## Title

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Journal
The Joint Commission Journal on Quality and Patient Safety, 44(7)

ISSN
1553-7250

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Publication Date
2018-07-01

DOI
10.1016/j.jcjq.2018.02.006

Peer reviewed

The Joint Commission Journal on Quality and Patient Safety 2018; 44:401–412

# A Lean Six Sigma Quality Improvement Project Improves Timeliness of Discharge from the Hospital

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**Background:** Hospital overcrowding has become a widespread problem, with constrained bed capacity and admission bottlenecks having far-reaching negative impacts on quality and safety. Focus on timing of discharge may be the least disruptive and most effective way to address constrained bed capacity, yet there may be significant institution-specific barriers to implementation.

**Methods:** With the creation of a "Value Team," a 627-bed, tertiary care academic medical center embarked on a quality improvement (QI) project using Lean Six Sigma process improvement methodology. After defining the problems around timeliness of discharge, the team went through the steps in the Define, Measure, Analyze, Improve, Control (DMAIC) framework. Interventions, which were implemented on the basis of an in-depth analysis of barriers to the discharge process, included geographic cohorts of internal medicine physicians on specific hospital units and multidisciplinary huddles one day before anticipated discharge.

**Results:** After accounting for the concurrent trends in the control group, the percentage of discharge orders released by 10:00 a.m. increased by 21.3 points ($p < 0.001$; adjusted odds ratio [OR] = 2.62; 95% confidence interval [CI] = 1.91–3.59), and the percentage of patients discharged by noon increased by 7.5 points ($p = 0.001$; adjusted OR = 1.70; 95% CI 1.15–2.51). There were no significant changes in the 30-day readmission rate or length of stay.

**Conclusion:** A QI program shaped by Lean Six Sigma principles and reinforced by clinician huddles and geographic cohorting was associated with earlier posting of discharge orders and physical discharge by noon.

Hospital overcrowding has become a widespread problem across the United States[1] and can have far-reaching deleterious effects. Constrained bed capacity and admission bottlenecks leave many admitted patients to linger in emergency departments (EDs) for hours to days, with negative impacts on quality and safety. Poor patient satisfaction levels, medication administration delays, and increased mortality, as a result of overcrowding, have all been documented.[2,3] In addition to exacerbating this problem in the ED, delayed discharges from the floor may result in longer length of stay (LOS), resulting in adverse hospital-related complications. In principle, hospital overcrowding can be mitigated in three ways: (1) decrease admissions, (2) shorten LOS (that is, decrease the number of "midnights" in the hospital), or (3) hasten discharge (without decreasing the number of "midnights") by focusing on timing of discharge. Of these, changes in discharge timing are arguably the least disruptive. In addition, timing of discharge from the hospital has been shown to have an impact on the need to board admitted patients in the ED,[4] and there have been studies that suggest that late afternoon hospital discharges contribute to crowding and increased LOS.[5–7] Discharges that occur early in the day reduce ED wait times, improve patient and provider satisfaction, and decrease health system costs.[8,9] A number of studies suggest that early discharge initiatives are achievable and sustainable.[10–13]

At the University of California, Davis (UC Davis), late afternoon discharges had been recognized as one of the primary barriers to movement of patients out of the ED and a major factor for lack of bed availability. For UC Davis Medical Center, a tertiary medical center and a regional referral center for specialty services, lack of bed availability has significant implications for both hospital finances and community access. Multiple prior attempts to promote early discharge were seen as largely unsuccessful and subsequently abandoned. The argument was made that rushed discharges without adequate preparation can lead to higher readmissions, and an excessive focus on meeting a superficial discharge metric will cause physicians to hold on to patients until the next day, leading to longer LOS.

Lean Six Sigma (LSS) is a set of techniques and tools for process improvement, with a focus on defects, variation reduction, and customer satisfaction, which in other sectors has been shown to better serve consumers, reduce costs, and improve safety.[14] In the health care setting, LSS can be used to reduce medical errors while maintaining patient and provider satisfaction through the development of a sustainable patient care model.[15–17] A systematic problem-oriented approach such as LSS may help focus on institution-specific barriers. We embarked on a quality improvement (QI) project using LSS process im-

1553-7250/$-see front matter

https://doi.org/10.1016/j.jcjq.2018.02.006

provement methodology to affect hospital throughput by discharging inpatients from our medical services earlier in the day. We evaluated the effort using a quasi-experimental design in which we evaluated discharge timing, as well as secondary outcomes such as LOS and readmission rate.

## METHODS

### Setting

The Morning Discharge Quality Improvement initiative was conducted from June 2015 through February 2016 on the nonteaching hospitalist service at UC Davis Medical Center, a 627-bed, tertiary care academic medical center. Physicians on this service rotate on an attending-only service without house staff or learners and admit patients to 1 of 14 combined medical/surgical wards. Physician rotations are week on, week off, with a capped census of 15 patients.

LSS methodology was used to identify barriers to early discharge and develop an intervention targeted to those barriers. After defining the problems around timeliness of discharge, the team went through the steps in the Define, Measure, Analyze, Improve, Control (DMAIC) framework. DMAIC methodology provides a systematic approach to improve an organization's efficiency and effectiveness.

