Using Six Sigma® Methodology to Improve Handoff Communication in High-Risk Patients

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Abstract

Background: During the analyses of adverse events, a commonly described risk factor is the sharing of patient information. **Objective:** The objective for this project was to better understand and improve the postoperative handoff process for children with heart disease. **Methods:** The existing handoff process was evaluated and improved using Six Sigma® methodology and medical simulation training. Time-based metrics were compared before and after implementing performance improvement initiatives. **Results:** 29 pre- and 142 post-intervention handoff events were studied. Initiatives resulted in a reduced handoff turnaround time (15.3 min to 9.6 min; $P < 0.001$) and time to obtaining critical laboratory studies (13.0 min to 2.4 min; $P < 0.001$); an increase in chest radiographs completed (60 percent vs. 94 percent; $P < 0.01$) and percent of patients placed on cardio-respiratory monitoring (86 percent vs. 99 percent; $P < 0.01$) within unit standards. **Conclusion:** In children undergoing surgical intervention, performance improvement principles can improve the handoff process and decrease the delay of time-sensitive therapies.

Introduction

Medical errors have been recognized as a relatively common and potentially avoidable cause of patient harm. In its landmark report, *To Err is Human: Building a Safer Health System*, the Institute of Medicine (IOM) estimated that up to 98,000 deaths occur each year because of preventable medical errors. Higher rates were observed in intensive care units (ICU), operating rooms, and emergency departments.[1] In contrast to the past model of individual responsibility, the IOM report's authors concluded that errors are more frequently "caused by faulty systems, processes, and conditions that lead people to make mistakes." Although an individual clinician might be the proximal cause of an adverse event, organizational factors can create the circumstances in which a failure of judgment occurs.

This organization-based approach to improving health care delivery echoes the model utilized in other safety-critical industries, such as aviation, nuclear power, and the military. These high-reliability organizations view increasing safety as a systems-based endeavor.[2, 3, 4, 5] To this end, attempts have been made to apply the manufacturing industry's Six Sigma® methodology and the automotive industry's Toyota Production System to medicine.[6, 7, 8, 9, 10] Regardless of the specific approach, the fundamental concept is the same: a system is viewed as a set of interdependent elements acting together toward a common goal.[11]

The focus on the process of health care delivery, in addition to the individuals who provide it, involves understanding each step used in a particular activity. By "mapping" the process, two important aspects of health care delivery have recently been brought to light: uncertainty about how a health care provider's task should be performed and the way the activities of many individuals are coordinated.[10] The frequent bedside solution is to treat the immediate problem but not to analyze the underlying obstacles that prevented optimal performance. This temporary fix is commonly referred to as a "workaround."[9, 10]

During the analyses of adverse events, a commonly described contributing factor is the sharing of patient information among health care providers.[12] An association between these communication failures and preventable medical errors has been suggested in all health care settings.[12, 13] Furthermore, the transfer of patient information between health care providers—the "handoff"—has been recognized as a risk factor for adverse events.[14, 15]

Communication among health care providers is particularly important in high-intensity, high-stress environments that demonstrate a greater incidence of medical error, such as the intensive care unit.[1, 16] In this setting, patients may be more susceptible to human error due to the severity of their illness and the need for more frequent intervention.[17, 18]

One such vulnerable patient population comprises children with heart disease. These patients are at increased risk for adverse events because of the complexity of their diagnosis and clinical instability, especially following a surgical intervention. Commonly, the management of such patients requires multiple disciplines—such as pediatric cardiothoracic surgery, cardiology, critical care, and anesthesiology—to coordinate decisions. Research suggests that communication failures frequently occur during the operative procedure, with "minor" events leading to serious consequences.[19, 20] As a result, a delay in communicating critical patient information could lead to deterioration in a child's clinical status.

Despite recognizing that communication failures can significantly affect clinical outcomes, limited data exist on how providers caring for critically ill children exchange patient information.

The overall objective of the current study was to apply performance improvement concepts to the handoff process in order to better understand and improve the way a pediatric critical care team communicates critical information for children with heart disease. We hypothesized that: (1) communication errors commonly occur during the postoperative handoff process, and (2) standardizing this process would decrease the time to obtain important diagnostic information. Specifically, standardization would reduce the time from patient arrival to completing handoff communication (turnaround time); reduce time to obtaining vital laboratory results (lab draw time); increase the percent of chest radiographs (CXR) taken within 15 minutes of patient arrival (unit standard); and increase the percent of patients placed on bedside cardiorespiratory (CR) monitoring within 3 minutes (unit standard).

