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Improving Hospital Discharge Time

A successful Implementation of Six Sigma Methodology

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Abstract: Delays in discharging patients can impact hospital and emergency department (ED) throughput. The discharge process is complex and involves setting specific challenges that limit generalizability of solutions.

The aim of this study was to assess the effectiveness of using Six Sigma methods to improve the patient discharge process.

This is a quantitative pre and post-intervention study.

Three hundred and eighty-six bed tertiary care hospital.

A series of Six Sigma driven interventions over a 10-month period.

The primary outcome was discharge time (time from discharge order to patient leaving the room). Secondary outcome measures included percent of patients whose discharge order was written before noon, percent of patients leaving the room by noon, hospital length of stay (LOS), and LOS of admitted ED patients.

Discharge time decreased by 22.7% from 2.2 hours during the preintervention period to 1.7 hours post-intervention ($P < 0.001$). A greater proportion of patients left their room before noon in the postintervention period ($P < 0.001$), though there was no statistical difference in before noon discharge. Hospital LOS dropped from 3.4 to 3.1 days postintervention ($P < 0.001$). ED mean LOS of patients admitted to the hospital was significantly lower in the postintervention period (6.9 ± 7.8 vs 5.9 ± 7.7 hours; $P < 0.001$).

Six Sigma methodology can be an effective change management tool to improve discharge time. The focus of institutions aspiring to tackle delays in the discharge process should be on adopting the core principles of Six Sigma rather than specific interventions that may be institution-specific.

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Abbreviations: AUB = American University of Beirut, AUBMC = American University of Beirut Medical Center, CI = confidence interval, DMAIC = define, measure, analyze, improve and control, ED = emergency department, ESI = Emergency Severity Index, LOS = length of stay, SPSS = Statistical Software for Social Sciences, TJC = The Joint Commission.

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INTRODUCTION

Pressures to cut cost have led many health care organizations to adopt strategies for reducing patient length of stay (LOS) and improving hospital throughput over the past 3 decades. In the United States, the introduction of the prospective payment system by Medicare in 1983, whereby hospital reimbursement moved from a per-diem basis to a flat payment related to diagnosis, was instrumental in driving down LOS, as was the emergence of managed care organizations that looked closely at hospital utilization.[1] As a result, average LOS for inpatients in the United States has dropped to around 5.2 days, from its peak of 7.3 days in the 1980s and will likely continue to feel similar pressures with the implementation of the Affordable Care Act.[2] Similar trends in decreased LOS of inpatients have been observed in other countries including the UK, Australia, and Sweden.[3]

Cost-effectiveness has not been the sole driver of improved hospital throughput. Concerns about quality and safety, particularly of emergency department (ED) patients impacted by lack of access to inpatient beds, have led Joint Commission to implement a leadership standard that hospitals should ''manage the flow of patients throughout the hospital'' (LD 04.03.11).[4] Boarding inpatients in the ED has become a global problem contributing to over-crowdedness and has been linked to deleterious patient care outcomes as well as adversely impacted ED efficiency metrics.[5–10] LOS of emergency patients is impacted by multiple factors including the efficiency of the discharging inpatients from the hospital as well as the timing of inpatient discharges.[11]

To improve access to beds, The Joint Commission (TJC) has stipulated that hospitals: have processes in place that support patient flow throughout the hospital; measure available supply of beds and efficiency of patient care areas; report measurements to leadership; and use data to drive improvements in patient flow processes.[4] TJC has also recently started urging hospitals to use specific quality improvement tools to develop more reliable processes, including Lean and Six Sigma.[12] The latter is an industrial management methodology for data-driven process improvement that is increasingly being applied in healthcare.[13–17] The objective of this study was to assess the effectiveness of using Six Sigma method to improve the patient discharge process at a tertiary teaching university hospital in a developing country.

