Optimizing Patient Care Processes in a Children's Hospital Using Six Sigma

Mayer Sagy, MD

Abstract

- *Objective:* To describe a children's hospital experience with applying Six Sigma methodology to improve clinical processes.
- *Methods:* Three projects are described. The first project sought to reduce the time from order to insertion of peripherally inserted central catheters (PICCs), the second sought to reduce the length of stay of patients requiring tracheostomy and gastrostomy tube placements prior to transfer to rehabilitation facilities, and the third sought to reduce medication order defects.
- *Results:* Implemented process changes resulted in a significant and progressive improvement in the mean time to PICC placement, which was reduced from 3.7 ± 2.7 days to 2.42 ± 1.6 days after 1 month and to 1.7 ± 1.2 days at 1 year. While we created a more efficient process that led to a shorter pediatric intensive care stay, we did not see a reduced time to transfer to rehabilitation facilities. At baseline, the mean number of defects per medication order was 2.1; this was improved to 1.4 at 1 month and 0.3 at 1 year.
- *Conclusion:* Clinical process analysis using Six Sigma methodology can significantly reduce defects as well as address quality aims established by the Institute of Medicine.

Six Sigma is a quality improvement method being utilized by health care systems as part of quality improvement programs [1–3]. The Six Sigma approach, with its roots in industrial manufacturing, entails an analysis of processes aimed at reducing variances, increasing efficiency and customer satisfaction, and ultimately reducing the incidence of errors or defects [4–6]. The Six Sigma method requires completion of 5 phases [7], in which a presumed problem is defined (Define phase), the critical factors for quality (or lack of) are measured (Measure phase), data are analyzed to find the root causes of the problem (Analyze phase), changes are implemented to create an improved process (Improve phase), and the project is finalized by demonstrating that an improved outcome is achieved and sustained (Control phase).

Schneider Children's Hospital is a pediatric tertiary care facility in New Hyde Park, NY. The hospital appointed a certified Six Sigma Black Belt medical officer (the author) to identify quality improvement projects that could be best handled by Six Sigma methodology. Such quality problems, once identified, are presented to the Children's Hospital Performance Improvement Coordinating Group and sponsored as Six Sigma projects by hospital administration. This paper reports on 3 projects.

Methods and Main Results

Each project was assigned a team comprising 1 to 2 physicians (1 physician was the project leader or "black belt") and 2 to 4 registered nurses (project team members, or "green belts"). Each project was allotted 6 months from start to completion. The projects were conducted under the supervision of North Shore–Long Island Jewish Health System's Center of Learning and Innovation. The Center provides broad-spectrum educational initiatives to clinical and non-clinical employees of the health system. These include, but are not limited to, Six Sigma quality projects, medical simulation training, courses in various computer programs, and workshops in utilization of administrative tools and statistics.

Data were tabulated in a program that enabled graphic presentations and statistical analyses (Minitab, State College, PA). Continuous data for all projects were first tested for normal distribution followed by analysis of process capability. These data were subsequently analyzed by analysis of variance, t tests, and regression analysis as deemed appropriate. For discrete data or data that failed to demonstrate normal distribution, the chi square and/or the Mood's median tests were employed. We defined an improved process to be "in control" when measurements of individual values did not fall outside the range of a mean ± 3 standard deviations. A

From the North Shore-Long Island Jewish Health System, Schneider Children's Hospital, New Hyde Park, NY.

$P \leq 0.05$ denoted statistical significance. The projects entailed retrospective review of patient data and were approved by the institutional review board in an exempt category.

Project 1—Delayed PICC Insertion

Patients requiring prolonged intravenous (IV) antibiotic treatment at home need peripherally inserted central catheters (PICCs) before they can be discharged. We reviewed the medical records of the 61 patients who had received PICC during the period 2001–2003. We found that the mean number of days that elapsed between the date of the attending physician's first entry note in the chart indicating the need for a prolonged course (> 14 days) of IV antibiotics at home to the time of PICC insertion was 3.7 ± 2.7 days. We had determined that the upper specification limit or acceptable performance limit was 3 days. Process analysis revealed that the required consultation from an interventional radiology specialist was contributing to delay in PICC insertion.

We changed the process by mandating that all consults for PICC insertion be first handled by the division of pediatric critical care medicine. Only if PICC failed to be inserted by a critical care physician would the consult be referred to the division of interventional radiology. This change resulted in a significant and progressive improvement in the mean time to PICC placement, which was reduced to 2.42 ± 1.6 days with 36% defects after 1 month (based on review of 19 patients) and further reduced to 1.7 ± 1.2 days with only 15% defects at 1 year (based on review of 97 patients; $P < 0.05$).

Project 2—Delayed Transfer to Rehabilitation Facilities

Acutely ill patients who become technology dependent customarily undergo a prolonged process of stabilization before they can be transferred to rehabilitation facilities. They often must undergo 2 procedures: tracheostomy cannula insertion for airway management and gastrostomy tube placement for nutrition, with subsequent recovery time. We sought to reduce hospital length of stay for these patients.

We reviewed the medical records of the 33 patients admitted to the PICU with acute respiratory failure who subsequently required tracheostomy and gastrostomy tubes during the 5-year period 2000 to 2005. All of the patients were chronically technology-dependent and required transfer to rehabilitation facilities. We found that the mean number of days from the attending physician's first entry note in the chart indicating the need to perform tracheostomy and gastrostomy to the time to transfer to a rehabilitation facility was 56 ± 30 days. We had determined that the upper specification limit was 40 days. Analysis suggested that efficiency could be enhanced by performing the 2 needed procedures (tracheostomy and gastrostomy) on the same day with 1 recovery period for both, as opposed to 2 sequential procedures with 2 separate recovery periods.

