COMMENTARY

The Natural Order of Time: The Power of Statistical Process Control in Quality Improvement Reporting

David P. Johnson, MD,[a,b] Barron L. Patterson, MD[b,c]

In this month's issue of *Hospital Pediatrics*, Kicker et al[1] shared their experience with a quality improvement (QI) project focused on the elimination of waste: unused propofol after pediatric sedations. After standardizing propofol preparation and ordering, the authors demonstrated a reduction in propofol waste per sedation from a median of 45.6 mL to 14.3 mL. This 68% reduction decreased institutional waste of propofol by an estimated 12.5 L per year. The authors shared steps that can be generalized not just to reduce propofol waste specifically but also to illustrate a methodology that we can use to reduce other medical resource waste, including laboratory overuse,[2,3] chest films in asthma,[4] and bronchodilator and steroid use in bronchiolitis.[5] We feel compelled to emphasize the power of this methodology; specifically, statistical process control (SPC) charts can be used tell QI stories better than traditional statistics, bar charts, or other methods can do alone.

What if improvement teams could recognize improvement in a day or week instead of a year? Or identify in real time when outside factors are perturbing their systems? Or predict future performance? In fact, they can. Once understood, SPC allows improvement teams to learn from data in real time, identify variation in data at multiple time points, determine quickly if planned interventions are working, note when nonrandom changes occur, and even (if data are stable) predict future results.[6] Here we highlight these points from Kicker et al's[1] work to demonstrate how SPC is used to provide superior information for QI when compared with traditional statistics, tables, or pre- and postbar charts.

Reporting only traditional statistics, either in simple numerical form or in tables, can be difficult to digest and may lead readers of QI projects to draw incorrect conclusions based on the data presented.[6] Measures of central tendency (mean or median) with an indication of variation (SD or interquartile range) are easily recognized by journal readers, but these may not provide a full understanding of the system being studied and improved. For example, in this study, if the authors had not used SPC, the reader would not have been able to determine how exactly the intervention was temporally related to the change in propofol waste: Was a change in their process already occurring before the intervention? Was there an aberrant peak in waste early in their process that artificially inflated their preintervention data? Was there a new provider who single-handedly lowered the waste who started just before or after the intervention? Imagine that the initial sedation in the baseline data had the highest waste and that the waste was slowly reduced incrementally over time because of other factors. One could

www.hospitalpediatrics.org
DOI:https://doi.org/10.1542/hpeds.2018-0127

Address correspondence to David P. Johnson, MD, Monroe Carell Jr. Children's Hospital at Vanderbilt, 2200 Children's Way, Suite 8020, Nashville, TN 37232. E-mail: david.p.johnson.1@vumc.org

HOSPITAL PEDIATRICS (ISSN Numbers: Print, 2154-1663; Online, 2154-1671).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: No external funding.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

Drs Johnson and Patterson drafted, revised, and approved the final manuscript as submitted.

[a]Divisions of Hospital Medicine and [c]Academic General Pediatrics, [b]Department of Pediatrics, School of Medicine, Vanderbilt University, Nashville, Tennessee

then imagine a linear, downward trend, resulting in the medians reported but without any indication that the intervention itself resulted in the difference. In such a situation, pre- and poststatistics would lead to an incorrect conclusion about the effectiveness of the intervention. Additionally, when QI teams rely on traditional statistics, there is often a desire to wait in the postintervention period to have a large enough sample size to determine if there is a statistical difference resulting from the intervention. Because the goal of improvement teams is to learn from data in an iterative fashion to make rapid improvements,[7] this watchful waiting strategy is unnecessary and contrary to the core tenets of QI. SPC charts can be used to detect change more quickly.