METHODS

Study Design and Setting

The American University of Beirut Medical Center (AUBMC) is a tertiary care teaching hospital with 386 beds located in Beirut, Lebanon. It is accredited by The Joint Commission International. AUBMC provides care to around 35,000 inpatients annually. This was a quantitative pre, post-intervention study of the impact of introducing a series of Six Sigma-driven interventions on hospital discharge time focusing exclusively on the discharge process. Five months of preintervention data (August 2012–December 2012) were compared with 5 months of postintervention (November 2013–March of 2014). The study was approved by the AUBMC hospital administration in accordance with the quality assurance policy and deemed exempt from human subject research by the institutional review board of AUB.

Intervention

The Hospital Throughput Project was conducted at AUBMC from August 2012 until October 2013 with ongoing key performance metrics monitoring, following a process improvement framework developed using Six Sigma principles. Six Sigma relies on a structured approach to uncover the root cause of a problem using the Define, Measure, Analyze, Improve and Control (DMAIC) method by: defining the problem; measuring the defect; analyzing the causes; improving the process by removing major causes; and controlling the process to ensure defects do not recur. A multidisciplinary team was formed at the outset and included a physician sponsor, chief medical resident, director of bed management, manager of billing, patient care unit manager, charge nurses, unit clerk representative, director of environmental services, assistant director of health information management, and manager of the transport services. A hospital administrator was the assigned Six Sigma expert responsible for team building and project management.

Following the DMAIC approach, the team set out to define the scope of the project and decided to focus on improving the administrative processes that contributed to delays in discharging patients. Mapping the steps from when the order is written to the patient leaving the room demonstrated a fragmented process with providers functioning in silos and relying on patients to alert staff to initiate the next step. The team redesigned the process to a single-piece flow that included electronically entered time stamps for each step that reflected the status of the discharge process to all the stakeholders and sent alerts to managers when delays beyond a set threshold occurred. Target discharge time was set at 105 minutes, approximately 20% reduction from baseline historical data that was around 130 minutes.

Once measurement of key process step times was ensured through the introduction of electronic time stamps, the team, through extensive discussions, completed a root cause analysis for delayed discharge and outlined barriers, waste, and proposed changes from the perspective of each stakeholder (Table 1). Interventions were sequentially tested through pilots on a few floors before full implementation across all hospital regular inpatient floors. Intensive care and intermediate care units were excluded as most patients on these units do not proceed through the routine discharge process but rather undergo transfer to a regular unit before discharge from the hospital.

Measurements

Two sets of data were structured for the purpose of addressing the objective of the study. The first dataset was for the hospital inpatients ''hospital analyses,'' which included 8494 patients in the preintervention phase and 8560 patients in the postintervention phase. The primary outcome of these analyses was discharge time, whereas the secondary outcomes were percent patients discharged before noon, percent orders written before noon, and hospital LOS. Hospital LOS was calculated in days by subtracting the discharge date from admission date. Before noon and after noon discharges were assigned according to the time during the day the discharge was completed. Specifically, ''before noon'' was between 12 AM and 12 PM, whereas ''after noon'' was between 12 PM and 12 AM.

The second dataset was for ED patients admitted to the hospital ''ED analyses,'' which included 2901 patients in the preintervention period and 3169 in the postintervention period. The primary outcome of these analyses was LOS. LOS of ED patients was calculated from ED registration time to ED discharge time.

Statistical Analysis

For both hospital and ED analyses, descriptive statistics were carried out, wherein categorical variables were summarized by number and percent, whereas continuous variables were summarized by mean and standard deviation. Assessing the association between the interventions (pre vs post) was carried out using the Student *t* test for continuous variables, whereas the Pearson Chi Square test was used for categorical ones.

Multivariate analysis was carried out to identify the association between the interventions and the outcomes, while controlling for the potentially confounding effect of the different factors. More specifically, multiple linear regression analysis using a backward selection procedure, with significance level for removal from the model set at 0.1, was conducted to examine the relationship between outcomes (discharge time and LOS) and various potential predictors mainly the effect of the intervention. All determinants that are statistically and clinically significant were included into the regression analysis. Multicollinearity was assessed by carrying out correlation analysis to identify explanatory variables, which were highly correlated with each other. The Statistical Software for Social Sciences (SPSS version 21) was used to carry out these analyses. The level of statistical significance was set at the 0.05 level.

