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A case study on early detection, prediction and prevention of heart disease in a multispecialty hospital by applying six sigma methodologies

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Abstract— Survey report on predicting positive Coronary Artery Disease from symptoms and evolving a diagnostic package for the 128 sliced computed tomography for a multispecialty hospital by using six sigma methodologies. Materials and methods Dynamic 128-slice Computed Tomography Scan was performed in patients admitted to the radiology department among October 2013 to January 2014. This paper deals with the data based decision making process by implementing Zero defect quality, Six Sigma methodologies. The presentation makes an attempt to study the "Existing process of numerous data generation" towards zero defect quality and make the Computed Tomography Scan diagnostic intelligent technology aware among the common man in bringing awareness on "Early Detection, Prediction and Prevention". To continuously upgrade the technology for an early diagnosis and to render excellent quality treatment to the patients.

Key words— Six Sigma, Quality, DMAIC, Breakthrough improvement, mini tab 17 software.

I. INTRODUCTION

Motorola engineering scientist William Smith, known as the father of *Six Sigma* [4], developed the concept in the 1980s. For many years, he and other pioneering engineers and scientists worked on this or similar concepts to reduce variation, improve quality. The methodology of *Six Sigma* uses the statistical theory and thus assumes that every process factor can be characterized by a statistical distribution curve [8-10, 16].

This work is a case study of Six Sigma [1], using the DMAIC improvement methodology, can be applied in a hospital environment. It is based on a project done by 81-person in multispecialty hospital in Coimbatore city in India. Continuously striving hard for "Early detection of Heart Disease" (CAD- coronary artery disease) particularly for the increase in the proportion of 60% of world's heart patients will be contributed by India (By 2010 WHO).

Adapting technological innovations [3] of "Intelligent systems" installing Computed Tomography Scan (CT scan) according to low and steady rate heart rates with lowest radiation (Dose 1-3mSv) (Adaptive cardio sequence) and high and steady rate heart rates (Adaptive ECG pulsing) (Dose 7-8mSv) Bringing out the right mix of machine and men to achieve brake through improvement [2].

The rest of this paper is organized as follows. In the next Section II the scope and design objective are described. Section III contains the methodology, measures and approach. Section IV contains statement of the problem, analysis, results and discussion is expressed by figures and tables to observe the significant symptoms of the disease. Section V presents the conclusion of the study in future directions.

II. SCOPE AND DESIGN OBJECTIVE

Scope of the study

The presentation makes an attempt to study the "existing process of numerous data generation" towards zero defect quality [5] and to make the CT scan diagnostic intelligent technology aware among the common man in bringing awareness on "Early Detection, Prediction and Prevention".

Goal

To continuously upgrade the Technology for an early diagnosis and to render excellent quality treatment to the patients.

Sigma

By definition *sigma* (s), a Greek letter, is the statistical quality measurement of standard deviation from the mean. *Six Sigma* [6] describes how a process performs quantitatively. In other words, it measures the variation of performance.

Six Sigma

Six sigma is a tool used to convert management problem into a statistical problem and to find a statistical solution then convert it to a Management solution [12].

Design for six sigma steps: (DMAIC)

• **Define** the project goals and customer (internal and external) requirements.

• **Measure** and determine customer needs and specifications (LSL and USL); benchmark competitors and similar industries.

• **Analyze** the process or product options to meet customer needs.

• **Improve** (detailed) the process or product to meet customer needs.

• **Control** the design performance and ability to meet customer needs [13, 14].

DEFINE PHASE

The strategic issue for the Hospital

Even at the highest rate of Rs. 12,000 per test, requires 6000 Patients per year to meet the Capital cost of investment alone (assuming Rs. 7.2 Crore's as the investment cost). Here comes the patient affordability cost and the availability volume. The Vital factor is the "**Accessibility**" of patients and building the communication in public, making patients as promoters through excellent, predictable and reliable service levels in order to prevent CAD.