### Planning the Intervention

The UC Davis Health Performance Excellence (Px) Department was created in 2011 at our medical center to champion hospital-based initiatives. The department consists of an LSS Black Belt in addition to experts in data analysis. Using the Vizient® consortium of reporting hospitals, we learned that our institution ranked last—out of 54 academic medical centers—on LOS in the ED (specifically, Core Measure ED-1b),[18] with a median wait time of 466 minutes in the ED before arrival at the admitting unit.

In December 2014, to address the ED LOS opportunity, the Px Department created a value stream work group ("value team") that used process stream mapping to embark on the patient flow improvement project. The health system chief medical officer, chief operations officer, and chief nursing officer were named as executive sponsors of the project. The executive sponsors were responsible for facilitating access to resources, such as data, and removing barriers so the work group could be successful. The hospitalist section chief was named as the owner of the process. The process owner was responsible for the overall success of the project. Three physician champions from the hospitalist service were appointed to the work group, primarily to serve as clinical work flow and subject matter experts, and to disseminate agreed-on interventions to other providers in the group. While input was sought from all stakeholders in the process, the work group was kept small to facilitate rapid decision making and implementation. Attention focused on the nonteaching hospitalist service for three reasons: (1) hospitalists are long-term employees rather than rotating house staff, ensuring continuity of commitment; (2) attending hospitalists on this service drive the medicine culture at our institution; and (3) the majority of medicine patients are admitted to this service. To evaluate the impact of the interventions, we chose two medical/surgical units (East 4 [E4] and East 8 [E8]) to serve as our intervention group, while all other medical/surgical units served as our control group for comparison. E4 and E8 each consist of 35 medical and surgical beds and admit patients attended by different services. E4 primarily boards patients on the adult internal medicine service. E8 is a ward that accommodates adult internal medicine patients as well as chronic conditions patients. Our control group comprised 12 other medical/surgical units throughout the hospital, each also consisting of 35 medical/surgical beds. Some of the units in our control group were focused on certain patient conditions, such as orthopedics. To create a fair and accurate comparison, we decided to analyze discharges from both the intervention and control groups that were discharged by only nonteaching hospitalists.

With the work group in place, and our intervention and control groups defined, the DMAIC process began. We now provide the details and time line of each step of the DMAIC process specific to this intervention. This was a QI intervention that was endorsed by the Medical Staff Executive Committee. The UC Davis Institutional Review Board (IRB) Administration determined that the project was not human subjects research and did not require IRB review.

### Define (May 1–7, 2015)

Undertaking a QI initiative involves clearly defining the problem. Using Vizient[18] and our electronic health record (EHR) data for the nine-month period prior to implementation, the work group determined that the time of day when discharge orders were written and released peaked between 12:00 P.M. and 1:00 P.M., and the time of physical discharge from the hospital was dependent on the time of order release. On the basis of these findings, the value team defined two primary goals: (1) Improve the rate of discharge orders written and released by 10:00 A.M. to 40% before the next calendar year (January 2016); and (2) Improve the rate of physical discharge by noon (DBN) to an absolute 12% over the same period. DBN was chosen as our outcome metric based on literature review that showed discharging a majority of inpatients by noon decreased boarding hours in the ED.[4] A two-hour lead time between discharge order release and DBN was deemed adequate by our value team as needed for preparation for physical discharge. As described above, the scope of the project was limited to the nonteaching hospitalist service, and only to patients admitted to E4 and E8.