Individual control chart was used to analyze trends in average daily discharge time, special cause variations (nonroutine events), and common cause variations (routine events), and assess the process for stability (statistical control). To further assess variation in the process, the following were also measured: six sigma scores (number of short-term standard deviations between the center of a process and the closest specification limit); yield (percentage of discharge times meeting team goal of 105 minutes); defects per million (number of times that discharge time exceeded the target, per million discharge opportunities).

RESULTS

For the hospital analyses, 38,495 patients were admitted to the hospital during the study period. After excluding admissions from units where the intervention was not implemented (3060), admissions during the intervention period from January 1, 2013 to October 31, 2013 (17860) and negative discharge times due to errors in the data entry (521), a total of 17054 admitted patients were analyzed. Table 2 presents the distribution of the different variables collected in the study for the whole sample, as well as by the intervention period (pre and post- intervention). There was a significant difference in age between the two periods (45.0 years preintervention and 46.4 postintervention, $P < 0.001$). The monthly rate of occupancy also was found to be higher in the postintervention period (68.9%, SD = 16.0%) as compared to the preintervention period (66.6%, SD = 13.1%) ($P < 0.001$). There was a statistically significant reduction in hospital LOS in the postintervention (3.1 days, SD = 4.2) versus the preintervention period (3.4 days, SD = 5.2) ($P < 0.001$). Similarly, there was a significant drop in discharge time

TABLE 1. Barrier, Waste, and Change from the Perspective of Different Stakeholders

Obstacles, Wastes, and Changes	Patient	Billing Officer	Patient Access Staff	Floor Clerk	RN	Attending Physician
Obstacles	Care providers unavailable; inconsistent communications from care providers; patient-driven discharge planning	Billing staff unavailable; unclear about the discharge load for the day; multiple calls to service staff to post charges; multiple calls to admission staffs to obtain financial coverage	No advance communication on planned discharges; no ability to determine need for additional financial clearance in advance	No clear defined role of the unit floor clerk. Unable to follow-up on requests from all stakeholders because s/he is unavailable most of the time hand delivering urgent requests	No defined care pathway, No discharge plan, discharge order written pending attending physician approval	Lab results not available, RN not available, discharge pending diagnostics services
Waste (misuse and overuse)	Waiting for care providers, waiting for services to post charges, waiting for discharge order to be written, waiting for the physician to sign the medical report for billing, waiting for the cashier to call for bill settlement	Waiting for physicians and service staff to post charges; waiting for insurance carriers to financially clear patient	Delay in communication between the patient and the insurance carriers; delay in communication between the admitting officer and patients related to transfers	Waiting for RN to give instructions to discharge patients; waiting for service request orders to post patient charges; waiting for billing to generate bills; waiting for cashier to call patients; waiting for patient to leave to log the discharge	Process variation results in fragmented care; waiting for medical staffs to write patients requests, waiting for floor clerk to deliver medication requests, waiting for pharmacy to bring medications before patient discharge	Waiting for Diagnostic Services (Lab and Radiology); rework in documentation to collect charges, rounding on patients before the medical results available leading to fragmented care and rework
Modifications and interventions	E-form request created to manage timely needed medical report for financial clearance. Created electronic pending charges report to facilitate charging. Increase transport team rounds to attend to patients needs timely	Created electronic pending charges report to facilitate updating charging; introduced ''Possible Discharge'' flag to prioritize needed documents for discharge	Introduced E-form to manage timely needed financial clearance between the insurance carriers and the admitting staffs; introduce E-form to manage all transfers	Enhanced the billing system to streamline and facilitate the clerk duty; revised clerk job description; introduced alerts at each phase of the discharge process and established 30-minute thresholds for each step. Added email alerts at each 30-minute delay addressed to the corresponding managers	Introduce the scanning of medication requests to reduce hand delivery by clerk and improve availability at nursing station. Increase transport round to every hour until 20:00 for medication transport	Added an additional phlebotomy round at 9:00 am