Focus Area

CT- SCAN with reference to Cardiac applications.

Objective

Work out a high risk prone group in the society and to prepare a package for the diagnosis.

"**HIGH QUALITY, LOW COST - HIGH VOLUME PROGRAM**"

The Economy Aspect

The Quality is not just giving the output, but making a "Process Plan" using the best use of "Voluminous Information " in discovering the pattern and evolving (not Patient focused treatment alone, but assessing the clinical trends for accelerating the Quality and the outcome) a "Patient – Focused Scheme" – according to the risk prone groups.

III . METHODOLOGY, MEASURES AND APPROACH

In assessing the clinical trends for accelerating the Quality and the outcome, a "Patient – Focused Scheme" – according to the risk prone groups is considered.

6000 patients to be tested per year, just to meet the Capital cost of Rs. 7.2 Crore's without the operational cost (i.e. Salary, Maintenance, Consumables and Stationeries), it means 20 patients per day or 500 patients in a month of 25 days to be diagnosed for CAD. Currently the average arrival is only 80 to 110 patients per month. How India is to upgrade technology despite high probability of CAD.

MEASURE PHASE

Data source

The hospital records Existing hard copies and case-data of individual patients for the months of October 2013 to January 2014.

Base line information

Quality of arriving patients Excluding Age, Sex, Urban/Rural the patient may arrive with previous history of defect events such as Hypertension, Smoking, Chest Pain, H/o MI, H/o PTCA , CABG and Diabetics. As such the defect in arrival rate (i.e. a patient will have at least one defect Event) is 83%. It means symptomatic people only had come for diagnosis mostly, but the results also show non-symptomatic people recording positive coronary artery disease (CAD).

Six sigma is a Benchmark:

The "Process" needs to be defined. It may not be possible, that a company attains "Benchmark" in all process. But it should be possible, to establish, to develop, to identified and compare with "someone" as a role model to grow and achieve as a continuous improvement. Six-sigma [6] demands performance improvements through numerical rating.

Glossary of symbols:

DPU – Defect per Unit
DPO – Defect per Opportunity
P – Probability
PPM – Parts per million opportunity
Z – Z value (Normal curve value)

A focus on classical and six sigma approach:

Issue	Focus	
	Classical	Six sigma
1. Management	Cost & time	Quality & time
2. Goal setting	Realistic perception	Reach-out & stretch
3. Direction	Seat-of-pant	Benchmarking &metrics
4. Chain of command	Hierarchy	Empowered team
5. Focus	Product	Process
6. Approach	Symptomatic	Problematic
7. Problems	Fixing	Preventing
8. Reasoning	Experience based	Statistically based
9. Problem solving	Expert based	System based
10.Analytical perspective	Point estimate	Variability
11. Design	Performance	Productivity
12. Variable search	One-factor-at-a-time	Design of experiments
13. Tolerance	Worst case	Root-sum-of-squares
14. Manufacturing	Trial and error	Robust design
15. Process monitoring	Specification limits	SQC charts
16. Process adjustment	fixed	Beta correction

IV. STATEMENT OF THE PROBLEM, ANALYSIS, RESULTS AND DISCUSSION

Problem Statement No. 1

Quality at data retrieval reducing the incidence of "Non availability" of patient's prior history information's in the hospital. Among 480 patients only 81 patients could be retrieved (among 10 opportunities of information age, Sex, Urban/Rural, Hypertension, Smoking, Chest Pain, H/o MI, H/o PTCA, CABG, Diabetics) for full history details which need to be achieved 100%. The other symptoms like chest pain, heart rate, were not captured for some of the patients.