Methods

Six Sigma Methodology

In order to better understand the process of handoff communication in the pediatric ICU (PICU), we utilized the Six Sigma methodology framework. This performance improvement philosophy began in the industrial sector and has gradually spread to other non-manufacturing industries. It is a data-driven approach that is focused on improving system capabilities and decreasing process variability. Often compared to the scientific method, this approach consists of the following five steps that are commonly abbreviated as “DMAIC”: Define, Measure, Analyze, Improve, and Control.[8, 21]

The “Define” phase consists of identifying integral elements of a process, such as the individuals involved and the steps deemed “critical to quality.” For example, during the first phase of this study, a multidisciplinary focus group created a list of 18 handoff elements considered essential to providing postoperative patient care.

The “Measure” phase focuses on understanding the current process. The aim of this stage is to determine the system’s capability within the existing organizational structure. In health care, this step often involves identifying drivers of patient outcomes, such as error rates. This stage also provides a baseline performance standard against which future changes can be measured.

Once the baseline performance is defined, the “Analyze” phase pinpoints areas of high variability and identifies potential causes. In this step, process flow diagrams may demonstrate areas of greatest process inconsistency or lack of role clarity that require more immediate intervention.

Through an iterative process, the “Improvement” phase centers on creating solutions to decrease the variability of a process and to bridge critical gaps in the current system. Changes may be large in scope or limited in size. More importantly, the solution to a problem is most effective when individuals actually performing the specified tasks are engaged in creating it. In health care, this creation should involve bedside providers, such as nursing staff.

Once a more robust process is achieved, the “Control” phase emphasizes efforts that sustain these improvements. In addition to ensuring continued success, this step also involves monitoring for new problems created by system changes. In health care, for example, this may involve new methods to detect medication errors.

Study Site and Population

The methodology for the first phase of this study—the “Define,” “Measure,” and “Analyze” steps of Six Sigma methodology—has been described in detail elsewhere.[22]

The second phase of this study—the “Improve” and “Control” steps of Six Sigma methodology—took place at a free-standing, tertiary care children’s hospital with a 20-bed PICU that cares for patients of all subspecialties, including those requiring extracorporeal life support. Of the approximately 1,200 children admitted per year, 25 percent of these patients have undergone surgical intervention for cardiac defects.

The study population for this second phase consisted of anesthesia, surgery, and PICU providers caring for children with heart disease following a surgical procedure.

Outcomes

Handoff process. The process of verbally communicating patient information between health care providers during the transfer of care is commonly referred to as a “handoff” and was the key process studied. Specifically, we focused on the handoff that occurs when a patient is admitted to the PICU following surgery for acquired or congenital heart disease.

The admission handoff process is critical for the following several reasons: (1) patients are often clinically unstable during the admission period and may require urgent therapies; (2) PICU staff often have limited knowledge of the patient’s medical history and, as a result, utilize this handoff process as a key source of information; (3) time to review the medical record prior to critical interventions is frequently limited; and (4) patients often require coordination of management decisions made by providers in multiple disciplines.

Data collection and outcomes. A clinically trained research assistant directly observed 29 pre-intervention and 142 post-intervention postoperative handoff events for children who had undergone surgery for congenital or acquired heart disease. Measured clinical metrics included: time from patient arrival to handoff completion (turnaround time), time to obtaining vital laboratory studies (lab draw time), the percent of chest radiographs (CXR) taken within 15 minutes of patient arrival (unit standard), and the percent of patients placed on bedside cardiorespiratory (CR) monitoring within 3 minutes (unit standard).

Statistical Analysis

The central focus of our data analysis was to determine the effect of a standardized handoff process on the aforementioned clinical metrics. A control chart was used to analyze process variation (including common cause and special cause variation) and to compare outcomes before and after intervention. All data analyses were performed with JMP® statistical software (SAS Institute, Cary, NC).

Approval by the Institutional Review Board at the Duke University School of Medicine was obtained prior to conducting this study.

Results

As identified in Phase 1 of this study—the “Define,” “Measure,” and “Analyze” steps of the Six Sigma framework—communication errors frequently occurred during the postoperative handoff communication process (mean 5.6; median 5.0 errors per handoff event). These most commonly involved information pertaining to a patient’s medical history or current surgical intervention (87 percent of communication errors). Furthermore, the handoff process was found to be negatively affected by the following three factors: (1) clinicians involved in a patient’s recent care did not consistently participate; (2) the handoff content and method were poorly standardized; and (3) interruptions or distractions were frequently present during handoff events.