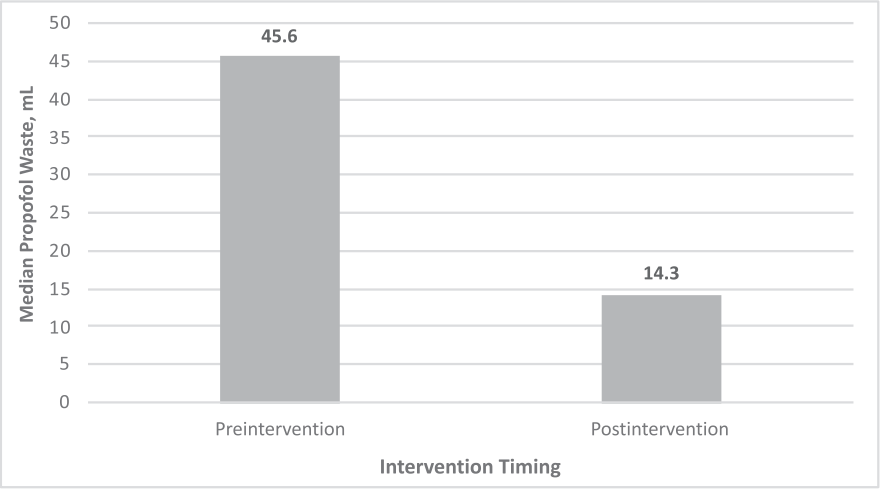

FIGURE 1 Hypothetical bar graph depiction of the difference in waste based on the medians reported in Kicker et al's[1] article.

In medical literature, tables are frequently used to provide large amounts of data that can be overwhelming, incompletely absorbed, and potentially misleading. William Playfair, a Scottish political economist, noted as early as 1786 that visual depictions were superior to tables:

> *Information, that is imperfectly acquired, is generally imperfectly retained; and a man who has investigated a printed table, finds, when done, that he has only a very faint and partial idea of what he has read; and that like a figure imprinted on sand, is soon totally erased and defaced.*[8]

Playfair goes on to state that visual depictions of data leave a more lasting and comprehensible impression.[8] We agree, but for QI, not all visual depictions are equal. One way to present the data in this project may have been a pre- and postbar chart in which we compare propofol waste before and after the intervention (Fig 1). Although this method provides a striking depiction of the magnitude of propofol waste reduction, similar to the numerical reporting of central tendencies, it does little to increase the viewers' degree of belief that the intervention itself resulted in the changes observed.

Improvement teams should follow the value and variation of measurements over time. For this reason, the most informative way to tell an improvement story is to display data over time.[6,7] Edward Tufte[9] describes the strength of time series in *The Visual Display of Quantitative Information*: "With one dimension marching along to the regular rhythm of seconds, minutes, hours, days, weeks, months, years, centuries, or millennia, the natural ordering of the time scale gives this design a strength and efficiency of interpretation found in no other graphic arrangement." In the 1920s, Walter Shewhart[10] built on the strengths of time series data displays, creating mathematically robust statistical theories and methods to visually depict data and detect nonrandom change over time based on data patterns. Shewhart's[10] theories undergird what we now refer to as SPC. These methods were championed by Shewhart's colleague W. Edwards Deming,[11,12] who is revered by many as the "grandfather" of QI. For Deming, SPC became integral to understanding variation (a core tenet in his theory of profound knowledge)[11] and improving outcomes in manufacturing.[12]

Although certain industries rapidly adopted SPC to drive improvement, health care has been slow to accept these powerful analytical tools. Despite calls on the medical community to embrace Shewhart's methods as early as the 1990s,[13] in our opinion, medical education of improvement science in general, and SPC in particular, remains lacking. Moreover, many peer-reviewed journals remain skeptical about the use of SPC in reporting findings. However, the proper use of SPC allows improvement teams to analyze data in real time and recognize when variation is expected (common cause variation) and when there appears to be an outside force acting on the system (special cause variation). By using SPC and understanding the types of variation in a system, improvement teams are given immediate feedback about the effectiveness of their interventions, and they can also detect other factors affecting their systems.[6,7,10,13,14] Additionally, to paraphrase Deming,[11] understanding variation also prevents teams from tampering: that is, acting unnecessarily on variation that should be expected (common cause). Conversely, it helps teams recognize and learn from data points that are statistically aberrant (special cause) within their systems.[11]