Problem Statement No. 2

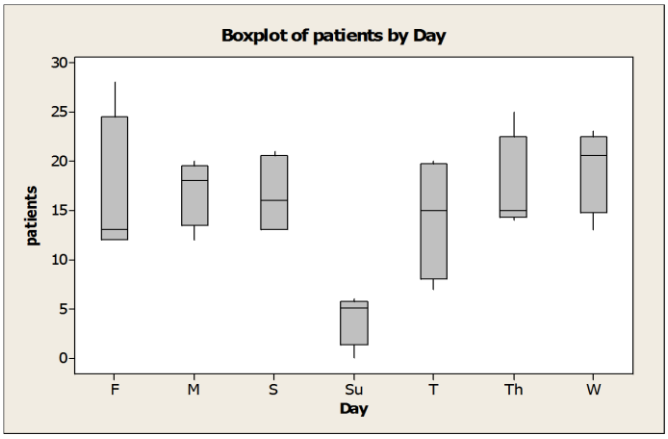
Arrival Quality of Patients Improving the "Defect free" prior history of Patients from 83 % of patients by Social Awareness program. The existing arrival rate of defect event per opportunities of history information is the effect of age, gender, and rural/urban place as a promotional factors (or) symptoms. It is only to be considered as promotional factors. (Please note now the arrivals are mostly symptomatic) [10]. Vispute and Singh [16] developed an economic acceptance sampling plan for variables under the method of second order auto correlation. In these problem "Positive" cases of CAD Among the patients arrival, the incidence of positive cases of CAD influenced by history information would drive home the prevention of severity of attacks-angina and the counseling required to increase patient's reference for longevity of life.

Coded Index

Coded index data were calculated by using Minitab 17 software, in ANALYSE PHASE

Total defects = 137 (for the 7 defects alone)
DPU = 1.6914 (Unit = Patient)
DPO = 0.241622575
P = 0.214647467
PPM = 214647
Z = 0.7904
SIGMA LEVEL = 2.2904
No. Of Patients = 81
Positive Reported = 46
Positive Percentage = 56.79012

The six sigma [5] statistical method in order to achieve the zero defect in any process.



BOX PLOT: (mini tab 17)

To view the central tendency & highlight the variability in the data [7]

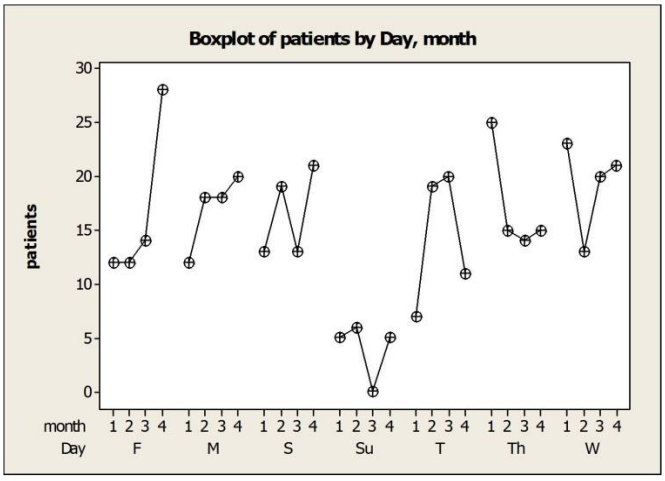
GO TO → graph → box plot

Individual95% Class Intervalsfor Mean Based on Pooled standard deviation

```
Day   Mean --+---------+---------+---------+-------
F     16.50                (-------*------)
M     17.00                (-------*-------)
S     16.50                (-------*------)
Su     4.00      (-------*-------)
T     14.25                 (------*-------)
Th    17.25                 (-------*------)
W     19.25                       (-------*------)
          --+---------+---------+---------+-------
            0.0       7.0       14.0      21.0
```

Individual 95% CIs For Mean Based on Pooled St. Dev

```
Month    Mean --------+---------+---------+---------+-
Oct      13.8571 (-------------*-------------)
Nov      14.5714       (-------------*------------)
Dec      14.1429 (-------------*-------------)
Jan      17.2857             (-------------*------------)
                 --------+---------+---------+---------+-
                 12.0      15.0      18.0      21.0
```