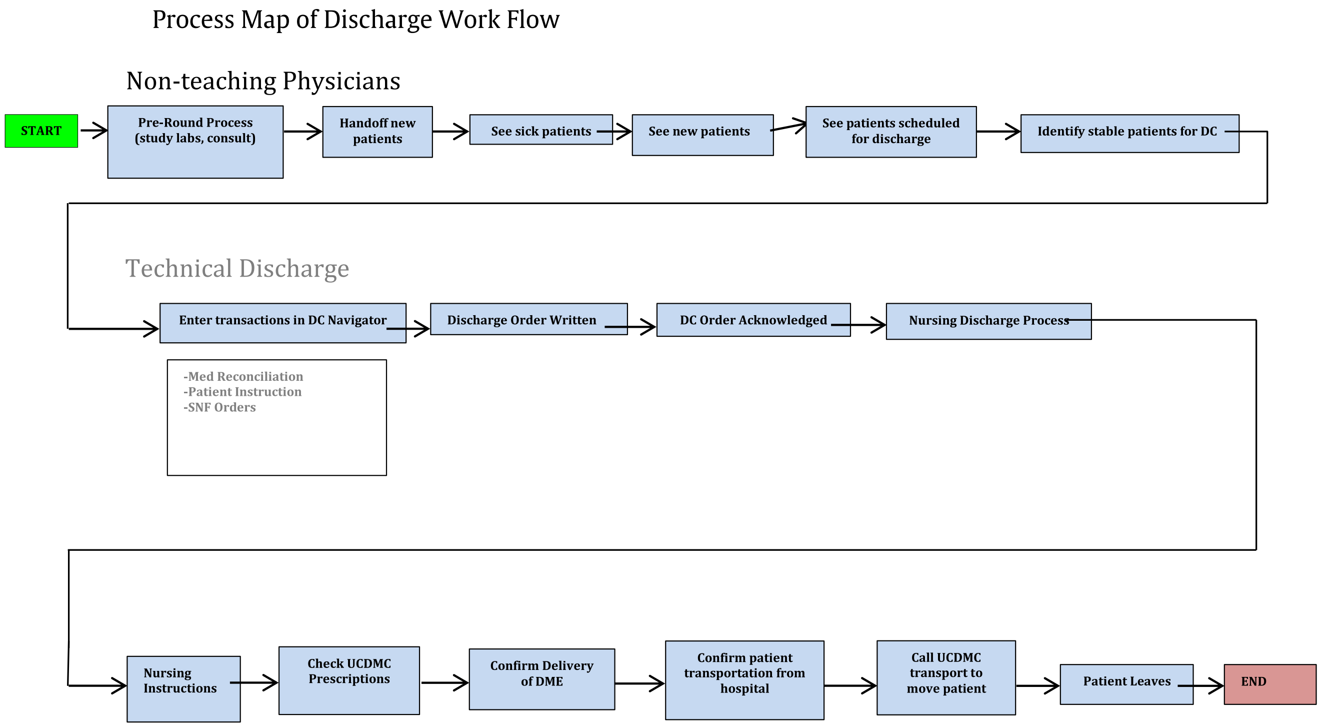


**Figure 1:** The process map facilitated identification of several steps that took place in the physician work flow that led to a delay in discharge order entry. DC, discharge; Med, medication; SNF, skilled nursing facility; DME, durable medical equipment; UCDMC, UC Davis Medical Center.

With the problem statement, scope, and goals of the initiative defined, the work group constructed a process map to define each step in the actual process to place and release discharge orders for the nonteaching physician teams. There was a group brainstorming phase, during which sticky notes were placed on a whiteboard to represent each step in the current process. Figure 1 depicts the final computerized "current state" document representing the group's work.

## Measure (September 2014–May 2015)

The next step of the process involved collecting and validating trend data on the average time of day and distribution for discharge orders to be released by the hospitalist services. We reviewed the trends that existed during the baseline period (September 2014–May 2015) and used them as the basis for improvement. The distribution was normal with a range of 8:00 A.M. to 7:00 P.M., peaking at 12:30 P.M. Further analysis of the hospitalist service on E4 and E8 revealed that 15.6% of discharge orders were written and released by 10:00 A.M. DBN rate averaged 10.5% of patients on those two units combined.

## Analyze (May 8–30, 2015)

The work group next conducted a root cause analysis (RCA), including constructing a fishbone (Ishikawa) diagram, to identify and thematically cluster causal factors leading to delays in releasing discharge orders. Major categories and individual factors are depicted in Figure 2.

Five main categories of delay were identified: (1) the discharge process itself (failure to arrange for outpatient intravenous [IV] antibiotics or home total parenteral nutrition prior to discharge), (2) discharge equipment delays (physical therapy–recommended mobility aids not ordered until late in the evening), (3) post-acute care need delays (insertion of peripherally inserted central catheter not performed until late in the evening), (4) medication reconciliation delays (medication reconciliation not done on admission), and (5) delays in rounding (physicians seeing dischargeable patients last). Each theme was explored and unpacked until a list of actionable root causes amenable to improvement was identified. The work group found that hospitalists are required to complete a large number of activities in the morning hours. These activities limited the time available to see patients and write discharge orders. In addition, communication with the other disciplines was fragmented with a lack of adequate preparation for discharge.

## Improve (June 1–15, 2015)

On the basis of our analysis, we decided that we needed to help the hospitalists plan and coordinate their morning discharge activities by way of multidisciplinary huddles and geographic cohorts. Hospitalists were cohorted to each unit (one specific hospitalist to E4 and one specific hospitalist to E8) during their week on service, which were the only two units geographically cohorted to the hospital medicine service. Our control group consisted of the other hospitalist