After implementing this process change, the mean time from physician's note to transfer to a rehabilitation facility was 36 ± 39 days with 46% defects at 1 month (based on review of 7 patients) and 44 ± 29 days with 54% defects at 1 year (based on review of 16 patients; P = NS).

Project 3—Medication Order Errors

There is a high incidence of defects in medication orders completed by residents. For the analysis phase, we examined the medication order forms completed by residents during a 2-week period in October 2006 and counted order writing defects. The following were considered to be defects: (1) no mention of allergies, (2) no demographic data (addressograph) stamped, (3) illegible handwriting, (4) no mention of dose per kg, (5) no accurate dose per kg prescribed as per Lexi-Comp (Lexi-Comp, Hudson, OH) (10% deviation permitted), (6) no accurate calculation of a dose to be administered as per current patient weight (10% deviation permitted), (7) trailing zero(s) (eg, 5.0), (8) leading decimal (eg, 0.5), (9) abbreviations, unless in compliance with the hospital's approved list of abbreviations, (10) no mention of route of administration (eg, IV, intramuscular, by mouth), (11) no mention of frequency of administration (eg, every 8 hours), (12) no physician's signature and stamp indicating full name and medical license number.

The average number of defects per order was 2.1 (533 defects in 256 orders). To improve the order writing process, we implemented an educational program. Residents, nurses, and unit clerks receive education and training in proper medication order writing twice per year. Following training, the average number of defects per order was 1.4 (567 defects in 398 orders) at 1 month (in May 2007) and 0.3 (38 defects in 140 orders) at 1 year (September–October 2007; $P < 0.05$).

Discussion

Schneider Children's Hospital is employing various strategies for improving clinical, operational, and administrative outcomes. The 3 projects described in this report featured the use of Six Sigma methodology to optimize clinical practice and resource utilization. We identified gaps in quality of care and implemented changes to reduce them. Projects 1 and 2 revealed initial sigma levels of 1.4 and 1.0, suggesting potentially unacceptable delays in care. By implementing and sustaining improved processes, these levels increased to 2.5 ($P < 0.05$) and 1.3 (P = NS), respectively. In project 3 the initial defects-to-order ratio of

2.1 was reduced to 0.3 ($P < 0.05$) through improved processes and is expected to lead to a lower incidence of medication errors.

Improving patient care processes can improve patient and parent satisfaction, enhance a hospital's reputation, and promote its growth and prosperity. In its *Crossing the Quality Chasm* report, the Institute of Medicine (IOM) identified 6 aims for improvement in health care [8]. The ideal health care system, they said, should provide patient care that is safe, effective, patient-centered, timely, efficient, and equitable. The process changes that we implemented utilizing Six Sigma methodology support many of these quality aims [9] (**Table**). Projects 1 and 2 were predicated on time measurement. Project 1 sought to reduce the time from order to insertion of PICC to decrease length of stay and facilitate discharge to home. Most obviously, this project addressed timeliness and efficiency; in addition, as PICC is the required catheter for safe delivery of IV medications at home, effectiveness and safety also were addressed. Project 2 sought to reduce the time to transfer to rehabilitation facilities in patients who were technology dependent. While we created a more efficient process that led to a shorter PICU stay, we did not see a reduced time to transfer. In project 3, the goal was to reduce the number of defects in medication order writing, thereby improving timeliness and efficiency of medication delivery and reducing potential harm to patients (safety).

The Six Sigma method requires completion of 5 phases of problem evaluation and process improvement. It is possible that improving a process by changing a specific factor assumed to be critical to quality may not yield the desired improvement. In project 2, the end result was disappointing, as no significant reduction in hospital length of stay prior to transfer to a rehabilitation facility was demonstrated. In retrospect, the timely performance of tracheostomy and gastrostomy tube placement is probably not critical to the quality for the evaluated process. We postulate that other factors may be impediments to transferring patients to rehabilitation facilities, such as delayed insurance provider approval, lack of family readiness for patient relocation, and clinical deterioration that may occur prior to the scheduled transfer of the patient and mandates its postponement.

Table. Institute of Medicine (IOM) Aims Addressed by Six Sigma Projects

Project	IOM Aims Addressed
Reduce time from order to insertion of peripherally inserted central catheter (PICC)	Timeliness: timely PICC insertion Efficiency: shorter length of stay Effectiveness: PICC is the required catheter for home management Patient-centeredness: patients prefer to be at home Safety: PICC is a safe mode for intravenous treatment at home
Reduce time to transfer to rehabilitation facility for patients receiving tracheostomy cannula and gastrostomy tube	Timeliness: timely stabilization and referral Efficiency: shorter length of stay in the pediatric intensive care unit Effectiveness: the procedures are needed for rehabilitation Patient-centeredness: patients require rehabilitation Safety: the use of a tracheostomy cannula for airway management and a gastrostomy tube for nutrition is the safest approach
Reduce the incidence of medication order defects	Timeliness: less time is spent on rewriting, corrections, and clarifications Safety: potential harm to the patient is reduced Efficiency: the desired medication is properly delivered

Summary

Six Sigma has been widely used to improve quality of processes in health care systems. However, pure clinical quality issues have not been widely evaluated by this methodology, as most clinical decisions involve clinical judgment and are hard to quantify. IOM quality aims can be assessed by measurable factors. Measuring response or turnaround time or counting events or defects in a given clinical process can be a useful approach in evaluating the level of adherence to IOM aims. Future additional work with Six Sigma for improving clinical quality is required before it is fully validated as a reliable method for this purpose.

Corresponding author: Mayer Sagy, MD, North Shore-Longsland Jewish Health System, Schneider Children's Hospital, 269-01 76th Ave., New Hyde Park, NY 11042, msagy@lij.edu.

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