Link Function: Logistic

Response Information

Variable	Value	Count
Coded: Results	1	46 (Event)
	0	35
Total		81

LOGISTIC REGRESSION

Logistic Regression						95% C.I.	
Predictor	Co.ef.	SE Co.ef.	Z-Value	P-Value	Odds Ratio	Lower	Upper
Constant	-12.77	3024082	-3.94	0.0	-	-	-
Age	0.219	0.0550224	4.00	0.00	1.25	1.12	1.39
Sex (M)	1.09	0.914123	1.19	0.23	2.98	0.50	17.85
Urban/Rural (U)	0.53	0.760697	0.70	0.47	1.70	0.38	7.55
Hypertension (Y)	0.03	0.710855	0.04	0.97	1.03	0.26	4.16
Smoking (Y)	-1.55	1.14820	-1.35	0.18	0.21	0.02	2.02
Chest Pain (Y)	0.35	0.793377	0.45	0.66	1.43	0.30	6.75
H/o MI (Y)	22.18	9144.96	0.00	0.99	4.28207E+09	0.00	*
H/o PTCA (Y)	2.15369	1.44589	1.49	0.136	8.62	0.51	146.59
CABG (Y)	19.4556	7798.33	0.00	0.998	2.81487E+08	0.00	*
Diabetic (P)	0.825613	0.756888	1.09	0.275	2.28	0.52	10.07

Log-Likelihood = -27.657

Test that all slopes are zero: G = 55.478, DF = 10, P-Value = 0.000

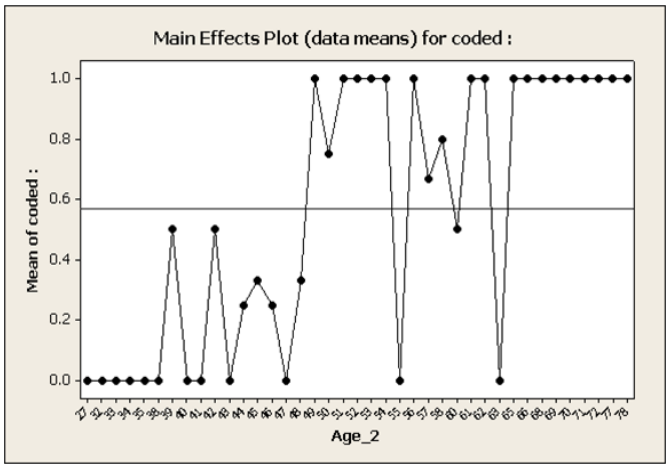
The data analysis showed that there is at least one factor which establishes as significant symptom for reporting positive CAD.This is analyzed by factor wise from the P value.

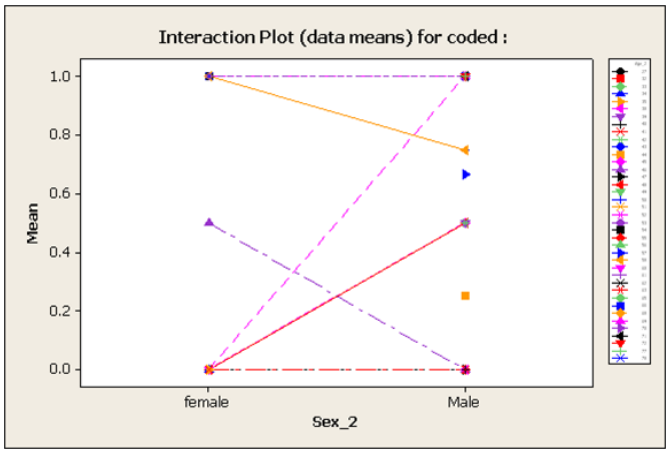
Measures of Association:

(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary	Measures
Concordant	1484	92.2	Somers' D	0.84
Discordant	124	7.7	Goodman-Kruskal Gamma	0.85
Ties	2	0.1	Kendall's Tau-a	0.42
Total	1610	100.0		

IMPROVE PHASE





CONTROL PHASE

Age:

The age has severe effect of reporting positive CAD with almost 100% lower limits with the odds of 1.25 times of younger people below 40 years of age. This report is shown in the main effect.

