# Statistical Quality Control Chart: An Initiative to Measure and Control Quality in Healthcare Operations


***By***

Shivani Arora


*Dissertation submitted for the partial fulfillment of the*
*MBA Hospital and Health Management*

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**Internship Training**

**At**

**MAX HOSPITAL (BATHINDA)**

# Statistical Quality Control Chart: An Initiative To measure and control quality in healthcare operations

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Under the esteemed guidance of

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**2014-2016**


**Institute of Health Management Research**
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**TO WHOMSOEVER MAY CONCERN**

This is to certify that Dr. Shivani Arora, student of MBA Hospital and Health Management from IIHMR University, Jaipur has undergone internship training at Max Hospital, Bathinda from 8 Feb, 2016 to April 30, 2016.

The Candidate has successfully carried out the study designated to her during internship training and her approach to the study has been sincere, scientific and analytical.

The Internship is in fulfillment of the course requirements.

I wish her all success in all her future endeavors.

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**TO WHOMSOEVER IT MAY CONCERN**

This is to certify that Ms. Shivani Arora D/o Dr. Birbal Arora has worked as an intern in the Department of Medical Operations from 08 Feb 2016 to 30 Apr 2016. She has successfully completed her project on Statistical Quality Control Chart: A Six Sigma Initiative to measure and control quality in healthcare operations.

During her tenure we found her to be sincere and hardworking. This performance is rated satisfactory by the Head of the Department.

We wish her success in future endeavors.

For Max Super Specialty Hospital

MAX SUPER SPECIALTY HOSPITAL
(A Unit of Hometrail Buildtech Pvt. Ltd.)
Near Civil Hospital, Bathinda-151001 (Punjab)

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## CERTIFICATE BY SCHOLAR

This is to certify that the dissertation titled**, Statistical Quality Control Chart: An Initiative**
**To measure and control quality in healthcare operations** submitted by **Dr. Shivani Arora**Enrollment IIHMR/01/2014-2016/0215,under the supervision of **Dr. Arindam Das** for award of MBA Hospital and Health Management of the university carried out during the period from **8 feb, 2016**to **April 30, 2015** embodies my original work and has not formed the basis for the award of any degree, diploma associate ship, fellowship, titles in this or any other Institute or other similar institution of higher learning.

Signature

**Acknowledgements**

The success of any task would be incomplete without the expression of gratitude to the people who made it possible. I hereby take an opportunity to express my sincere gratitude towards everyone who helped directly or indirectly incompletion of my Internship at Max Hospital, Bathinda.

At the onset of my report, I would like to acknowledge my sincere thanks to our institute, Institute of Health Management and Research, Jaipur for providing us platform to gain enough knowledge and skills in different aspects of hospital management, and Max Hospital, Bathinda for believing in my abilities.

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Finally, and most importantly, I would like to thank God for allowing me to complete my project, my beloved parents and brother for their blessings and my friends for their help and wishes for the successful completion of this Internship.

Dr. Shivani Arora
IIHMR/01/2014-2016/0215, IIHMR University Jaipur

**Table of Contents**

**List of Figures**



**List of Tables**

**List of Abbreviations**

**C-CHART-COUNT CHART**

**P-CHART-PROBABILITY CHART**

**T.A.T-TURNAROUND TIME**

**H.A.I-HOSPITAL ACQUIRED INFECTION**

**U.C.L-UPPER CONTROL LIMIT**

**L.C.L-LOWER CONTROL LIMIT**

**I.C.U-INTENSIVE CARE UNIT**

**S.P.C.-STATISTICAL PROCESS CONTROL**

**T.P.A.-THIRED PARTY ASSURANCE**

**V.A.P.-VENTILATOR ASSOCIATED PNEUMONIA**

**C.A.U.T.I.-CATHETER ASSOCIATED URINARY TRACT INFECTION**

**C.L.B.S.I.-CENTER LINE BLOOD STREAM INFECTION**

**DISSERTATION REPORT**

**Statistical Quality Control Chart: An Initiative**
**To measure and control quality in healthcare operations**

## 1.1Abstract


**Statistical Quality Control Chart: An Initiative To Measure and Control Quality in Healthcare Operations**

**Arora Shivani (The IIHMR University, Jaipur, Rajasthan)**

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"Statistical Process Control" is a methodology of analysis used to discover variation in a process. A "statistical quality control chart" is a tool that graphically displays the control limits on process outcomes. Attribute based c-charts are used to count bad occurrences in a process, attribute based p charts are used to monitor the proportion of defects in a process and mean and range charts are used for variables that are measured continuously.

In a health care setting, quality managers can use the appropriate type of control chart to monitor the outcomes like infections, accuracy of medications, satisfaction among patients regarding hospital services and various others issues that hampers the smooth running of a hospital.