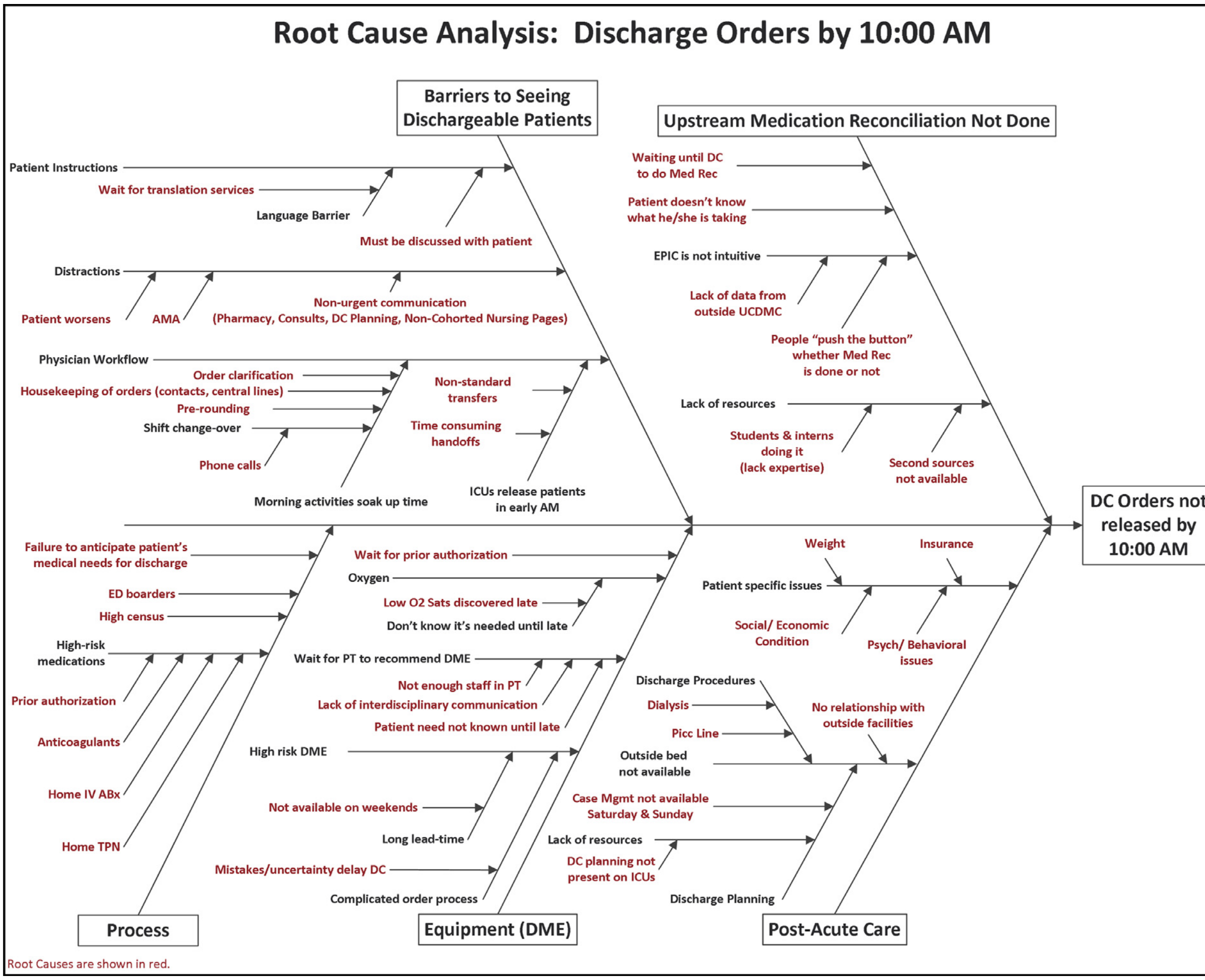


**Figure 2:** An Ishikawa diagram was constructed to identify and thematically cluster causal factors leading to delays in releasing discharge orders. DC, discharge; Med rec, medication reconciliation; AMA, against medical advice; UCDMC, UC Davis Medical Center; ED, emergency department; O2, oxygen; Psych, psychiatric; PT, physical therapy; DME, durable medical equipment; Picc, peripherally inserted central catheter; IV, intravenous; Abx, antibiotics; TPN, total parenteral nutrition.

services that were non-cohorted, where physicians could be responsible for overseeing care for medical patients located in as many as 14 different wards and did not participate in the multidisciplinary discharge huddles. Group policy was to cap a hospitalist at 15 patients and to keep all hospitalists relatively even in terms of distribution of patients. This resulted in little change in workload or census associated with the geographic cohort. Because physicians were cohorted to units according to their weekly schedule, these cohorts extended through the weekend, even when multidisciplinary huddles were not taking place.

Early on, through consensus and recommendations from the work group, we decided to cohort hospitalists to our intervention units to provide consistency in staff and allow a platform by which the other interventions could be implemented. We believed that a critical number of patients was needed to optimize efficiency for the interventions. For example, if only two patients were on the unit, than any interventions involving just those patients would not be an efficient use of the hospitalist's time. With a majority of patients on their rounding list on the unit, they could discuss their patients with the other disciplines, coordinate patient needs, and communicate the plan in one sitting, and with all providers involved in their patients' care. We began cohorting hospitalists to E4 and E8, starting in January 2015, several months before the other components of the intervention bundle, as it was felt that this was a necessary prerequisite and needed to be perfected for the other parts of the bundle. Cohorting physicians to specific units was considered a major practice change for many within the group; several iterations were attempted, and multiple challenges needed to be worked through in order to perfect the process. With a lack of hospital beds, trying to redirect patients to these units was not feasible, as patients from the ED were admitted to the first available bed in as many as 14 different units. Rather, we cohorted hospitalists to those units, and assigned patients to that hospitalist's list after their bed had been assigned during the admission process. The cohorts were not perfect, in that the hospitalist on this service would occasionally see some patients on other units either to maintain continuity or to help with distribution of patients when the other teams were capped by census. However, efforts were made to ensure that the majority of patients on each of these units were part of the hospitalist's cohorted list. Hospitalists who worked on the two intervention floors crossed over to the control floors in subsequent weeks and vice versa.