TABLE 1. (Continued)

Obstacles, Wastes, and Changes	Patient	Billing Officer	Patient Access Staff	Floor Clerk	RN	Attending Physician
						Executive support for discharge when medical criteria met. Introduced "Possible Discharge" flag to prioritize diagnostics service provision

RN = registered nurse.

($P < 0.001$), wherein the discharge time was 2.2 (SD = 1.8) and 1.7 hours (SD = 1.6) for the preintervention and postintervention periods, respectively. The percentage of before-noon discharge order was less frequent in the postintervention period (44.6%) as compared with the preintervention period (46.6%) ($P = 0.008$). However, the percentage of the before-noon discharge was larger in the postintervention period (20.7%) as compared with the preintervention period (15.9%), ($P < 0.001$). Sex, payment method, and admission hours are not statistically associated with the pre and postintervention period.

After controlling for possible confounding variables including monthly occupancy, admission hours, unit specialty, guarantor group, and weekday/weekend, we found that the discharge time decreased by 0.47 hour (confidence interval [CI]: −0.52, −0.41; $P < 0.0001$) in the postintervention as compared with the preintervention phase (Table 3). The evening and night admission hours were predictors for a longer discharge time, where the discharge time increased by 0.15 hours (95% CI: 0.09–0.21, $P < 0.001$) in the evening hours and 0.22 hours (95% CI: 0.14–0.30, $P < 0.001$), compared with the day hours, while controlling for the intervention.

For ED analyses, a total of 6077 patients were analyzed with 2901 in the preintervention phase and 3169 in the postintervention phase (Table 2). The mean LOS was found to be significantly lower in the postintervention than in the preintervention phase (6.9 ± 7.8 vs 5.9 ± 7.7, $P < 0.001$).

The multiple linear regression revealed that the LOS decreased by 0.979 hours (CI: −1.405, −0.554; $P < 0.001$) in the postintervention as compared with the preintervention phase when controlling for monthly hospital occupancy, age, Emergency Severity Index (ESI), and guarantor group (Table 3). Moreover, age and monthly hospital occupancy were found to be risk factors for a longer LOS in the ED.

Six Sigma score ranged in the preintervention phase between 1.37 and 1.55 with a process yield of around 45% in August of 2012, when over 55% of the patients exceeded the target discharge time of 105 minutes. After the intervention, the process Sigma ranged between 1.84 and 1.91 with a process yield ranging between 63% and 67% denoting a drop in defects with only 37% to 33% of patients exceeding the target discharge time of 105 minutes (Table 4). The individual control chart upper control limit postintervention dropped from 139.2 to 107.3 minutes (Figure 1). During the intervention phase, a mixture pattern is observed denoting an unstable process with one out of control point. In the postintervention phase, no special cause variations are observed, denoting a stable process.

DISCUSSION

Delays in discharging inpatients can cause bottlenecks in-hospital operations and impact admissions from the ED, the operating room, and the general admitting unit. The process of discharging patients is complex requiring the coordination of multiple different groups including physicians, nurses, ancillary service staff, patients, their families, and in some settings the finance/billing department.[18,19] Complex processes, in which variability tends to be high, lend themselves well to Six Sigma tools that focus on reducing defects and variations.[20] Our study demonstrated that Six Sigma methodology can be effective in improving discharge time of patients at a tertiary care hospital in a developing country where finalization of patient billing and account settlement are completed at patient discharge.