Objectives of the study are to construct various quality control charts. In this study ,Attribute based c- chart are constructed to monitor the infection rate .Attribute based p-chart to monitor the patient satisfaction level regarding delivery of services and Variable based mean and range charts to monitor the T.A.T. of initial assessment in Emergency department.

The study was conducted in a tertiary care hospital in Bathinda. Primary data was collected through observations (using checklist) and retrospective data was collected through hospital information system. To create c-chart, data was collected from a sample of 60 patients over a period of 11months.

For creating p-chart, data was collected from 50 patients monthly for a period of 3 months. To construct mean and range chart, data was collected from 5 patients daily for 10days.

Analysis of attribute based and variable based charts revealed that the many processes under study were statistically out of control as per 3sigma limits. Further, it was

analyzed after calculating upper control limit and lower control limit of mean range of data that, no “specialcause” was found in context of hospital acquired infection ,patient satisfaction and initial assessment in emergency department. However, there were 5 months in which hospital acquired infection was found beyond the average and in 6 months hospital acquired infection were below the mean range. In context of patient satisfaction and initial assessment in emergency department, 1 month in which dissatisfaction of patient towards hospital was found beyond the average and in 5 days out of 10days in which initial assessment to patient was given below the average time. Further, after measuring the variation in the processes from mean range, cause of variation were identified by using tool of fish bone diagram and recommendations were given to further improve the processes.

Hence it was concluded that Statistical Process Control is both a data analysis method and a process management philosophy, with important implications on the use of data for improvement in various processes, thus ensuring improved standards of healthcare.

Control charts have found their applicability in various areas such as hospital performance infection rates, rates of patient falls, waiting times of various sorts, rates over time in a medical context, such as mortality rates, rates of disease ,bio –vigilance such as patient identification and non-infectious hazards of transfusion, surveillance of infectious diseases ,lab turnaround, patient satisfaction scores, medication errors, emergency service response times, post-operative lengths of stay, “door-to-needle” times, counts of adverse events and many others. Thus, they act as phenomenal tool in providing an effective method to visualize data over a period while considering for boundary conditions and helps to check if the corrective action has resulted in an improved process.

**Key words**: control charts, tools of healthcare operations, statistical process control

### 1.2 Introduction:

Statistical Process Control is a methodology of analysis used to discover variation in a process. A statistical quality control chart is a tool that graphically displays the control limits on process outcomes. It is a methodology for ongoing improvement of systems, processes, and outcomes. In this methodology a set of methods used to discover variation in a process. It is a powerful and versatile tool that graphically displays the control limits on process outcomes. These graphical depictions of process performance enable quality manager to know exact condition of their processes and enable them to make appropriate decisions.

A control chart also includes three reference lines which are determined by historical data: a central line which represents the average, an upper line which represents the upper control limit, and a lower line which represents the lower control limit.

- **Mean (X):** A statistically calculated number that defines the average amount of variation.
- **UCL (Upper Control Limit):** A statistically calculated number that defines the higher limit of variation
- **LCL (Lower Control Limit):** A statistically calculated number that defines the lower limit of variation.

These values are not ideally defined. They are determined by the process and sample of the process. The UCL is the largest value which would expect from a process with common causes of variation. The LCL is the smallest value which would expect. As long as the all the points are within the limits and there are no patterns, only common causes of variation are present. The process is said to be "in control." If all the points are beyond the upper control limit then process is said to be “out of control” with some “special causes”. All the “special causes” are not the signs of out of control process. If a point occurs below the lower limit then also a process is not part of the normal process and is said to be with “special causes”. After getting information regarding “special causes” and” common causes” Quality manager can improve the process.

Statistical Process Control charts consist of various types of charts as follows:

| **Type Of Statistical Process Control** | **Probability Distribution** | **Use** | **Examples** |
|---|---|---|---|
| *c* chart | Poisson | • Total number of event Note: Assumes constant op-opportunity or sampling area in each time period | • Number of patient falls<br>• Number of central line infections<br>• Number of ventilator associated pneumonias<br>• Number of needle sticks |
| *p* chart | binomial | • Fraction of dichotomous cases generated by a process that result in a certain outcome Note: Sample size can change from sample to sample | • Fraction of surgeries that develop a surgical site infection<br>• Fraction of patients who receive an antibiotic on time Fraction of patients readmitted<br>• Patient satisfaction |
| *Xbar chart* (mean and range chart) | Normal | • Continuous measuremen ts with "bell shape" Note: *Xbar* and *R*used as an | • Length of patient waits<br>• Procedure durations<br>• Timing of perioperative |

| | | | |
|---|---|---|---|
| | | alternative. | antibiotics.<br>• Physiologic data<br>• Time from decision to first incision for emergent Cesarean deliveries<br>• Turn Around Time |
| *u* chart | Poisson | • Rate of some event, where no exact upper bound, can be more than one event per pa-tient or sampling unit. | • Average number of patient falls per 100 patient days<br>• Number of central line infections per 100 line-days<br>• Number of ventilator associated pneumonias per 100 ventilator days |
| *g* chart | geometric | • Number of cases or amount of time between occurrences. Note: Particularly useful for rare events low rate < .01) | • Number of surgeries between infections<br>• Number patients between complications |

