

## Evaluation of Quality control data of hormones using six sigma metrics tool in clinical laboratory

### ABSTRACT

**Background:** In health care system it is necessary to provide high quality and reliable test results to the patients. Many clinical laboratories are using six sigma as a tool to improve the quality control in health care system. Keeping this in mind, the present study was conducted using the quality control data of hormones under NABL which were assayed in our clinical laboratory. **Material and methods:** In this retrospective study, both the internal and external quality control data of 11 hormones were collected for a period of 6 months from April 2020 to September 2020 and the six sigma analysis was done. **Results:** Testosterone level 1(6.8), level 2(6.5) and Folate level 1(6.9), level 2(6.6) showed sigma level more than 6 and hence excellent performance. The hormones, FT3 level 1(3.7), level 2(4.8), HCG level 2(3.6), TSH level 1(4.8), level 2(4.7) and Vitamin B12 level 1(4.4), level 2(4.5) showed average performance with sigma level between 3.5 and 6. The hormones, FT4 level 1(1.7), level 2(2), HCG level 1(2.2), Prolactin level 1(3), level 2(3.3), FSH level 1(1.9), level 2(2.0), LH level 1(2), level 2(1.9) and Progesterone level 1(3.4), level 2(3.3) showed poor performance with sigma level less than 3.5. **Conclusion:** Stringent rules need not be applied for hormones with  $\sigma > 6$ . Moreover, control limits can be relaxed to 3S so that false rejections can be minimized. For hormones with  $\sigma < 6$ , internal QC rules have to be strictly applied and the root cause analysis has to be done. To conclude, six sigma metrics is a powerful quality control tool which helps to improve the performance of the clinical laboratory and hence the efficiency of the health care system.

**Key words:** Sigma metrics, quality control, hormones

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### INTRODUCTION:

Six sigma is a quality control tool which helps to define, measure, analyze, improve and control the clinical laboratory performance. It has set a benchmark for excellence. Six sigma is a quality assurance approach which tends to raise the standards of Quality management system. Sigma metrics helps to quantify the errors which occur during analytical phase of measuring system<sup>1</sup>. Six sigma, a quality management tool was first introduced by Sir Bill Smith to Motorola in 1986 for the process improvement<sup>2</sup>. It quantifies the errors by combining the precision, bias and Total allowable error (TEa). Precision is obtained from internal quality control data while bias is obtained from external quality control (EQAS). External quality control involves analysis and reporting of Quality control sample provided by external agency. The external agency then studies the results of all participants and provides feedback<sup>4</sup>. Sigma level  $\geq 6$  infers good performance of the laboratory while sigma level between 3.5 and 6 infers average performance. Sigma level  $< 3$  indicates poor performance<sup>5</sup>. The focus of the current study was to measure and analyze sigma metrics of hormones under the scope of NABL accreditation.

### MATERIAL AND METHODS:

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The current study was a retrospective study conducted in Central clinical Biochemistry laboratory, Chettinad hospital and research institute, Kelambakkam. The Hormones control that were assayed includes Free T3, Free T4, TSH, Luteinising hormone, Follicle stimulating hormone, Prolactin, Progesterone, Testosterone, Folate, Vitamin B12 and Human chorionic gonadotrophin. Both Internal and External Quality control material were procured from BIO-RAD. Internal quality control data of both level 1 (Normal) and level 2 (pathological) of 11 hormones under NABL scope were collected for a period of 6 months from April 2020 to September 2020. Mean, Standard deviation and Coefficient of Variation were calculated for each level separately.

**Coefficient of Variation was calculated using the formula:**

**Coefficient of Variation = (Standard deviation/Mean) x 100**

Bias percentage for each hormone was calculated from External Quality control data. Bias percentage is the systematic difference between the expected result obtained from lab test method and that of the reference method. Clinical Laboratory Improvement Amendment (CLIA) has given acceptable performance for each hormone in terms of Total allowable error (TEa)<sup>6</sup>.

Sigma metrics for each hormone was calculated using the formula:

**Sigma = TEa – Bias/CV**

Quality Goal Index ratio (QGI) was calculated for those hormones with sigma value less than 6 using the formula

**QGI = Bias/1.5 x CV%**

**Table 1 -Quality Goal Index ratio**

QGI	Problem
<0.8	Imprecision
0.8-1.2	Imprecision and inaccuracy
>1.2	Inaccuracy

QGI = Quality Goal Index ratio

**Table 2 –Sigma metrics of 11 hormones calculated from Total allowable error (TEa), average percentage of Coefficient of variation and Bias from April 2020 to September 2020**

Hormone	TEa%	Average Bias %	Average CV%		Sigma score	
			Level 1	Level 2	Level 1	Level 2
FT4	15	-0.783	74.1	8.9	1.7	2.0
FT3	30	-4.275	9.5	7.3	3.7	4.8
TSH	20	-6.131	6.1	6.4	4.8	4.7
HCG	18	4.026	6.6	3.9	2.2	3.5

Prolactin	20	-1.868	5.7	6.8	3.0	3.3
FSH	18	2.559	7.9	7.2	1.9	2.1
LH	20	0.257	11.0	12.8	2.0	1.8
Folate	30	-2.205	5.1	5.1	6.9	6.6
Progesterone	25	2.066	7.5	7.4	3.4	3.3
Testosterone	30	2.8	4.4	4.7	6.8	6.5
Vitamin B12	25	-2.398	7.3	6.6	4.4	4.5