With the geographic cohorts in place, an intervention bundle was assembled with the other components: medication reconciliation assistance, a checklist to be used during mandatory multidisciplinary huddles, performance audit, and feedback to participating hospitalists. With the anticipated needs cared for the day before during huddles, hospitalists could then quickly see patients to be discharged the morning of, and release their discharge orders before seeing other patients on their lists. With the exception of geographic cohorts, the intervention bundle was constructed and implemented over a period of two weeks at the start of our intervention period. The other components of the bundle are described in more detail below:

The multidisciplinary discharge huddle was designed to focus on causal factors for delay identified in our RCA. Prior to implementation, there were no multidisciplinary huddles on any of the units. The work group decided that 2:00 P.M. was the optimal time when physicians could participate with minimal interruptions, yet interventions could still be executed in anticipation of discharge the next day (for example, order durable medical equipment for the following day based on the physical therapist's assessment). Huddles would take place Monday through Friday, and members were required to sign in—specifically, charge nurse, discharge planning, hospitalist, pharmacy, nutrition, and physical therapy. Participants were chosen based on perceived needs as defined by the process map and RCA. For example, lack of accurate medication reconciliation on admission was identified in our RCA. This led to delays downstream, as efforts had to be made to update and correct or perform medication reconciliation on discharge. Other delays resulted from the prior authorization process for new prescriptions, or determination of the patient's outpatient pharmacy, and discharge counseling on new prescriptions. A pharmacy technician attended the huddles and identified which patients were targeted for discharge the next day. The pharmacy technician would then work with the hospitalist and complete medication reconciliation the day before discharge, perform discharge counseling, and work on the prior authorization process, so that these would not become barriers on the day of discharge. The hospitalist could then quickly see the patient in the morning and write the discharge orders by 10:00 A.M. Participants were brought together and used a huddle checklist (Sidebar 1), which encouraged a proactive multidisciplinary approach to recognized discharge barriers. Physician and nursing leadership (Hospital Medicine section chief, nurse unit manager) also attended to ensure adherence to our institutional goals and checklist. Attendance was monitored with formal sign-in sheets taken during the intervention period. Goals for discharge order release time were reiterated at every monthly business meeting. Leadership attendance and engagement were critical to maintaining integrity and structure of the huddle.

**Sidebar 1.** Multidisciplinary Huddle Checklist

1. **Physician anticipate the patient to be medically cleared for discharge:**
   - ☐ **Today**
   - ☐ **Tomorrow**
   - ☐ **In 1-2 days**
   - ☐ **In 3-5 days**
   - ☐ **In > 5 days**
2. **Discharge barriers:**
   - ☐ **None**
   - ☐ **Medications (prior authorization, etc.)**
   - ☐ **Placement**
   - ☐ **DME**
   - ☐ **Home IV antibiotics, TPN or home O2**
   - ☐ **Psycho-social issues**
   - ☐ **Transportation**
   - ☐ **Pain**
3. **Choosing wisely / Restful Night's Sleep**
   - ☐ **Frequency of vitals check**
   - ☐ **Appropriateness of labs**
   - ☐ **Medication times at night**

DME, durable medical equipment; IV, intravenous; TPN, total parenteral nutrition; O2, oxygen.

Audit and feedback was also an integral part of the huddle process: A discharge order release time and DBN dashboard was created and e-mailed weekly to huddle participants and to the hospital medicine group (Appendix 1, available in online article). The dashboards were constructed by the Px Department and included retrospective review of performance on a weekly basis. Individual physicians could review their performance and were provided feedback from the previous week's discharge order release rate. We also reviewed the dashboards at our monthly business meetings and provided feedback to the entire hospitalist group as a whole. Goals were reiterated that discharge orders should be released by 10:00 A.M. 40% of the time, and our DBN rate should be greater than 12%. The dashboards were also reviewed with the other disciplines (discharge planning, patient care services, pharmacy) every Tuesday morning with executive leadership during value team hud-