Because of this initial evaluation, the “Improvement” step focused on a standardizing the communication process. This standardization centered on establishing a team handoff model and modifying the environment in which the handoffs occurred.

Team Handoff Model

As previously identified, clinicians involved in a patient’s recent care often do not contribute to the sharing of critical data during the handoff process. To address this communication gap, a team approach was created. This model required all relevant members of the care team—specifically, at least one representative from the pediatric cardiothoracic surgery, anesthesia, and critical care services, as well as the primary and unit charge nurses—to be present during the handoff process.

To further improve the role clarity of each provider during the handoff process, two additional process steps were outlined. First, to avoid competing clinical demands from distracting providers during the verbal report, each patient care discipline identified urgent tasks that needed to be completed prior to the verbal handoff process. For example, the patient’s primary nurse had to first review all currently infusing intravenous medications before listening to the patient report.

Second, to improve understanding of a patient’s current clinical status and expected trajectory, the verbal handoff event was divided into specialty-specific sections. For example, the cardiothoracic surgery team reviewed the patient’s history and current surgical procedure first; the anesthesiology team reviewed the anesthetic course second; and the critical care team asked clarifying questions third.

To educate the multidisciplinary health care providers caring for children’s heart disease in structured communication techniques, the staff underwent “team training” through the TeamSTEPPS™ curriculum. This program, developed by the Agency for Healthcare Research and Quality (AHRQ) in collaboration with the Department of Defense, is an evidence-based curriculum focused on improving patient outcomes by developing communication and other teamwork skills among health care professionals.[23]

Work Environment

To minimize interruptions and distractions during the handoff process, we adapted a concept championed by the aviation industry—the “sterile cockpit.” In response to the increasing number of commercial airline accidents involving the cockpit crew’s attention being diverted from more critical tasks, the Federal Aviation Administration enacted regulations to prohibit crew members from performing nonessential duties or activities (including conversation) while the aircraft is involved in the phases of flight most commonly associated with error: taxi, takeoff, and landing.[24]

Interpreting this concept for clinical medicine, the sterile cockpit was employed during the verbal transfer of patient information. Specifically, only patient-specific conversation or urgent clinical interruptions occurred during the sign-out process. As in the aviation industry, the integrity of this environment is the responsibility of all providers at the bedside, not just the reporting staff.

The aforementioned performance improvement interventions resulted in a reduction of turnaround time (15.3 min to 9.6 min; *P* <0.001) and lab draw time (13.0 min to 2.4 min; *P* <0.001); an increase in chest radiographs completed (60 percent vs. 94 percent; *P* <0.01); and percent of patients placed on bedside cardiorespiratory monitoring (86 percent vs. 99 percent; *P* <0.01) within unit standards. (Figures 1 and 2)

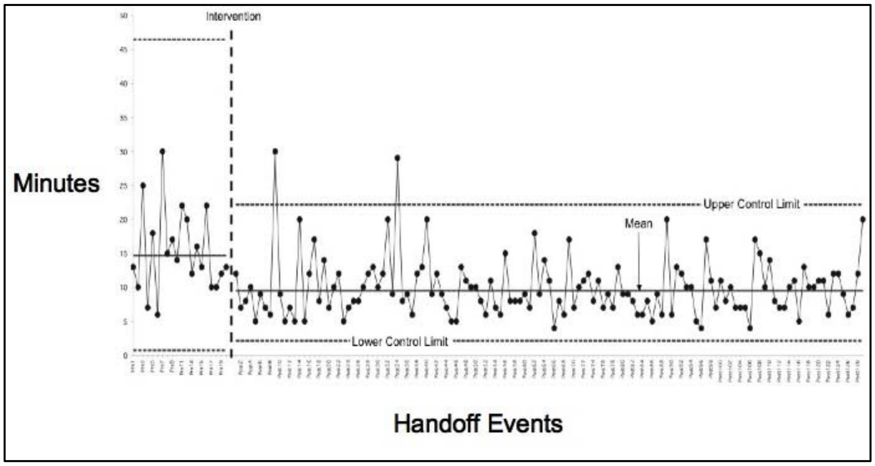

Figure 1. Handoff turnaround time.