**Table 3 shows Quality Goal Index Ratio of Hormones with sigma less than 6 and its interpretation**

Hormone	Level	Sigma score	Quality Goal Index	Cause
FT4	Level 1	1.7	0.1	Imprecision
	Level 2	2.0	0.2	
FT3	Level 1	3.7	0.3	Imprecision
	Level 2	4.8	0.4	
TSH	Level 1	4.8	0.8	Imprecision and inaccuracy
	Level 2	4.7	0.6	
HCG	Level 1	2.2	0.4	Imprecision
	Level 2	3.6	0.7	
Prolactin	Level 1	3.0	0.2	Imprecision
	Level 2	3.3	0.2	
FSH	Level 1	1.9	0.2	Imprecision
	Level 2	2.0	0.2	
LH	Level 1	2.0	0.2	Imprecision
	Level 2	1.9	0.1	
Progesterone	Level 1	3.4	0.2	Imprecision
	Level 2	3.3	0.2	
Vitamin B12	Level 1	4.4	0.2	Imprecision
	Level 2	4.5	0.2	

### RESULTS:

The hormones, testosterone level 1(6.8), level 2(6.5) and folate level1 (6.9), level 2(6.6) showed sigma score more than 6. The hormones, FT3 level 1(3.7), level 2(4.8), HCG level 2(3.6), TSH level 1(4.8), level 2(4.7) and Vitamin B12 level 1(4.4), level 2(4.5) showed sigma score between 3.5 and 6. The hormones, FT4 level 1(1.7), level 2(2), HCG level 1(2.2), Prolactin level 1(3), level 2(3.3), FSH level 1(1.9), level 2(2.0), LH level 1(2), level 2(1.9) and Progesterone level 1(3.4), level 2(3.3) showed sigma score less than 3.5.

### DISCUSSION:

In the current study, the hormones, testosterone and Folate showed sigma score more than 6 and hence excellent performance. Stringent rules need not be applied for Testosterone and folate. Moreover control

limits can also be relaxed to minimize false rejections. The hormones, FT3, HCG level 2, TSH and Vitamin B12 showed average performance with sigma level between 3.5 and 6. Quality goals for these hormones can be met by applying more elaborate quality control strategies. The hormones, FT4, HCG level 1, Prolactin, FSH, LH and Progesterone showed poor performance with sigma level less than 3.5. For these hormones, reduction of analytical bias and imprecision are the two remedies available to improve the quality. Westgard rules and guidelines proposed by Cooper et al can be implemented according to the sigma values in the clinical laboratory.

Simple Westgard rules as follows<sup>7</sup>:

- $\geq 6\sigma$  :- 2 levels of QC per day with a 13.5s greater rule
- $5\sigma$  :- 2 or 3 levels of QC per day with a 12.5s or 13s rule
- $4\sigma$  :- 3 or 4 levels of QC per day with a 13s / 2 22s / R 4s / 4 1 s rule
- $3.5\sigma$  :- 6 of QC per day with a 13s / 2 22s / R 4s / 4 1 s rule
- $< 3.5\sigma$  :- maximum affordable levels of QC per day with a 13s / 2 22s / R 4s / 4 1 s rule

Another guideline proposed by Cooper et al as follows<sup>8</sup>:

- $> 6\sigma$  (excellent tests) –one QC per day (alternating levels between days) and a 13s rule.
- $4\sigma$ – $6\sigma$  (suited for purpose) –two levels of QC per day and the 12.5s rule.
- $3\sigma$ – $4\sigma$  (poor performers) –combination of rules with two levels of QC twice per day.
- $< 3\sigma$  (problems) – maximum QC, three levels, three times a day. Preferably testing specimens in duplicate.

## CONCLUSION:

Six sigma methodologies is a powerful tool in clinical laboratories. It should be used in health care system, until the quality improves to six sigma level. This can be achieved by using an optimal Westgard rule and thereby highly reliable results of diagnostic tests can be delivered.

**ETHICAL CLEARANCE:** Ethical Clearance for this study was got approved from the Institutional Human Ethical Committee.

## COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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## REFERENCES

1. Westgard JO. Internal quality control: Planning and implementation strategies. Ann Clin Biochem 2003;40:593-611.
2. Coskun A, Inal T, Unsal I, Serteser M. Six Sigma as a Quality Management Tool: Evaluation of Performance in Laboratory Medicine Quality Management and Six Sigma. InTechOpen: Rijeka, Croatia; 2010. p. 248-61.

3. Angmo D, Kant S. Six sigma implementation in healthcare industry: Past, present and future. *Int J Eng Res Technol* 2015;4:1078-82.
4. Lewis SM. The WHO International External Quality Assessment Scheme for Haematology. *Bulletin of WHO* .1988; 66: 283-290.
5. Adiga US, Preethika A, Swathi K. Sigma metrics in clinical chemistry laboratory - A guide to quality control. *Al Am een J Med Sci* 2015; 8: 281-287
6. Westgard JO, Westgard SA. An assessment of  $\sigma$  metrics for analytic quality using performance data from proficiency testing surveys and the CLIA criteria for acceptable performance. *J Vet Diagn Invest* 2008;20:536-44
7. Schoenmakers CHH, Naus AJM, Xvermeer HJ, Loon DV and Steen G. Practical application of sigma metrics QC procedures in clinical chemistry. *Clin Chem Lab Med* 2011; 49(11):1837–1843
8. Cooper G, Jonge N D ,Ehrmeyer S, Pacheco J Y, Jansen R , Rico C, Plebani M . Collective opinion paper on findings of the 2010 convocation of experts on laboratory quality .*Clin Chem Lab Med* .2011;49(5):793–802

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