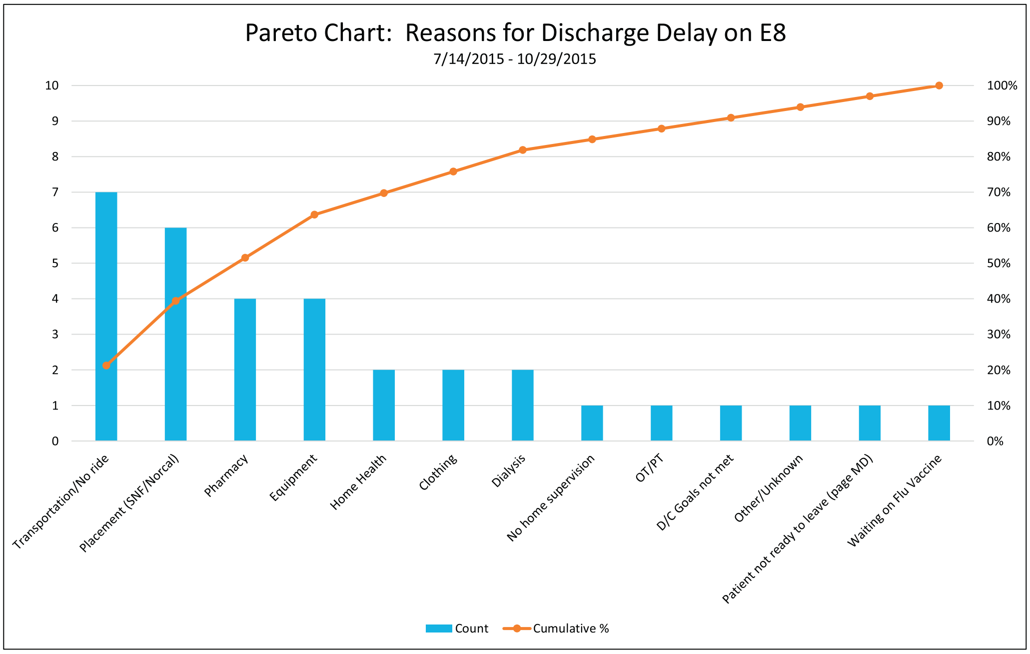


**Figure 3:** Patient ride home and ambulance transport were identified as common barriers leading to delay in discharge. SNF, skilled nursing facility; OT/PT, occupational therapy/physical therapy; D/C, discharge.

dles. Here, participants were recognized for their success at meeting goals, and problems were brought to the attention of executive leadership.

## Control (July 2015–February 2016)

To sustain our results, the team reviewed control chart data on a weekly basis. Shortly after implementation, the team noted that on E8, physicians were meeting their goal of releasing discharge orders by 10:00 A.M. approximately 40% of the time, but the percentage of DBN was below target. E8 huddle team representatives were brought together to discuss reasons potentially contributing to delays. We constructed a Pareto chart (Figure 3) to identify factors leading to delay of physical discharges from this unit. Lack of transportation (no patient ride or ambulance transport) was identified as a common cause of delayed discharge. As a result, more focus was placed on this aspect of the daily huddle.

## Outcome Measures

**Primary Outcomes.** The primary outcomes were the percentage of discharge orders released by 10:00 A.M., and the percentage of DBN. All discharges that took place on the nonteaching hospitalist service were analyzed, both before and after the intervention began. Discharge order entry times and actual discharge from the hospital on these two units were compared with historical controls as well as with our control group.

**Secondary Outcomes.** Our secondary outcomes were the ratio of observed to expected LOS, and 30-day readmission rates. All measurements were based on a merger of Vizient[18] case profile data with data from the hospital's EHR system.

## Statistical Analysis

Our primary objectives were to show that our interventions on E4 and E8 improved the process (as measured by discharge orders released by 10:00 A.M.) and that the process improvement had the intended beneficial effect on an outcome (as measured by patients discharged by noon). To ensure that the process change did not cause any harmful spillover effects, we assessed the performance of two additional outcomes: patient readmissions (as measured by patients readmitted within 30 days) and patient LOS (as measured by LOS index). Historically, individual physicians could not achieve early discharge or influence discharge time on a regular basis; therefore, we did not account for clustering of patient outcomes by physician in our analyses.

For both of the nursing units on which discharge huddles were implemented (the treatment group), study outcomes and patient characteristics were compared to the control group during a nine-month baseline period (September 2014–May 2015) and a nine-month intervention period (June 2015–February 2016). Patient characteristics were summarized by group and period using frequencies and percentages for categorical variables, and means and standard deviations for numeric variables; differences between the groups in each period, and between periods within each group, were assessed using chi-square tests or $z$-tests to compare proportions and $t$-tests to compare means. A difference-in-differences (DID) approach was employed to compare the outcome measures between the baseline and intervention periods, and between the treatment and control groups. This technique estimates the effect of a treatment on an outcome by comparing the change over time in the treatment group with the change over time in the control group, thereby accounting for temporal trends as well as baseline differences between the groups. For binary outcome variables, we computed the difference between the intervention and baseline periods in the proportion with the outcome (for example, discharge orders released by 10:00 A.M.) in each group, subtracted the difference in proportions in the control group from the difference in proportions in the treatment group, and used a *z*-test to determine statistical significance. We analyzed LOS index using two-way analysis of variance (ANOVA) with main effects for group and period, as well as a group-by-period interaction to determine whether the period effects differed significantly between treatment and control. To adjust for imbalances in patient characteristics, we also developed a multivariable model of each outcome variable as a function of group, period, a group-by-period interaction, and patient characteristics (age, gender, race, and presence/absence of major illness). We used logistic regression to estimate adjusted odds ratios (ORs) with 95% confidence intervals (CIs) for binary variables, and linear regression to estimate coefficients with 95% CIs for LOS index. Statistical significance was assessed at the 0.05 level (two-sided).

## EVALUATION RESULTS

### Patient Characteristics

Table 1 compares demographic characteristics of intervention and control group patients. Age, race, sex, severity of illness, and expected mortality (calculated using Vizient's 2015 AMC risk model) were analyzed for both the intervention and control groups. A total of 4,134 patients were included in the analysis, with 1,471 patients in our intervention group and 2,663 patients in our control group during both the baseline and intervention periods. The mean age of patients was higher in the control group than in the study group, as was the proportion of patients age 65 and over. Patients with major illnesses were more likely to be in the control group in both time periods. The proportion of patients with major illnesses in the control group increased from the baseline to the intervention period, and there was an increase in the expected mortality rate. There was not a significant change in proportion of patients with major illness in the intervention group, and there was no significant change in expected mortality rate between the baseline and intervention periods.