**TABLE.1.1: Types of statistical process control charts**

Attribute based c-charts are used to count bad occurrences as quality defects, attribute based p charts are used to monitor the proportion of defects in a process mean and range charts are used for variables that are measured continuously.[1]

Quality managers can use the appropriate type of control chart to monitor the outcomes like infections, accuracy of medications, satisfaction among patients regarding hospital services and various others issues that hampers the smooth running of a hospital.[1]

## 1.3. Review of literature:

Morton et.al in 2008 used SPC charts to monitor infection rates. This provided insights and led to improved standardized cleaning procedures and the early detection of new outbreaks.[2]

The Research Journal of Medical Sciences (2009) discussed on the "Importance of Statistical Process Control in Health Care." In this paper, the author is looking at using a control chart to analyze the results of surgeon-specific mortality rates following colorectal cancer surgery.[3]

Sonesson and Bock (2003) provided a review paper on prospective statistical surveillance in public health. They pointed out some of the problems and issues related to the statistical evaluation of the proposed methods[4].

In a study done by Johan, Jonnas and Jackob, Statistical process control was applied in a wide range of settings and specialties, at diverse levels of organization and directly by patients, using 97 different variables Statistical process control helped to improve healthcare processes. It also enabled patients with, for example asthma or diabetes mellitus, to manage their own health, and thus has therapeutic qualities. Thus they concluded that Statistical process control is a versatile tool which can help diverse stakeholders to manage change in healthcare and improve patients' health.[5]

Bisgaard and Trusko et al. conducted a study in United States on the use of control charts to monitor the infection rate in ICU. A considerable decrease of 6.5% was seen in the number of infectious spread cases after the specific causes were identified using control charts.[6]

Sonesson and Bock (2003) provided a paper on prospective statistical surveillance in public health. They pointed out some of the problems and issues related to the statistical evaluation of the proposed methods.[7]

Winkel and Zhang (2007) and Montgomery (2008) discussed the use of control charting. One commonly recommended approach is to use a times series model to predict one time period ahead and to then plot the one-step-ahead forecast errors on a control chart.[8]

Lee and McGreevy (2002) reviewed the control charting approaches, (2010).Sawalpurkar; Reynolds and Arnold have used the Markov chain approach in control charts.[9]

Raz and Wang (1990)present a work on construction of control charts for linguistic data results suggests that on the basis of sensitivity to process shifts ,control charts for linguistic data outperform.[10]

Costa (1994) has discussed the properties of the control chart with variable sample sizes when the size of each sample depends on what is observed in the proceeding sample.[11] Stoumbos (2001) discussed the properties of the control charts for a single observation. Wu et al. (2009) considered control chart for monitoring the process mean and variation.

Prajapati and Mahapatra (2009) has used variable control chart to monitor the process mean and variance[12]

Robinson, Susan,(2014) wrote a thesis on Monitoring Hospital Safety Climate Using Control Charts of Non-harm Events in Reporting Systems.[1]

### 1.4 Statement of the problem

There is a gap in measurement of processes in hospital operations.

### 1.5 Rationale of the Study:

SPC are used to visualize and analyses the performance of a process—including patient satisfaction, hospital acquired infections and turnaround times.Statistically derived decision rules help users to determine whether the performance of a process is stable and predictable or whether there is variation in the performance that makes the process unstable and unpredictable. Application of statistical process charts allows quality manager to monitor the processes for out-of- control data points. The purpose of this paper to discusses how control charts can be used in hospitals to

assist in improving quality. The focus of this paper is on the application of control charts to monitor quality and productivity in a tertiary care hospital

.

**1.6 Research Question**

Howcan we use control charts to measure and control quality in healthcare operations?

**1.7 Objectives**

- To monitor the infection rate with the help of attribute based c-chart.
- To monitor the patient satisfaction level regarding delivery of services by the application of p-chart.
- To monitor turnaround time of initial assessment in emergency department by application of mean and range charts.

**1.8.Aim**

- To measuring and controlling quality in health care operations.

**1.9 Methodology**

**Study Design:**

Observational Descriptive study

**Study Location:**

This study was conducted in Max Hospital, Bathinda.

**Sampling:**

Primary data was collected through observations in a systemic manner and retrospective data was collected through hospital information system.

To create c-chart, data was collected from purposive sampling a sample of 60patients over a period of 11months.Time duration of data was May 2015 to March 2016.Out of 11 months, data of 9months was taken retrospectively from

Hospital information system and 2 months data was collected through systemic observation.