With these points in mind, let's examine how the authors' use of an analytical approach with SPC charts better facilitated sharing their improvement story than the enumerative approaches often taught as the "gold standard" in medicine.[15] SPC allows the reader (and the improvement team) to identify variation between any 2 points in time. This is an advantage over the potential simple reporting of a pre- and postmedian

with interquartile range. We are also able to see that they had a stable system before the intervention with all data within the control limits. By providing multiple data points over time, the reader and the team can see that there was perhaps something nonrandom happening in the system before the time of the actual intervention. Notice the multiple consecutive data points below the mean line in Fig 2 of Kicker et al's[1] article. This pattern is an example of special cause variation and indicates a change in the system before the main intervention, which the authors discuss in the results. This allowed them to identify reasons why this change may have occurred before the intervention. Furthermore, SPC charts quickly reveal that the mean waste was lower in the postintervention period, eliminating the need for the team to wait for a large enough sample size to see if results were improving. A simple comparison of means or a pre- and postbar chart would never have provided the team or the reader with the ability to learn from this important, time-sensitive information. Finally, by looking at the SPC chart, we can predict with fair certainty that the next child sedated in the unit will have waste within the process capability, which, for an individuals and moving range chart, consists of the bounds of the control limits.[6] Indeed, for all future sedations with propofol, waste should be expected to fall between 0 mL and 37 mL. Any waste >37 mL would reveal special cause variation, which would warrant investigation. These predictions would not have been possible using a more traditional approach to data analysis.

Kicker et al[1] should be commended for their use of SPC to report their team's propofol waste reduction QI initiative. Readers can learn from the interventions they incorporated to reduce waste and improve value, but we should also not miss the opportunity to learn from the methods of analyzing and reporting their data. We believe that authors in and improvers of health care should use SPC charts more broadly to detect, discern, and disseminate improvement.

REFERENCES

1. Kicker J, Heather H, Matheson C. Better pairing propofol volume with procedural sedation needs: a propofol waste reduction quality improvement project. *Hosp Pediatr*. 2018;8(10): e20180010
2. Johnson DP, Lind C, Parker SE, et al. Toward high-value care: a quality improvement initiative to reduce unnecessary repeat complete blood counts and basic metabolic panels on a Pediatric Hospitalist service. *Hosp Pediatr*. 2016;6(1):1–8
3. Tchou MJ, Tang Girdwood S, Wormser B, et al. Reducing electrolyte testing in hospitalized children by using quality improvement methods. *Pediatrics*. 2018; 141(5):e20173187
4. Watnick CS, Arnold DH, Latuska R, O'Connor M, Johnson DP. Successful chest radiograph reduction by using quality improvement methodology for children with asthma. *Pediatrics*. 2018; e20174003
5. Mussman GM, Lossius M, Wasif F, et al. Multisite emergency department inpatient collaborative to reduce unnecessary bronchiolitis care. *Pediatrics*. 2018;141(2):e20170830
6. Provost LP, Murray SK. *The Health Care Data Guide: Learning From Data for Improvement*. 1st ed. San Francisco, CA: Jossey-Bass; 2011
7. Langley GJ. *The Improvement Guide: A Practical Approach to Enhancing Organizational Performance*. 2nd ed. San Francisco, CA: Jossey-Bass; 2009
8. Playfair W, Corry J. *The Commercial and Political Atlas: Representing, by Means of Stained Copper-Plate Charts, the Exports, Imports, and General Trade of England; The National Debt*. London, United Kingdom: Printed for J. Debrett; 1786
9. Tufte ER. *The Visual Display of Quantitative Information*. 2nd ed. Cheshire, CT: Graphics Press; 2001
10. Shewhart WA. *Economic Control of Quality of Manufactured Product*. Milwaukee, WI: American Society for Quality Control; 1980
11. Deming WE. *The New Economics: For Industry, Government, Education*. 2nd ed. Cambridge, MA: MIT Press; 2000
12. Deming WE. *Out of the Crisis*. 1st ed. Cambridge, MA: MIT Press; 2000
13. Berwick DM. Controlling variation in health care: a consultation from Walter Shewhart. *Med Care*. 1991;29(12): 1212–1225
14. Wheeler DJ. *Understanding Variation: The Key to Managing Chaos*. 2nd ed. Knoxville, TN: SPC Press; 2000
15. Provost LP. Analytical studies: a framework for quality improvement design and analysis. *BMJ Qual Saf*. 2011; 20(suppl 1):i92–i96

The Natural Order of Time: The Power of Statistical Process Control in Quality Improvement Reporting

David P. Johnson and Barron L. Patterson

Hospital Pediatrics 2018;8;660
DOI: 10.1542/hpeds.2018-0127 originally published online September 11, 2018;

The Natural Order of Time: The Power of Statistical Process Control in Quality Improvement Reporting

David P. Johnson and Barron L. Patterson

Hospital Pediatrics 2018;8;660
DOI: 10.1542/hpeds.2018-0127 originally published online September 11, 2018;