### Difference-in-Differences Analysis

The four response measurements were compared between the study and control groups across the baseline and intervention periods (Table 2). These comparisons enabled us to estimate how much of the change in an outcome measurement was attributable to the process intervention after accounting for changes that would have happened in the absence of the intervention, such as the trend over time, a change that also occurred in the control group. The DID estimates confirmed that the intervention was associated with increases in both the percentage of discharge orders released by 10:00 A.M. and the percentage of patients DBN. After accounting for the concurrent trends in the control group, the percentage of discharge orders released by 10:00 A.M. increased by 21.3 points ($p < 0.001$; adjusted OR = 2.62; 95% CI = 1.91–3.59), and the percentage of patients discharged by noon increased by 7.5 points ($p = 0.001$; adjusted OR = 1.70; 95% CI = 1.15–2.51) (Table 2 and Table 3).

### Secondary Outcomes: Observed to Expected Length of Stay and 30-Day Readmission Rate

The intervention did not have a deleterious effect on either the 30-day readmission rate, or LOS index. There were no significant changes in the 30-day readmission rate (DID estimate, 1.6 points; $p = 0.492$, adjusted OR = 1.13; 95% CI = 0.79–1.61) or LOS index (DID estimate, 0.08; $p = 0.153$, regression coefficient = 0.09; 95% CI = -0.02–0.21) (Table 2 and Table 3).

### Association Between Patient Characteristics and Outcomes

As one might expect, patients with major illnesses were less likely to have their discharge orders by 10:00 A.M.—and less likely to be discharged by noon. They were also more likely to be readmitted and to experience a longer LOS.

### Statistical Process Control Results

The percentage of discharge orders written and released and the percentage of physical discharge from the hospital were analyzed using a statistical process control chart to distinguish between special-cause and common cause variation, on the basis of a merger of Vizient's case profile data with data from the hospital's EHR system (Figure 4 and Figure 5). There was marked improvement in discharge order release time and DBN in the intervention group, with sustained results throughout the intervention period (ending February 2016). An RCA of dips in performance revealed that new hires were rotating on our intervention units (September and February 2016). Discharge order release time and DBN rate were analyzed using statistical process control, beyond the intervention period, and show sustained results through December 2016.

### ED Throughput as Measured by Core Measure ED-1b

Core Measure ED-1b was not significantly affected by our intervention. In the postintervention period (June 2015–February 2016), the median wait time from presentation

**Table 1. Comparison of Demographic Data in the Study and Control Groups During the Baseline (September 2014–May 2015) and Intervention Periods (June 2015–February 2016)**

| Demographic Characteristics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Characteristic | Baseline Period | | Intervention Period | | *P* Values | | | |
| | Study Group ($n=675$) | Control Group ($n=1{,}393$) | Study Group ($n=796$) | Control Group ($n=1{,}270$) | Baseline Study vs. Control | Intervention Study vs. Control | Study Intervention vs. Baseline | Control Intervention vs. Baseline |
| Age, mean (SD) | 55.4 (18.8) | 60.7 (18.5) | 54.9 (18.8) | 58.8 (18.6) | < 0.001* | < 0.001* | 0.582** | 0.007* |
| 65 and Over, *n* (%) | 214 (31.7) | 597 (42.9) | 258 (32.4) | 513 (40.4) | < 0.001† | < 0.001† | 0.772† | 0.197† |
| Male, *n* (%) | 353 (52.3) | 680 (48.8) | 421 (52.9) | 642 (50.6) | 0.137† | 0.300† | 0.820† | 0.371† |
| Race, *n* (%) | | | | | 0.007‡ | 0.060‡ | 0.765‡ | 0.567‡ |
| Asian | 56 (8.3) | 138 (9.9) | 67 (8.4) | 123 (9.7) | | | | |
| Black | 124 (18.4) | 332 (23.8) | 140 (17.6) | 277 (21.8) | | | | |
| White | 377 (55.9) | 677 (48.6) | 433 (54.4) | 628 (49.5) | | | | |
| Other | 118 (17.5) | 246 (17.7) | 156 (19.6) | 242 (19.1) | | | | |
| Major Illness, *n* (%) | 341 (50.5) | 771 (55.3) | 420 (52.8) | 751 (59.1) | 0.039† | 0.005† | 0.390† | 0.048† |
| Expected Mortality, mean (SD) | 0.031 (0.075) | 0.028 (0.064) | 0.029 (0.067) | 0.038 (0.086) | 0.373* | 0.004* | 0.591* | < 0.001* |

SD, standard deviation.
* Two-sample *t*-test.
† Two-proportion test.
‡ Chi-square test.