For creating p-chart, data was collected from non-probability convenient sampling 50 patients monthly for a period of 3 months. Out of 3 months, data of 2 months was taken retrospectively from Hospital information system while data of 1 month was collected through systemic observations.

To construct mean and range chart, data was collected from non-probabilityconvenience sampling 5 patients daily for 10days.Data was collected through observations using checklist.

**Methods and Instruments of Data Gathering**

- Checklist was used for the assessment of infection rate.
- Hospital information system

**Target Population**

For c chart: Patients admitted in hospital who had acquired infection after being admitted into hospital

For p chart: patients of relatives of patients who came to hospital.

For mean and range chart: patients who came in emergency department of hospital.

**1.10 Statistical Treatment**

Data collected was cross checked for any incomplete or partial filling. Using excel version 2010 and POM QM software, collecteddata was then analyzed.

**1.11 Ethical Considerations**

Prior information was given before visiting any department. Confidentiality was ensured to all patients.

**1.12Results:**

In this section of the report, data was analyzed and discussed. Analysis of attribute based and variable based charts revealed that the processes under study were statistically in control limits as per 3sigma limits.

| Name of Measure | Purpose | Data Collection | Analysis |
|---|---|---|---|
| • Hospital Acquired Infection<br>• Patient Satisfaction<br>• T.A.T. of Initial Assessment in Emergency Department | To track a critical outcome of care | Retrospective and through checklist | control charts over time |

**Table 1.2: Summary of data collection**

**C charts:**

C charts of statistical process charts were used to monitor and control the infection rate of hospital. Retrospective and prospective data was collected through hospital information system and observation respectively.

Further , Upper control limit for infection rate is calculated as-

AVERAGE=60/11

=5.45

(Upper Control Limit) UCL= average $_+$ z $\sqrt{}$ average

Here, Z= 3(for 3 sigma limit)

= 5.45 + 3 $\sqrt{}$5.45

=5.45+ 3 * 2.33

= 5.45 + 6.99

= 12.44

Lower control limit for infection rate is calculated as-

(Lower Control Limit) LCL= Average - z $\sqrt{}$Average

Average - z ∫ Average

= 5.45 - 3 √ 5.45

=5.45- 3 * 2.33

= 5.45 - 6.99

= -1.54

After calculating upper control limit and lower control limit of mean range of data following graph was plotted for 11 months of duration.

