average VITROS 5600 (1373)

S. No	Parameter	April			May			June			Average		
		CV%		Bias	CV%		Bias	CV%		Bias	CV%		Bias
		L1	L2		L1	L2		L1	L2		L1	L2	
1	Glucose	1.2	0.9	1.56	1.3	1.3	1.71	1.6	1.8	13.3	1.36	1.33	5.52
2	TC	1.5	1.5	2.36	1.8	1.9	0.293	1.9	1.4	5.64	1.73	1.6	2.76
3	Creatinine	1.2	1.9	0.814	3.1	2.9	0.552	5.5	3.8	3.75	3.26	2.86	1.7
4	Urea	3.4	1.8	2.87	3.4	2.8	6.92	4.1	2.5	0.251	3.63	2.36	3.34
5	AST	1.9	2.8	2.67	4.4	2.8	5.53	4.1	2.4	0.177	3.46	2.66	2.79

6	ALP	4.4	2.7	11.7	3.7	2.5	3.26	3.7	2.6	7.2	3.93	2.6	7.38
7	ALT	5.7	2.9	8.7	4.3	3.0	7.9	4.5	3.0	3.43	4.83	2.96	6.67
8	TIBC	2.1	2.6	2.7	2.1	2.0	0.1	1.9	2.5	2.47	2.03	2.36	1.75
9	TSH	4.1	3.1	6.1	3.8	4.5	1.05	5.2	3.5	5.92	4.36	3.7	4.35
10	β-HCG	5.7	5.4	3.81	4.4	3.6	4.52	0.3	5.3	0.393	3.46	4.76	2.90

CV- Coefficient of Variation, TC- Total Cholesterol, AST- Alanine Transaminase, ALP- Alkaline Phosphatase, ALT- Alanine Transaminase, TIBC- Total Iron Binding Capacity, TSH- Thyroid Stimulating Hormone, β-HCG- Human Chorionic Gonadotropin.

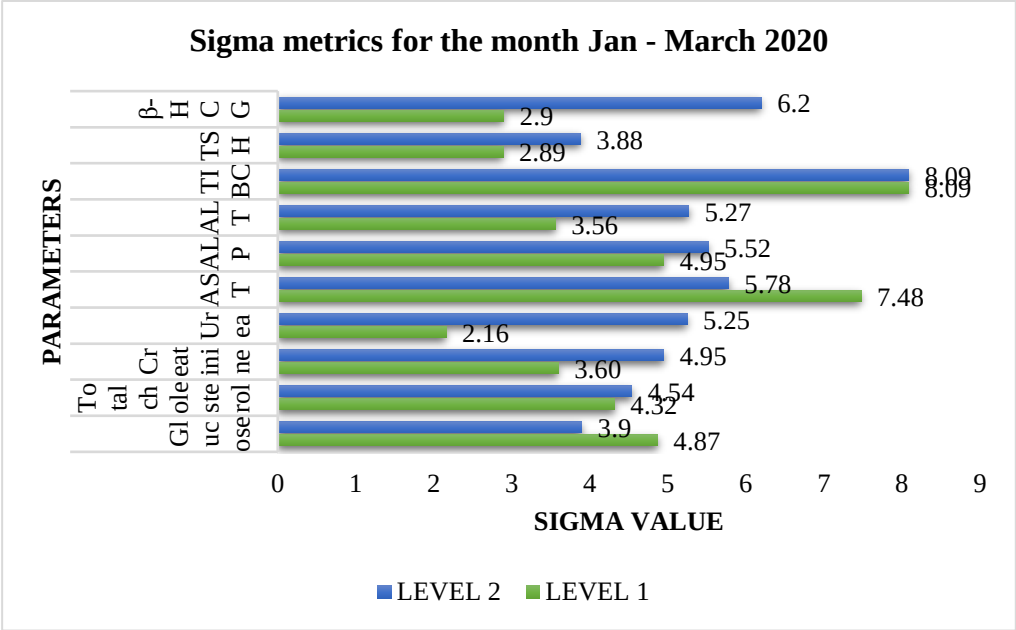

Fig.1: Graphical representation of sigma metrics for the month January to March 2020

AST- Alanine Transaminase, ALP- Alkaline Phosphatase, ALT- Alanine Transaminase, TIBC- Total Iron Binding Capacity, TSH- Thyroid Stimulating Hormone, β-HCG- Human Chorionic Gonadotropin.