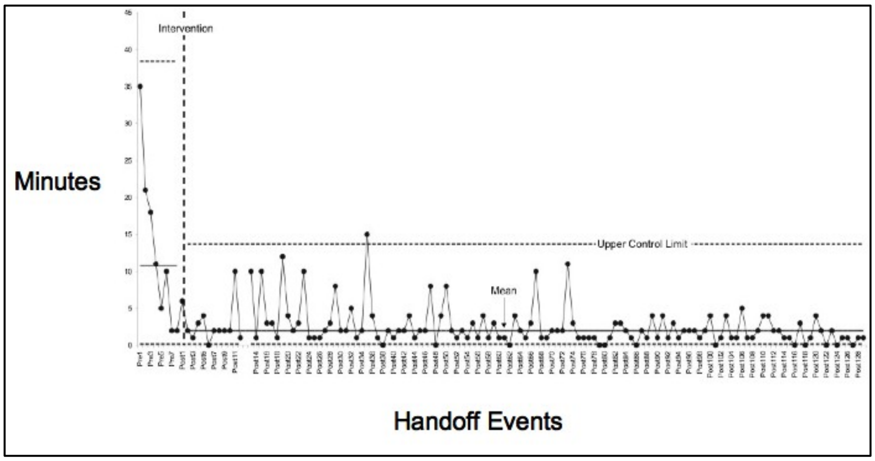

Figure 2. Time to critical lab draw.

Discussion

To better understand and improve the handoff communication process in the critical care setting, we applied the Six Sigma methodology framework to current clinical practice.

In the “Define,” Measure,” and “Analyze” steps of the process, several important contributing factors for communication error were demonstrated:

- Clinicians involved in a patient’s recent care did not consistently participate in the communication process.
- The handoff process was poorly standardized.
- Interruptions or distractions were frequently present during handoff events.

Furthermore, our results revealed that communication errors most often involved information about the medical history and current surgical intervention.

In the “Improve” and “Control” steps, we demonstrated that standardizing the handoff process reduced the time necessary to obtain clinically important diagnostic information—specifically, handoff communication time; reduced time to obtaining critical laboratory studies; and increased the percentage of chest radiographs completed and the percentage of patients placed on bedside cardiorespiratory monitoring to within unit standards.

In delivery of time-sensitive therapies, our structured team approach to communication also may have contributed to more effective team performance. As evident in other high-reliability organizations, team training concepts—such as teamwork, communication techniques, flattening of hierarchy, mutual respect within and across disciplines and situational awareness—are key components of a culture of safety. Furthermore, improving coordination of care through a structured communication process is especially important in environments in which uncertainty, interruptions, and multitasking are commonplace, such as the critical care setting. This coordination of care helps to create a "shared mental model" of a patient's status and the expected clinical trajectory. As a result, any deviation from the anticipated postoperative course is more readily identified.

Future Directions

In addition to the two handoff communication aspects considered "critical to quality" in this study, minimizing disruption and the team handoff model, a third factor remains undefined: standardizing the sign-out content to ensure that each member of the team similarly understands the salient clinical data.

Communication checklist. Addressing the content of handoff communication involves principles of cognitive psychology. To facilitate an individual's comprehension of what is communicated, information must be organized in a form that the recipient is prepared to mentally process. This realization has led many high-reliability organizations to utilize structured communication techniques, such as checklists and "read-back" techniques.[5, 25, 26]

The use of a checklist as a memory aid serves two purposes: First, it ensures that critical information necessary for patient care is not overlooked; and second, it provides a consistent order in which information should be communicated. However, a checklist's content and design must be prudent and strategic.

Although a checklist can enhance memory, longer lists may negatively influence their function. When the checklist is lengthy, there is a tendency to perform other tasks while reading the checklist in an effort to overcome a time-consuming procedure.[27]

Furthermore, errors in the use of aviation checklists most often occurred when crews were nearing the end of the workday or rushing to make a scheduled departure time. During these latter periods, the checklist was either done from memory or was initiated but never completed.[28] The similarity between the cockpit setting and other high-stress clinical environments, such as the ICU, suggests a need to employ human factors engineering and crew resource management tools when implementing checklists.

Medical simulation. Although checklists may improve the consistency of handoff content, they may not directly address the question of whether all members of the health care team understand a patient's current clinical status or expected trajectory. To this end, the use of human patient simulators has previously been employed to assess a team's situation awareness. The concept refers to a person's understanding of a continually changing environment, such as the ICU, and is associated with the availability of relevant information and an individual's expertise.[29]

Situation awareness may be divided into the following three levels: (1) perceiving elements in an environment, (2) comprehending the current situation, and (3) anticipating future status.[29] Furthermore, the principles of situation awareness can be applied to team environments, such as the critical care setting, and can be integral to the "Control" phase of the Six Sigma framework

Outcomes. The efficacy of system-based interventions can be assessed by process measures, outcome measures, and balancing measures.