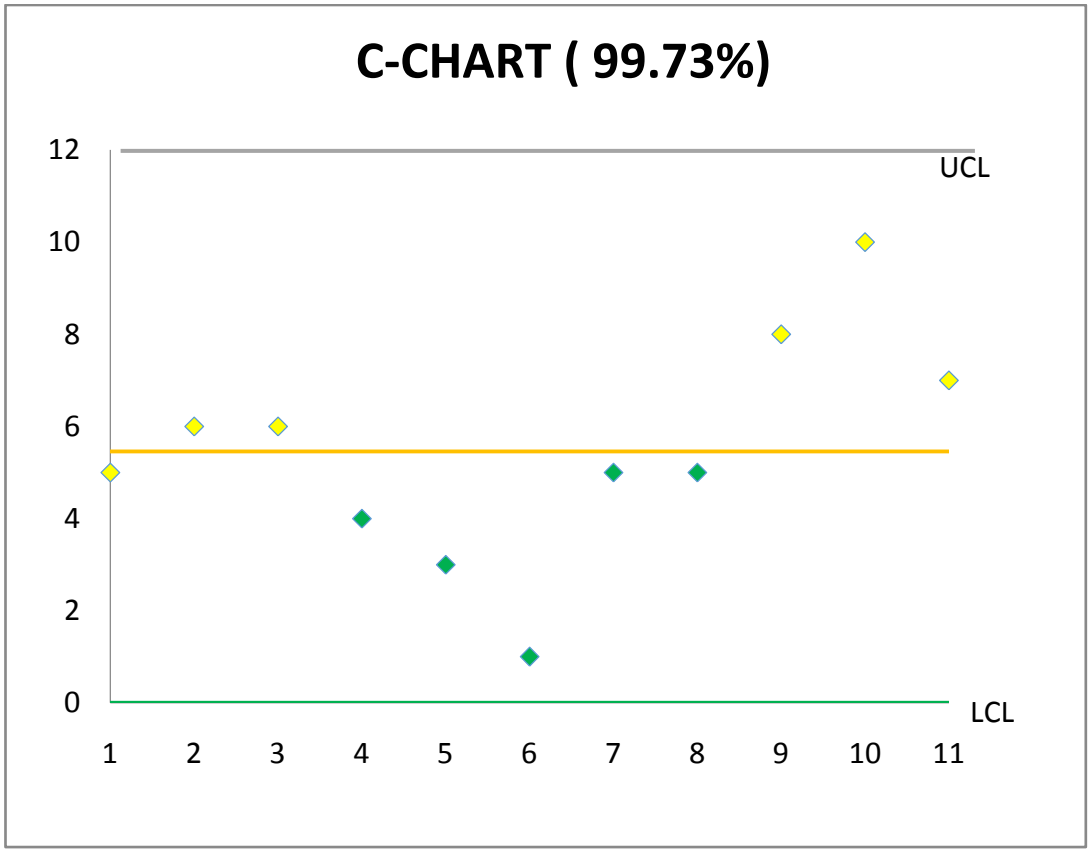



**Fig 1.1: HospitalAcquired Infection in 11 months**

From the above graph, it was observed that, no "special cause" was found in context of hospital acquired infection within the duration of 11 months.However,observation of June, July 2015 as well as jan,feb,march 2016 was found beyond average .

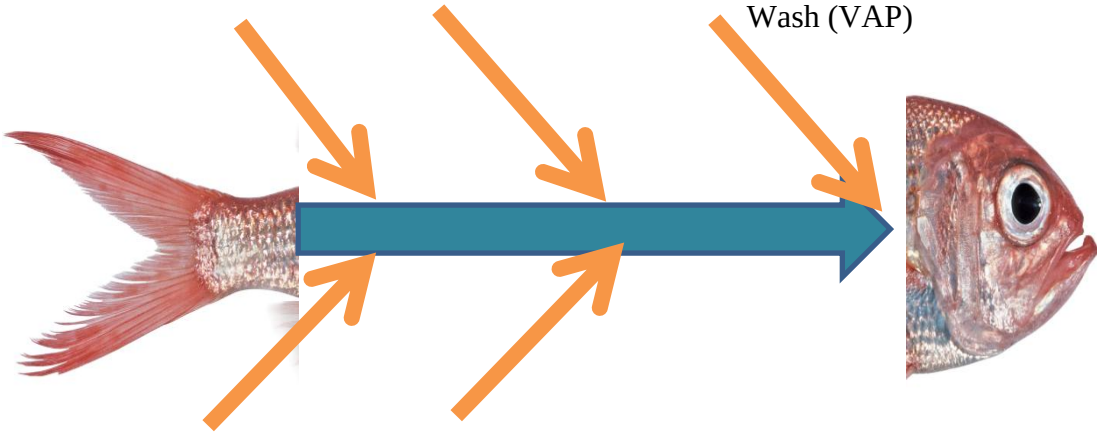
There were 5 months in which hospital acquired infection was found beyond the average .and in 6 months hospital acquired infection were below the mean range. Further in month of February infection was highest among 11 months. And in month of October infection control was lowest.

After analyzing the variations, causes of variations was churned out by using tool of fish bone analysis.

Nurse patient ratio increases  Poor hand hygiene adherence

Negligence In chlorhexidine

Wash (VAP)



Poison& Gunshot cases  Culture report were not send timely

Are higher

**FIG.1.2:Fish Bone Diagram for c- chart**

**P chart:**

P charts of statistical process charts were used to monitor and control the patient satisfaction level towards the hospital. Retrospective and prospective data was collected through hospital information system and observation respectively.

Further, Upper control limit for satisfaction level of patients is calculated as-

P- Bar = Total no. of Dissatisfied Patients/Total no. of Observations

=10/3*50

= .066

(Upper Control Limit) UCL= p-bar + z $\sqrt{}$p-bar(1- p- bar)/n

Here, Z= 3(for 3 sigma limit)

=.066+ 3 √. 066(1-.066)/50

=.066+ 3√.066 *.934/50

=.066+3√ .0616/50

=.066+3√ .00123

= .066 + 3 *.0350

=.066+ .1052

=.17

Lower control limit for satisfaction level of patients is calculated as:

(Lower Control Limit) LCL= p-bar - z √p-bar (1- p- bar)/n

=.066- 3 .066(1-.066)/50

=.066- 3√.066 *.934/50

=.066-3√ .0616/50

=.066-3√ .00123

= .066 - 3 *.0350

=.066-.1052

=-.039

After calculating upper control limit and lower control limit of mean range of data following graph was plotted for 3 months of duration.