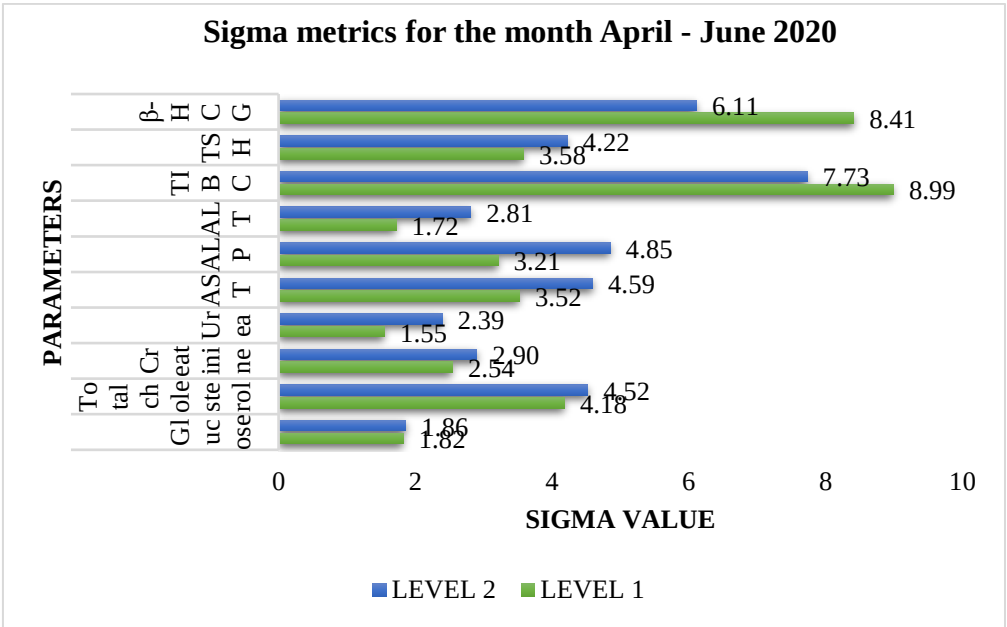

Fig. 2: Graphical representation of sigma metrics for the month April to June 2020

AST- Alanine Transaminase, ALP- Alkaline Phosphatase, ALT- Alanine Transaminase, TIBC- Total Iron Binding Capacity, TSH- Thyroid Stimulating Hormone, β-HCG- Human Chorionic Gonadotropin.

Table 3: Quality goal index ratio of analytes performed low for sigma for accuracy and precision problem

S. No	Analyte	QC level	Bias %	CV%	Sigma	QGI	Month	Problem
1	Urea	Level 1	0.434	3.96	2.16	0.073	Jan-March	Imprecision
		Level 1	3.34	3.63	1.55	0.613	April-June	Imprecision
		Level 2	3.34	2.36	2.39	0.94	April-June	Imprecision and Inaccuracy
2	TSH	Level 1	4.75	5.26	2.89	0.6	Jan-March	Imprecision
3	β-HCG	Level 1	4.72	9.2	2.9	0.34	Jan-March	Imprecision
4	Glucose	Level 1	5.52	1.36	1.82	2.7	April-June	Inaccuracy
		Level 2	5.52	1.33	1.86	2.76	April-June	Inaccuracy
5	Creatinine	Level 1	1.7	3.26	2.54	0.34	April-June	Imprecision
		Level 2	1.7	2.86	2.9	0.396	April-June	Imprecision
6	ALT	Level 1	6.67	4.83	1.72	0.92	April-June	Imprecision and Inaccuracy
		Level 2	6.67	2.96	2.81	1.5	April-June	Inaccuracy

ALT- Alanine Transaminase, TSH- Thyroid Stimulating Hormone, β-HCG- Human Chorionic Gonadotropin

DISCUSSION

The current study which is aimed to calculate and compare both the sigma metric and QGI index ratio during and before the pandemic period is successful in finding the reason for the lower sigma value during the pandemic period.

