The Journal of Emergency Medicine, Vol. 48, No. 5, pp. 628–638, 2015

0736-4679/$ - see front matter

http://dx.doi.org/10.1016/j.jemermed.2014.12.019

Administration of Emergency Medicine

STATISTICAL PROCESS CONTROL: SEPARATING SIGNAL FROM NOISE IN EMERGENCY DEPARTMENT OPERATIONS

Laura Pimentel, MD[*,†] and Fermin Barrueto Jr., MD[†,‡]

*University of Maryland Emergency Medicine Network, †Department of Emergency Medicine, University of Maryland School of Medicine, Baltimore, Maryland, and ‡Department of Emergency Medicine, Upper Chesapeake Health Systems, Bel Air, Maryland

Reprint Address: Laura Pimentel, MD, Department of Emergency Medicine, University of Maryland School of Medicine, 110 South Paca Street, 6th Floor, Suite 200, Baltimore, MD 21201

☐ **Abstract—Background: Statistical process control (SPC) is a visually appealing and statistically rigorous methodology very suitable to the analysis of emergency department (ED) operations. Objective: We demonstrate that the control chart is the primary tool of SPC; it is constructed by plotting data measuring the key quality indicators of operational processes in rationally ordered subgroups such as units of time. Control limits are calculated using formulas reflecting the variation in the data points from one another and from the mean. SPC allows managers to determine whether operational processes are controlled and predictable. We review why the moving range chart is most appropriate for use in the complex ED milieu, how to apply SPC to ED operations, and how to determine when performance improvement is needed. Discussion: SPC is an excellent tool for operational analysis and quality improvement for these reasons: 1) control charts make large data sets intuitively coherent by integrating statistical and visual descriptions; 2) SPC provides analysis of process stability and capability rather than simple comparison with a benchmark; 3) SPC allows distinction between special cause variation (signal), indicating an unstable process requiring action, and common cause variation (noise), reflecting a stable process; and 4) SPC keeps the focus of quality improvement on process rather than individual performance. Conclusion: Because data have no meaning apart from their context, and every process generates information that can be used to improve it, we contend that SPC should be seriously considered for driving quality improvement in emergency medicine. © 2015 Elsevier Inc.**

☐ **Keywords—statistical process control; control chart; quality improvement; special cause variation; common cause variation; emergency department quality improvement**

INTRODUCTION

The Patient Protection and Affordable Care Act calls for "a national quality strategy," including the development of measures of several dimensions of health care quality. Defining quality and designing the environment in which it can be achieved are more elusive than the goal. In the statistical world, a landmark text began with this quote: "In September 1960, a new definition of World-Class Quality was quietly introduced … 'On Target with Minimum Variance.'" Wheeler and Chambers, the authors of *Understanding Statistical Process Control*, explain why statistical process control (SPC) is an excellent tool for studying and improving processes from which performance data can be measured accurately (1). SPC can be easily incorporated into the assessment and improvement of quantifiable and measurable emergency department (ED) operational processes. The results of using this powerful tool might greatly enhance quality improvement in emergency medicine.

SPC is a rigorous methodology for analyzing a process over time by measuring its key indicators; the individual data points are considered in the context of their dispersion

RECEIVED: 6 September 2013; FINAL SUBMISSION RECEIVED: 10 October 2014;
ACCEPTED: 21 December 2014

Table 1. SPC Definitions

Binomial distribution	Frequency distribution in which only two mutually exclusive outcomes are possible, such as "left before treatment was complete" or "completed treatment." The key difference between a binomial distribution and normal distribution is that a binomial distribution is discrete, not continuous. There are no values between any two data points in a binomial distribution.
Capable process	A process meeting the optimal or desirable level of performance.
Common cause variation	Fluctuation caused by factors intrinsic to a process resulting in steady but random distribution of values around the mean of the data (the noise).
Control chart	A graphically displayed statistical tool used in quality control to analyze and understand process variables and determine process capabilities. Control charts include upper and lower control limits and analyze metrics over time to determine whether processes are in control (exhibiting only common cause variation) or out of control (exhibiting special cause variation).
Control chart types	
c Chart	A count chart used for counted data in which the underlying values follow a Poisson distribution.
p Chart	A proportion chart used for binary data reflected as a percentage in which the underlying data follows a binomial distribution.
XmR Chart	A moving range chart used for evaluation of measured data requiring no specific underlying distribution. Control limits are calculated based on point-to-point data variation. XmR charts consist of an individual values chart and a moving range chart.
Lower control limit	The limit below which individual data points represent special cause variation or three standard deviations below the mean.
Poisson distribution	Discrete random variable distribution that expresses probabilities concerning the number of events per unit time. Unlike normal distribution, it is not symmetrical but instead is skewed to the left of the median.
Rationally ordered subgroup	Metrics produced under the same set of conditions. Rational subgroups represent a snapshot of the process. They reflect how data are collected (monthly for example), and represent the inherent common cause variation in the process at a given time.
Run chart	A quality control graph that displays observed process metrics on the vertical access and the times they were observed on the horizontal access. Run charts are used to determine whether the long-run trend of a process is changing.
Special cause variation	An external variation that triggers an essential change in a defined process (the signal).
Type 1 error	Attributing common cause variation to special cause variation, thus predisposing a stable process to tampering.
Type 2 error	Failing to attribute special cause variation where it exists. This allows a process to destabilize without analyzing and stabilizing.
Upper control limit	The limit above which individual data points represent special cause variation or three standard deviations above the mean.

SPC = statistical process control.

from the mean and variation from one another. Think of a histogram placed on its side and plotted over time. Process analysis is performed by plotting control limits on each side of the mean and studying the patterns of the data according to validated rules. More than this, SPC is a philosophy with the core concept of learning through data. It incorporates process thinking, analytic study, prediction, and the analysis of stability and capability through which one can achieve true continuous improvement (2). The control chart is the premier tool of SPC; it allows intuitive and visually appealing real-time understanding of any quantifiable process with a measurable outcome. Given the marked increase in data availability with the proliferation of electronic medical records, emergency physicians and directors are in need of readily available analytics to capitalize on this wealth of information. Our contention is that SPC capably meets this need.

DISCUSSION

The Control Chart

A control chart (Table 1) is a graph of a process on which statistical analytical tools are programmed (Figure 1). When evaluating an outcome measure such as door-to-physician time, the variable in question is plotted graphically against a unit of time. The optimal number of data points or subgroups for a statistically strong analysis is 20 to 30 (1). Control lines representing standard deviations of dispersion of the moving range among the data points are calculated and delineated on the graph. The upper control limit and lower control limit (Table 1) represent three standard deviations above and below the mean, respectively. The work of the control chart is to determine whether the process is in control and thus predictable, or out of control and therefore, unpredictable. A controlled process is predictable because it will continue to perform within the control limits until affected by an external force. In a controlled process, the variation in data points represents common cause variation (Table 1), referring to the normal daily variation (noise) in any measured process. With respect to door-to-physician time with a median value of 30 min, common cause variation is reflected in normal intrinsic process variations. One month, the median might be 32 min and the next, 27 min, even though no meaningful external factors changed or affected the process. If that process is achieving the