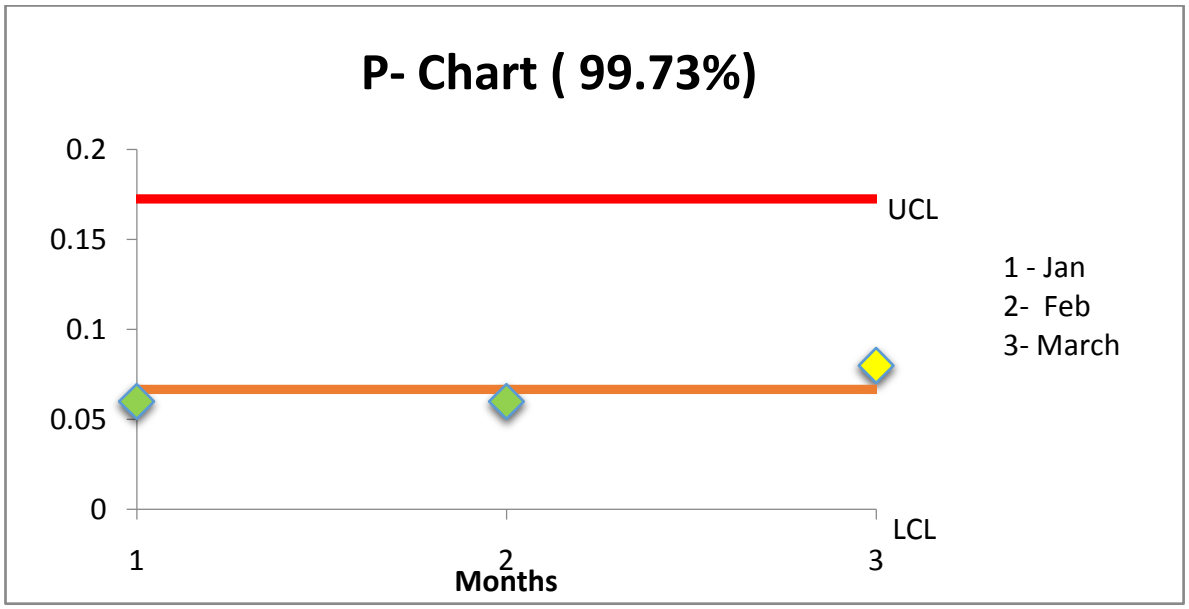


**FIG.1.3.: Patient satisfaction level regarding delivery of services**

From the above graph, it was observed that, no "special cause" was found in context of patient satisfaction towards hospital within the duration of 3 months. However, observation of March 2016 was found beyond average.

There were 2 months in which satisfaction of patient towards hospital was found beyond the average but it was only on the border of the mean range. So, corrective actions should be taken for both January and February month also.

After analyzing the variations, causes of variations was churned out by using tool of fish bone analysis.

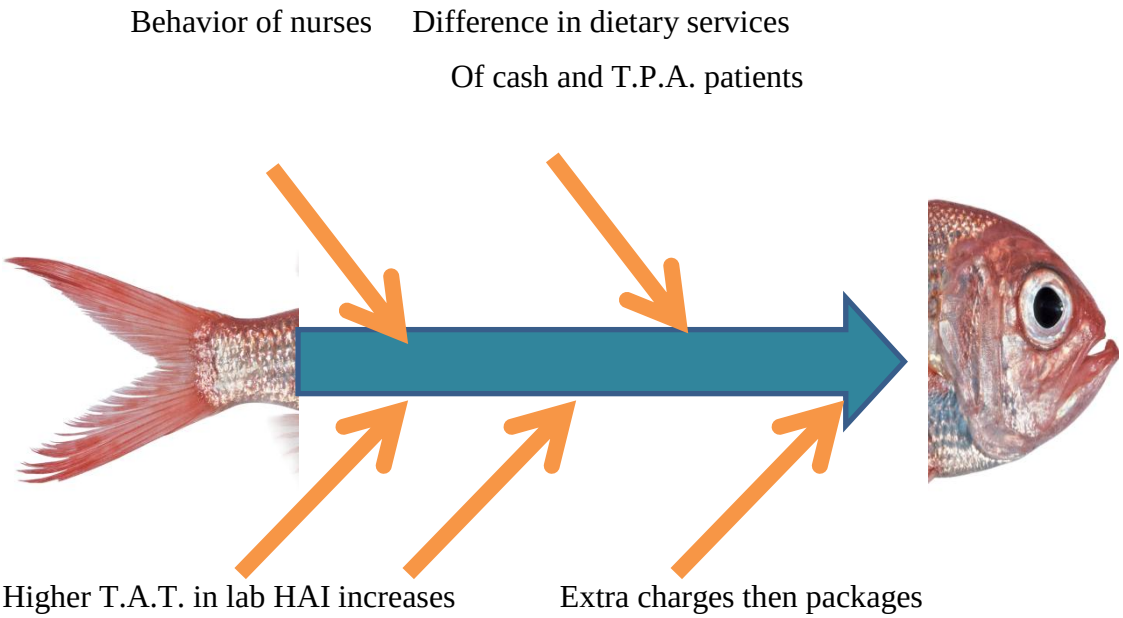



**FIG.1.4:Fish Bone Diagram for p- chart**

**Mean and Range chart:**

Mean and range charts of statistical process charts were used in a tertiary care hospital of Bathinda to monitor and control the Turnaround Time (T.A.T.) for initial assessment the hospital. Data was observation.