S.No.	Age	Sex	Urban/Rural	Hyper Tension	Smoking	Chest Pain	H/o MI	H/o PTCA	CABG	Diabetic P/N	Coded Result	No.def/pat
1	49	1	1	1	0	0	0	0	0	0	1	1
2	46	0	1	0	0	1	0	1	0	1	1	3
3	46	0	1	0	0	0	0	0	0	0	0	0
4	44	1	1	0	0	0	0	0	0	0	0	0
5	78	0	0	1	0	1	0	0	0	1	1	3
6	68	1	1	0	0	1	0	0	0	0	1	1
7	60	1	1	0	0	1	0	0	1	0	1	2
8	40	1	1	1	0	0	0	0	0	0	0	1
9	45	1	0	0	0	1	0	0	0	0	1	1
10	66	1	0	0	0	1	0	0	1	1	1	3
11	56	1	0	1	1	0	1	0	0	0	1	3
12	58	0	1	1	0	0	0	0	0	1	1	2
13	62	1	1	0	0	1	0	0	0	0	1	1
14	61	1	1	1	0	0	0	0	0	0	1	1
15	50	1	1	0	1	0	0	0	0	1	1	2
16	58	1	1	1	0	0	0	0	0	0	1	1
17	70	1	1	1	0	1	0	0	1	1	1	4
18	40	1	0	0	0	1	0	0	0	1	0	2
19	50	1	0	1	1	1	1	0	0	0	1	4
20	39	1	1	1	0	1	0	1	0	1	1	4
21	68	1	1	1	0	1	0	0	0	1	1	3
22	65	1	0	1	0	1	0	0	0	1	1	3
23	50	1	0	1	0	0	0	0	0	1	1	2
24	51	1	0	0	0	0	0	0	1	0	1	1
25	43	1	0	1	0	1	0	0	0	0	0	2
26	77	1	1	0	0	1	0	0	0	1	1	2
27	71	1	0	1	1	0	1	0	1	1	1	5
28	44	1	1	0	0	1	0	0	0	0	1	1
29	44	1	0	1	0	0	0	0	0	1	0	2
3	4	1	0	1	0	0	0	0	0	1	0	2