Many studies were carried out to calculate and evaluate the sigma metrics on various analytes, but only a few of them included the reason for the lower sigma value i.e., by calculating the QGI index ratio.

Adiga *et al.*, Nanda *et al.*, and many others evaluated sigma metrics of various biochemical parameters in a clinical biochemistry laboratory but none of these assessed the cause of low sigma, *i.e*., either imprecision, inaccuracy, or both. Verma *et al.*, attempted to find the reason behind the low sigma value i.e., by calculating the QGI index ratio for those parameters which failed to attain the minimum sigma value of 3.

The differences between our study and others' studies' sigma values can be attributable to the use of different instruments, quality control materials, and other pre- and post-analytical conditions. In comparison, it was found that CV% was higher for parameters- total cholesterol, creatinine, AST and ALT (at both levels) during the lockdown period implicating imprecision. Glucose and ALP showed imprecision at level 1 during this period, however, urea, TIBC and β-HCG showed imprecision at level 2. And TSH being the only parameter that did not show imprecision problem during the lockdown.

- The imprecision during lockdown may be because of
- Less stringent monitoring of IQC because of a smaller number of laboratory personnel.
- Lower sample load leading to a smaller number of IQC runs.

Open vial stability of IQC material reaching the close upper permissible limit.

The highest bias for TSH (4.75) and the lowest was for urea (0.434) from Jan to march. From April to June, it was observed that ALP had the highest bias and creatinine had the lowest (1.7). Less bias means greater accuracy. This indicates the potential for error in the above-mentioned analytes' measurement methods, which should be assessed (1).

It was found that only urea, TSH and β-HCG showed a sigma value less than 3 during Jan to march whereas glucose, creatinine, urea and ALT failed to meet the minimum sigma value of 3 during the month April to June 2020. These parameters need to be subjected to stringent internal quality control, the frequency of internal QC (n) should be raised, and remedial action must be performed for these parameters. Before a technique may be employed for routine production for less than 3 sigma, method

performance needs to be increased. Therefore, the values of sigma metrics are helpful in establishing the internal QC acceptable standards (1). We have obtained our sigma value between 3-6 for Glucose, total cholesterol, creatinine, ALP, ALT (L1, L2), urea, AST, TSH (L2) before lockdown and total cholesterol, AST, ALP and TSH (L1, L2) during the lockdown.

Sigma was more than 6 for AST (L1), TIBC (L1, L2) and β-HCG(L2) before lockdown and TIBC, β-HCG (L1, L2) during the lockdown. In this instance, less stringent QC guidelines can be used. In these circumstances, lowering control limits to 3s helps reduce false rejections. On analyzing the QGI index ratio, imprecision was the reason for lower sigma values for urea, TSH and β-HCG before lockdown. Inaccuracy was the problem for glucose and ALT(L2) during the lockdown and both imprecision and inaccuracy was the problem for urea(L2) and ALT(L1) during the lockdown months.

Based on sigma metrics and QGI, it was found that our biochemistry section in the central laboratory performed well before the lockdown than during the lockdown period. The underlying reason could be that the laboratory had a full staff on duty before lockdown whereas during the lockdown, the staffs were reduced to 50%.

Limitations

This study was done for a short period and the study parameters were restricted to only ten, which were randomly chosen.

CONCLUSION

This study highlights the necessity for stringent IQC and EQA monitoring even during the lockdown period of the pandemic. Hence, a contingency plan must be put in place to address these concerns:

1. Deployment of an adequate number of trained laboratory personnel.
2. Providing the best possible storage facility for IQC/EQAS material and reagents.
3. Strict adherence to the environmental condition needs and maintenance of the equipment.
4. A system for remote monitoring of IQC run, reagent status and calibration record of equipment by consultants may be made available.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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