Process measures refer to how the system components function. Composite measures assess whether each step in the process is being performed as planned, whereas "all-or-nothing" measures evaluate how often a patient receives the intended care when all process steps are completed. In our handoff communication process, for example, a composite measure may include how often the sterile cockpit environment is present. Although these measures reflect how well providers consistently perform the process, they do not provide information regarding patient-specific outcomes.

Outcome measures refer to the results of an intervention—i.e., metrics that are important to the patient. In our study of handoff communication, we used the time to obtain diagnostic information as a surrogate for outcome measures. However, it is not possible to conclude a direct cause-and-effect relationship, since many factors—such as duration of mechanical ventilation, length of stay in the PICU, and mortality rates—affect global measures.

Balancing measures refer to changes in the system, intended and unintended, following an intervention. Understanding these metrics requires individuals to avoid applying theories or models of safety to health care without first understanding the existing health care environment. Not doing so could result in the reasons for success or failure of an intervention remaining unclear. As growing evidence suggests, success in one environment does not necessarily predict success in another.[30] For the described structured handoff process, these measures include staff satisfaction and surrogates of productivity, such as patient flow.

Limitations

Despite the increasing complexity of patients with congenital heart disease cared for at our institution, the last several years have seen a gradual decline in mortality (Figure 3). The impetus for this decrease is most probably multifactorial, in which performance improvement efforts may have played a significant role. However, without the detection of adverse events, it is not possible to

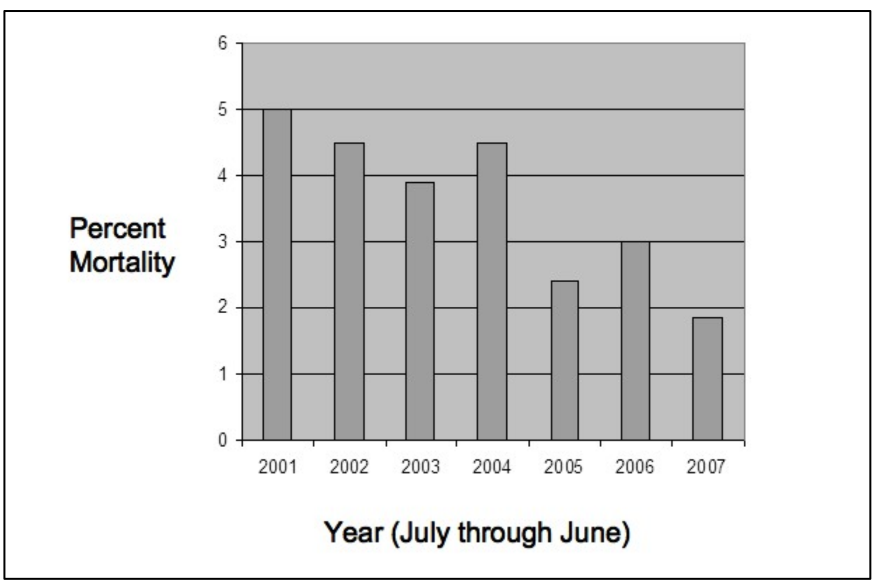

Figure 3. Congenital heart disease operative mortality.

know which handoff communication errors are clinically relevant. Since adverse events are often the result of a series of system failures, a direct causal relationship between miscommunication and an unintended outcome is often not practical.[31, 32, 33] Communication errors, however, can be considered a gap that, when addressed, may help prevent accidents from occurring.

Conclusion

We found that communication delays commonly occurred during the handoff process of patients being transferred from the operating room to the intensive care unit. The solution to these gaps in communication was probably not based on a single approach but, rather, was due to the combination of performance improvement principles, information technology, human factors methodology, crew resource management/team training, and cognitive psychology.[5, 34, 35, 36, 37, 38, 39]

The results of this study not only add to the growing literature demonstrating the prevalence of communication failures, but also provide insight into how process improvement concepts from other high-reliability organizations can be applied successfully to health care. Given the success of this initiative in the pediatric ICU, we have since expanded the project to focus on handoffs between other inpatient units—for example, between the PICU and noncritical care units. Furthermore, the study's findings suggest solutions to meet national health care mandates regarding communication, such as the National Quality Forum's *Safe Practices for Better Healthcare* recommendations to facilitate "information transfer and clear communication" among health care providers, and the Joint Commission's *National Patient Safety Goals* requirement to standardize an approach to handoff communication.[40, 41]

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