Upper control limit for turnaround time of initial assessment of patients is calculated as-

Mean Chart:

(Upper Control Limit) UCL= X-bar bar + A2*R- bar

Here A2 is constant for 5 sample size A2 = .58

= 38 + .58*58.3

= 38 + 33.81

= 71.81

Range chart:

(Upper Control Limit) UCL= D4*R -bar

=2.11*58.3

=123

Lower control limit for turnaround time of initial assessment of patients is calculated as-

(Lower Control Limit) LCL= X-bar bar - A2*R-bar

= 38 - .58*58.3

=38- 33.81

= 4.91

(Lower Control Limit) LCL= D3*R-bar

=0*58.3

=0

After calculating upper control limit and lower control limit of mean range of data following graph was plotted for 10 days of duration

.

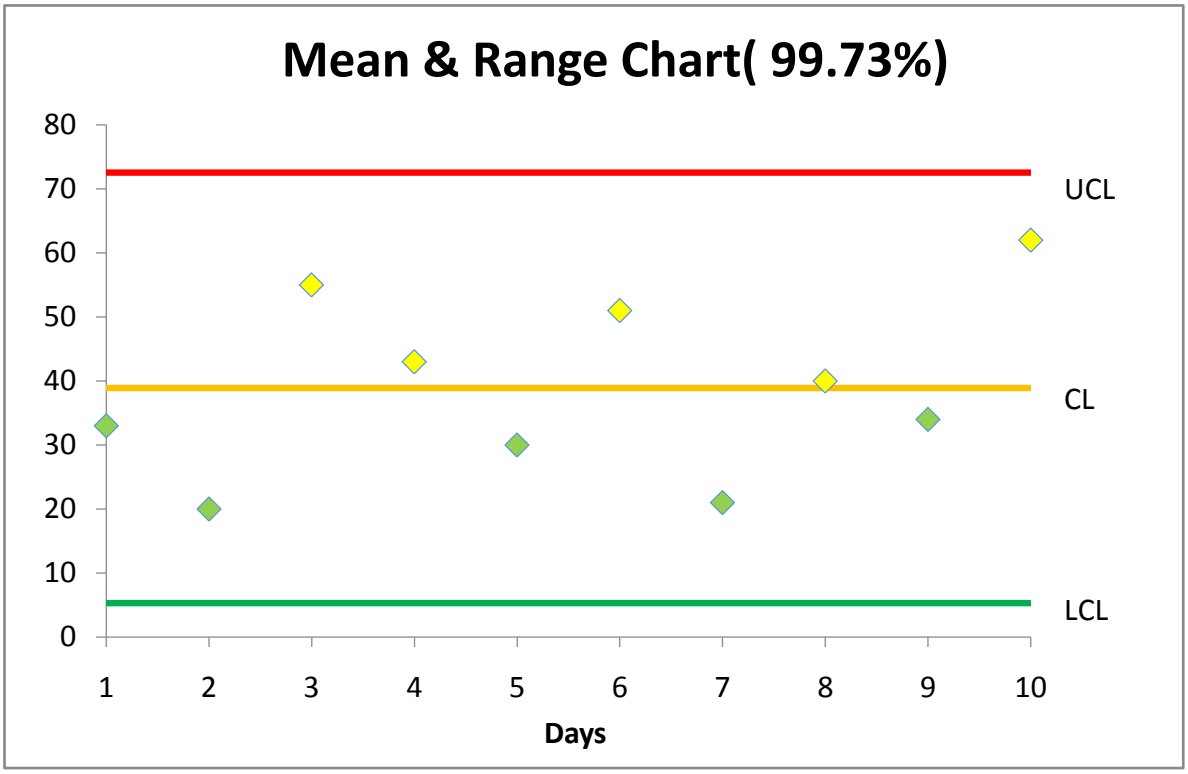



**FIG.1.5: T.A.T of Initial Assessment in Emergency Department**

From the above graph, it was observed that, no "special cause" was found in context of initial assessment in emergency department within the duration of 10 days. However, observation of 3, 4, 6, 8 and 10$^{th}$march 2016 was found beyond average.