0	6											
31	61	0	0	1	0	1	0	0	0	0	1	2
32	55	1	1	1	0	0	0	0	0	0	0	1
33	52	1	1	1	0	1	0	0	0	0	1	2
34	53	1	1	0	0	0	0	1	0	0	1	1
35	41	1	0	1	0	1	0	0	0	1	0	3
36	62	1	1	1	0	0	0	0	0	1	1	2
37	62	1	0	1	0	1	0	0	0	1	1	3
38	57	1	1	1	0	1	0	0	0	1	1	3
39	45	0	0	0	0	0	0	0	0	1	0	1
40	72	1	0	0	0	0	0	0	0	0	1	0
41	56	1	1	1	0	0	0	0	0	0	1	1
42	32	0	1	0	0	0	0	0	0	0	0	0
43	35	0	0	1	0	1	0	0	0	0	0	2
44	57	1	0	0	0	1	0	0	0	1	0	2
45	42	1	0	0	0	0	0	0	0	0	0	0
46	41	1	1	0	0	0	0	0	0	0	0	0
47	68	1	1	0	1	1	1	0	1	0	1	4
48	54	0	1	1	0	0	0	0	0	0	1	1
49	63	1	1	0	1	0	0	0	0	0	0	1
50	39	1	1	0	0	0	0	0	0	0	0	0
51	41	1	0	0	0	0	0	0	0	0	0	0
52	69	1	0	0	0	0	0	0	0	1	1	1
53	60	0	0	1	0	1	0	0	0	0	0	2
54	34	0	0	0	0	0	0	0	0	1	0	1
55	47	1	0	1	1	0	0	0	0	1	0	3
56	77	1	1	0	0	0	0	0	0	0	1	0
57	47	0	1	0	0	1	0	0	0	1	0	2
58	38	1	0	0	0	0	0	0	0	0	0	0
59	48	1	0	0	1	1	1	0	0	0	1	3
60	41	0	1	0	0	0	0	0	0	0	0	0
61	68	1	1	1	0	1	0	0	0	0	1	2
62	45	1	1	0	0	0	0	0	0	1	0	1
63	72	1	0	1	1	0	0	0	0	0	1	2
64	57	1	1	0	0	0	0	0	0	1	1	1
65	58	1	0	0	1	0	0	0	0	0	1	1
66	41	1	1	0	1	1	0	0	0	0	0	2
67	51	1	0	0	0	0	0	0	0	1	1	1
68	48	1	1	0	0	1	0	0	0	0	0	1
69	52	1	0	1	0	0	0	0	0	1	1	2
70	27	1	1	1	1	0	0	0	0	0	0	2
71	38	1	1	0	0	1	0	0	0	0	0	1
72	48	0	1	1	0	1	0	0	0	1	0	3
73	52	0	1	0	0	1	0	0	0	1	1	2
74	58	1	1	1	0	0	0	0	0	0	0	1
75	33	1	0	0	1	1	0	0	0	0	0	2
76	46	1	1	1	1	0	0	1	0	1	0	4
77	58	1	1	0	0	0	0	0	0	0	1	0
78	66	1	1	1	1	0	0	0	0	0	1	2
79	50	1	1	0	0	0	0	0	0	0	0	0
80	42	1	1	1	0	0	0	0	0	1	1	2
81	44	1	1	1	0	0	0	0	0	1	0	2

Smoking / Nonsmoker:

Note the smoker as a factor event and note the negative sign coefficient, it means nonsmoker has also odds of reporting positive CAD at 83% confidence level.

Sex:

Male has got three times more chance than the Female to be reported as positive CAD

Sex	**Male**	**1**	**Female**	**0**
Urban/ Rural	**Urban**	**1**	**Rural**	**0**
Hypertension	**Positive**	**1**	**Negative**	**0**
Smoking	**Positive**	**1**	**Negative**	**0**
Chest Pain	**Positive**	**1**	**Negative**	**0**
H/o MI	**Positive**	**1**	**Negative**	**0**
H/o PTCA	**Positive**	**1**	**Negative**	**0**
H/o CABG	**Positive**	**1**	**Negative**	**0**
Diabetics	**Positive**	**1**	**Negative**	**0**

Sigma level	PPM level
2	3, 08, 537
3	66210
4	6210
5	233
6	3.4

PTCA:

It is obvious that PTCA patients have got 9 times more chance than the non PTCA patients for reporting positive CAD.

CABG:

It is also obvious that CABG patients have 3 times more chance than the non PTCA patients for reporting Positive CAD. The remaining factors such as urban/rural, hypertension, chest pain, H/O MI, Diabetics do not have significant effect.

V. CONCLUSION

The age has severe effect of reporting positive CAD with almost 100% lower limits with the odds of 1.25 times of younger people below 40 years of age. This report is shown in the main effect. Note the smoker as a factor event and note the negative sign coefficient, it means nonsmoker has also odds of reporting positive CAD at 83% confidence level. Male has got three times more chance than the Female to be reported as positive CAD. It is obvious that PTCA patients have got 9 times more chance than the non PTCA patients for reporting positive CAD. It is also obvious that CABG patients have 3 times more chance than the non PTCA patients for reporting Positive CAD. The remaining factors such as urban/rural, hypertension, chest pain, H/O MI, Diabetics do not have significant effect.

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