Although some of the evidence for effectiveness of Six Sigma in the healthcare setting has been criticized for weak

TABLE 2. Association Between all the Variables and the Pre and Postintervention for Hospital and ED Analyses

	Variable	Preintervention, N (%)	Postintervention, N (%)	*P*
	Total sample	N = 8494	N = 8560	
Hospital data	Age, y, mean (±SD)	45.0 (±25.9)	46.4 (±25.7)	<0.001
	Sex			
	Male	4147 (48.8%)	4141 (48.4%)	0.56
	Female	4347 (51.2%)	4419 (51.6%)	
	Payment Method			
	Self-payer	1749 (20.6%)	1707 (19.9%)	0.24
	Private insurance	4989 (58.7%)	5136 (60.0%)	
	Other	1756 (20.7%)	1717 (20.1%)	
	Admission hours			
	Day	4961 (58.4%)	5148 (60.1%)	0.06
	Evening	2424 (28.5%)	2366 (27.6%)	
	Night	1109 (13.1%)	1046 (12.2%)	
	Monthly rate of occupancy (%), mean (±SD)	66.6% (±13.1%)	68.9% (±16.0%)	<0.001
	Hospital LOS, days, mean (±SD)	3.4 (±5.2)	3.1 (±4.2)	<0.001
	Discharge time, hours, mean (±SD)	2.2 (±1.8)	1.7 (±1.6)	<0.001
	Before-noon discharge order			
	Before Noon	3957 (46.6%)	3815 (44.6%)	0.008
	Afternoon	4537 (53.4%)	4745 (55.4%)	
	Before-noon discharge			
	Before noon	1354 (15.9%)	1772 (20.7%)	<0.001
	Afternoon	7140 (84.1%)	6788 (79.3%)	
ED data	Total sample	Pre (2901)	Post (3169)	
	Age, y, mean (±SD)	50.9 ± 26.9	51.9 ± 27.1	0.168
	Sex			
	Male	1603 (55.3%)	1662 (52.4%)	0.028
	Female	1298 (44.7%)	1507 (47.6%)	
	Payment method			
	Self-payer	1015 (35.0%)	925 (29.2%)	<0.001
	Private insurance	1765 (60.8%)	2056 (64.9%)	
	Other	121 (4.2%)	188 (5.9%)	
	ESI			
	1 and 2	474 (16.3%)	231 (7.3%)	<0.001
	3	2197 (75.7%)	2872 (90.6%)	
	4 and 5	230 (7.9%)	66 (2.1%)	
	Volume per day, mean (±SD)	126.9 (± 15.3)	131.1 (± 16.8)	<0.001
	LOS, hours, mean (±SD)	6.9 (± 7.8)	5.9 (± 7.7)	<0.001
	LOS for ESI = 1 and 2, hours, mean (±SD)	8.0 (± 12.3) (N = 474)	7.3 (± 8.9) (N = 231)	0.417
	LOS for ESI = 3, hours, mean (±SD)	6.8 (± 6.8) (N = 2197)	5.9 (± 7.6) (N = 2872)	<0.001
	LOS for ESI = 4 and 5, hours, mean (±SD)	5.6 (± 4.3) (N = 230)	4.5 (± 4.2) (N = 66)	0.080

ED = emergency department, ESI = Emergency Severity Index, LOS = length of stay.

methodological design,[20,21] our study included a large pre and postintervention analysis of a total of 17054 patient records. Single piece flow was used to achieve linkage between administrative steps in the discharge process and successfully reduce discharge time by 22.7%, from 2.2 to around 1.7 hours. In our review of the literature, other studies that looked at effectiveness of Six Sigma on improving discharge time based their conclusions on less robust methodology. A study at an Indian hospital where delays in billing at discharge were also found to hold up discharges reported successful use of Six Sigma methods to identify and implement administrative interventions that reduced discharge time from 247 to 195 minutes postintervention. This was based on a 2-month experience with no mention of total records included.[18] Allen et al used Six Sigma to improve discharge times by focusing on improving communication between nurses and physicians through the implementation of a standardized discharge form that led to a drop in discharge time from 3.3 to 2.8 hours. This was however based on an audit of only 27 discharged charts 1 year after the team charter.[22]