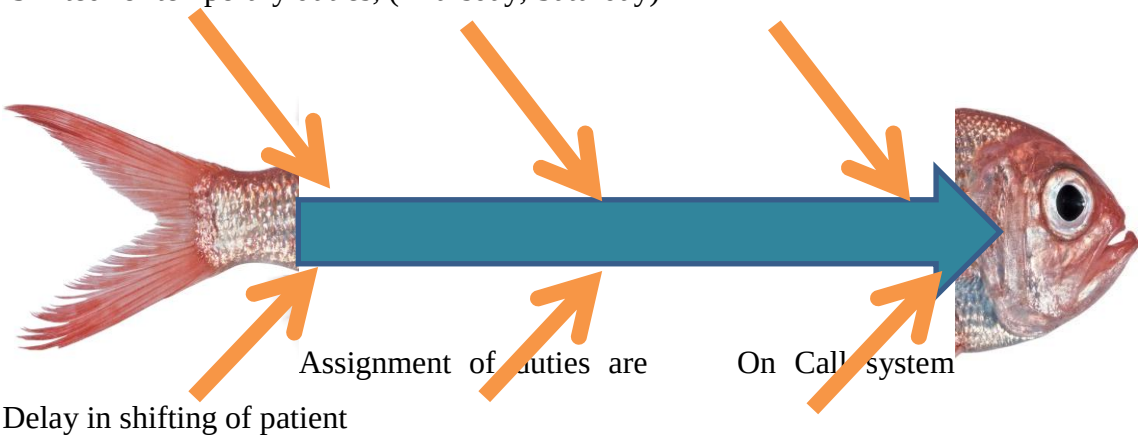
There were 5 days out of 10days in which initial assessment to patient was given below the average time.it was observed that on Thursdays and Saturday initial assessment was not done timely.

Thus, no special causes are found appropriate measures and bring the processes under control. So, as common causes are present, it must find the cause of the problem and then eliminate it from ever coming back.

Further causes was analysed through fish bone diagramme-

C.P.R.S. System used less patient inflow so staff

Shifted for temporary duties, (Thursday, Saturday)



Assignment of duties are On Call system

Delay in shifting of patient

From ambulance/wheelchair to bed

Not assigned is not effective

**FIG.1.6:Fish Bone Diagram for p- chart**

**1.13 Conclusion:**

SPC is both a data analysis method and a process management philosophy, with important implications on the use of data for improvement in various clinical and administrative processes, thus ensuring improved standards of healthcare.

SPC can also help clinicians as well as to patients also to understand and improve patients' health when applied directly to health indicators such as on blood sugar concentrations in diabetes. Control Charts can also be used to:

- To control ongoing processes by finding and correcting problems as they occur.
- To predict the expected range of outcomes from a process.
- To determine whether a process is stable.
- To analyses patterns of process variation from special causes or common causes.
- To determine whether quality improvement project should aim to prevent specific problem, should aim on common causes or to make fundamental changes to the process. Control charts have found their applicability in various areas such as hospital performance infection rates, rates of patient falls, waiting times of various sorts, rates over time in a medical context, such as mortality

rates, rates of disease ,bio –vigilance such as patient identification and non-infectious hazards of transfusion, surveillance of infectious diseases ,lab turnaround, patient satisfaction scores, medication errors, emergency service response times, post-operative lengths of stay, "door-to-needle" times, counts of adverse events and many others. Thus, they act as phenomenal tool in providing an effective method to visualize data over a specific monitoring period while considering for boundary conditions and helps to check if the corrective action has resulted in an improved process.

**1.14 Limitations of the Study**

This study was done for 3 sigma limits.

**1.15 Recommendations**

- There should be separate accommodation for T.P.A. and cash patients so that dietary difference cannot be visible.
- Movement of truth should be used in explaining proper breakup of charges.
- Internees of DMLT should be invited, so that they can help technicians in accessary work such as attending phone calls, starting control in equipments.
- Emergency staff should have given responsibilities which are limited to the department only.
- Department wise monthly reward should be given to team, in which hospital acquired infection is minimum

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4:476–520

13.Monitoring Hospital Safety Climate Using Control Charts of Non-harm Events in Reporting Systems by *Susan Robinson* (2014)

## 2: Annexures

### 2.1:VAP Audit Checklist

VAP Audit Checklist

| Pt.Name | SSN | AGE | Gender | IPID | Department | Admission Date | Care Provider | Ventilator Procedure Order Date | Culture Order Date | Culture Result Date | Organism |
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## 2.2Cauti Audit Checklist

## Cauti Audit Checklist

| Patient Name | SSN | AGE | Gender | IPID | Department | Admission Date | Care Provider | Catheter Order Date | Culture Order Date | Culture Result Date | Organism |
|---|---|---|---|---|---|---|---|---|---|---|---|
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## 2.3:**CLBSI Audit Checklist**

CLBSI Audit Checklist

| Patient Name | SSN | AGE | Gender | IP ID | Dep. | Admission Date | Care Provider | Central Line Procedure Name | Central Line Procedure Order Date | Culture Order Date | Culture Result | Organism |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
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2.4: Patient Satisfaction in O.P.D.

Patient Satisfaction in O.P.D.
Month:

| Patient Name | Max I.D. | Patient Age | Gender | Over All Feedback | Patient Satisfaction Level |
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2.5: Initial Assessment in Emergency Department

Initial Assessment in Emergency Department

| Date | Patient SSN No. | Care Provider | Time Difference |
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