Evidence for use of Six Sigma in healthcare has also been criticized for lack of demonstrable sustainability.[20,21] In our study, improvements in discharge time were sustained for the duration of the postintervention phase, which began 10 months after project initiation. All measures of controlled processes, including Six Sigma, Yield and Defects Per Million Opportunities, improved in the postintervention period. Initial Six Sigma score reflected a process that was operating at one Sigma level, denoting significant variability. This reached 1.91 Sigma levels by December 2013 and remained high at 1.85 by March 2014. Control charting demonstrated a drop in upper control limit with no out of control points in the sustainment period. All

TABLE 3. Multivariate analysis for the predictors of the discharge time for the hospital data and the length of stay for the ED data

	Predictors	Unstandardized Beta	95% CI	P
Hospital analyses*	Intervention	−0.47	−0.52, −0.41	<0.001
	Monthly rate of occupancy	−0.004	−0.007, −0.002	0.001
	Admission hours			
	Days	Reference	Reference	Reference
	Evening (2 vs 1)	0.15	0.09, 0.21	<0.001
	Nights (3 vs 1)	0.22	0.14, 0.30	<0.001
	Specialty			
	Medicine	Reference	Reference	Reference
	Surgical (2 vs 1)	0.21	0.13, 0.30	<0.001
	Med surgical (3 vs 1)	0.10	0.03, 0.17	0.007
	OBGYN (4 vs 1)	0.33	0.22, 0.44	<0.001
	Ped and Neuro (5 vs 1)	0.43	0.33, 0.53	<0.001
ED data†	Intervention	−0.979	−1.405, −0.554	<0.001
	Monthly rate of occupancy	0.047	−0.001, 0.096	0.057
	Age	0.023	0.012, 0.034	<0.001
	ESI			
	1 and 2	Reference	Reference	Reference
	3 (2 vs 1)	−1.128	−1.744, −0.513	<0.001
	4 and 5 (3 vs 1)	−2.065	−3.118, −1.012	<0.001
	Payment method			
	Private insurance	Reference	Reference	Reference
	Self-payer (2 vs 1)	−1.353	−1.777, −0.930	<0.001
	Other (3 vs 1)	−2.178	−3.125, −1.232	<0.001
	Age* intervention	−0.023	−0.038, −0.009	0.002

CI = confidence interval, ED = emergency department, ESI = Emergency Severity Index, OBGYN = obstetrics and gynecology.
* Variables entered in the model are intervention, monthly rate of occupancy, guarantor group (insurance, other), age, admission hours (evening, nights, weekdays/weekends), specialty (surgical, medical-surgical, OBGYN, pediatric [ped] and Neurology [Neuro]).
† Variables entered in the model are intervention, monthly rate of occupancy, guarantor group, ESI, age, sex, volume per day.

TABLE 4. Summary of Sigma Process Results

	Mean Time From Discharge Order Logged Until Patient Leaves, min	Standard Deviation, min	Six Sigma Score	Yield	Defect Per Million Opportunities
Team goal	105	80	1.85	64	363,636
August 2012	139	95	1.37	45	549,920
September 2012	136	97	1.41	46.8	536,453
October 2012	126	90	1.52	50.8	492,348
November 2012	126	85	1.53	51	487,409
December 2012	126	87	1.55	52	478,434
January 2013	126	85	1.53	51	486,501
February 2013	118	76	1.59	54	464,688
March 2013	116	77	1.61	54	455,069
April 2013	112	77	1.70	58	420,366
May 2013	102	74	1.90	65	345,219
June 2013	102	74	1.90	65	345,733
July 2013	100	73	1.90	66	344,262
August 2013	107	83	1.85	64	364,909
September 2013	105	80	1.85	64	363,636
October 2013	104	79	1.88	65	352,076
November 2013	104	80	1.84	63	365,054
December 2013	100	79	1.91	67.0	334,997
January 2014	101	82	1.91	66	339,468
February 2014	101	79	1.91	66	341,270
March 2014	104	77	1.85	64	364,849

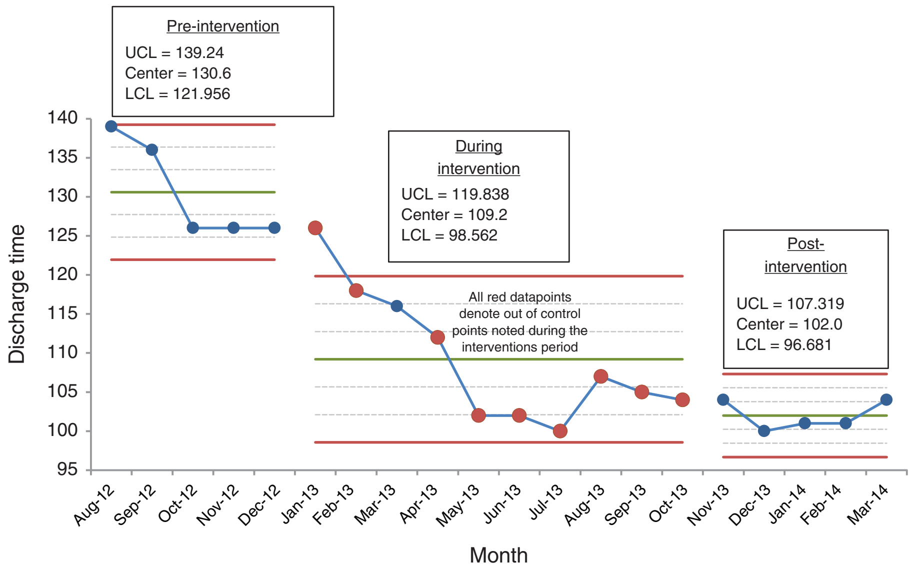

FIGURE 1. Individual control chart of average discharge time calculated in minutes. LCL = lower control limit, UCL = upper control limit.

these reflect a more statistically controlled process with less variation.

Before-noon discharge is an important indicator for hospital throughput that is thought to reduce ED overcrowding by opening up bed capacity at times that better match hourly trends in inpatient bed demand.[11,23] Increasing before-noon discharges relies on efficiently organizing multidisciplinary rounds and discharge coordination among care providers.[11] Even though our interventions did not target the healthcare provider rounds, the percentage of patients who left before noon in the post-intervention period did improve from 15.9% in the preintervention phase to 20.7% in the preintervention phase. This is likely related to overall drop in discharge time because the percentage of patients whose discharge orders written before noon did not change.

Multiple studies have looked at factors that impact LOS of ED patients linking delays to increased hospital occupancy, extended LOS of hospital patients, and high volume of ED admissions.[5,24] The ED LOS for admitted patients in our study dropped significantly from 6.9 to 5.9 hours. This drop persisted even after controlling for potential confounders including age, sex, payment method, ESI, daily ED visits, and hospital occupancy, demonstrating the significance of discharge time for ED throughput.

Limitations

The limitations of the study are related to the pre, post-intervention observational design that limits ability to control for all possible confounders. Acuities of patients and staffing levels of the different stakeholders are possible confounders that we did not account for. Our outcomes were captured from an administrative database that included time stamps that were manually entered by clerks and prone to error. In addition, we did not complete a cost analysis or look at patient satisfaction.

CONCLUSIONS

In conclusion, Six Sigma can be an effective change method to improve complex operational processes that have multiple stakeholders. Given a key combination of factors—leadership commitment and support, front-line engagement, and repetitive cycles of interventions based on continuous metric monitoring and reporting—deployment of Six Sigma can have a significant and sustainable impact on hospital throughput metrics and flow. Institutions aspiring to tackle delays in the discharge process should focus on adopting the core principles of Six Sigma rather than the actual interventions that may be institution-specific.

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