**Table 2. Difference-in-Differences Analysis**

| Measurement | Study Group | | Control Group | | Difference-in-Differences Estimate (percentage points) |
|---|---|---|---|---|---|
| | Baseline Period ($N=675$) | Intervention Period ($N=796$) | Baseline Period ($N=1{,}393$) | Intervention Period (Difference-in-Differences Analysis [$N=1{,}270$]) | |
| Discharge orders by 10:00 A.M., *n* (%) | 105 (15.6) | 375 (47.1) | 227 (16.3) | 336 (26.5) | 21.3 ($p < 0.001$) |
| Patient discharged by noon, *n* (%) | 71 (10.5) | 164 (20.6) | 130 (9.3) | 151 (11.9) | 7.5 ($p=0.001$) |
| 30-day readmission, *n* (%) | 100 (14.8) | 121 (15.2) | 241 (17.3) | 204 (16.1) | 1.6 ($p=0.492$) |
| Length of stay index, mean (SD) | 1.04 (0.96) | 0.98 (0.88) | 1.11 (1.03) | .97 (0.77) | 0.08 ($p=0.153$) |

SD, standard deviation.

**Table 3. Parameter Estimates for the Four Multivariate Models**

| | Discharge order by 10:00 A.M. ($N=4{,}134$) | | Patient discharged by noon ($N=4{,}134$) | | 30-day readmission ($N=4{,}134$) | | Length of stay index ($N=4{,}134$) | |
|---|---|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | Coeff. | 95% CI |
| Group | 0.94 | (0.73–1.21) | 1.09 | (0.80–1.48) | 0.87 | (0.67–1.12) | -0.08 | (-0.16–0.01) |
| Period | **1.87** | (1.54–2.26) | **1.32** | (1.03–1.70) | 0.90 | (0.73–1.11) | **-0.16** | (-0.23– -0.09) |
| Group Period | **2.62** | (1.91–3.59) | **1.70** | (1.15–2.51) | 1.13 | (0.79–1.61) | 0.09 | (-0.02–0.21) |
| 65+ | 1.02 | (0.88–1.19) | **0.72** | (0.59–0.89) | 1.00 | (0.84–1.19) | **-0.12** | (-0.17– -0.06) |
| Male | 0.94 | (0.82–1.09) | 1.08 | (0.90–1.30) | 1.08 | (0.92–1.28) | 0.03 | (-1.03–0.09) |
| Asian | 0.76 | (0.57–1.00) | 0.95 | (0.67–1.36) | 0.93 | (0.68–1.27) | -0.02 | (-0.12–0.08) |
| Black | 0.97 | (0.80–1.17) | 1.19 | (0.94–1.50) | **1.49** | (1.21–1.83) | **-0.07** | (-0.15– -0.01) |
| Other | 0.96 | (0.79–1.17) | 1.07 | (0.83–1.38) | 0.96 | (0.76–1.21) | **-0.08** | (-0.16– -0.01) |
| Major Illness | **0.82** | (0.71–0.95) | **0.67** | (0.55–0.81) | **1.70** | (1.43–2.03) | **0.26** | (0.20–0.31) |

Bold type indicates statistical significance at 95% CI.
OR, odds ratio; CI, confidence interval; Coeff., regression coefficient.

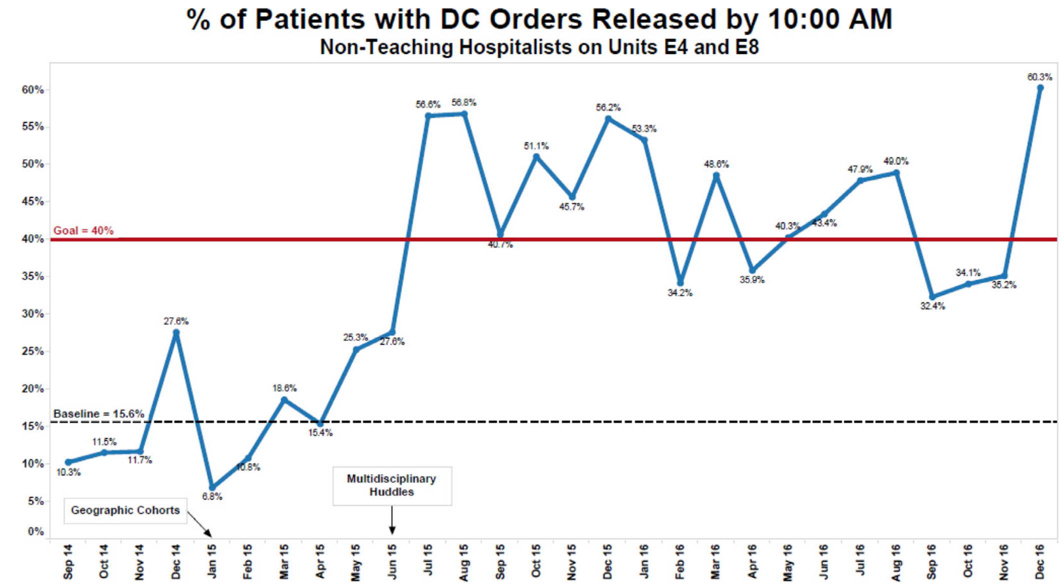


**Figure 4:** This statistical process control chart demonstrates marked improvement in discharge release time by 10:00 A.M. after implementation of interventions. Geographic cohorts were implemented on January 1, 2015, and multidisciplinary huddles were implemented on June 1, 2015. Root cause analysis for dips in performance in September 2015 and February 2016 revealed that new physician hires were rotating on these units.

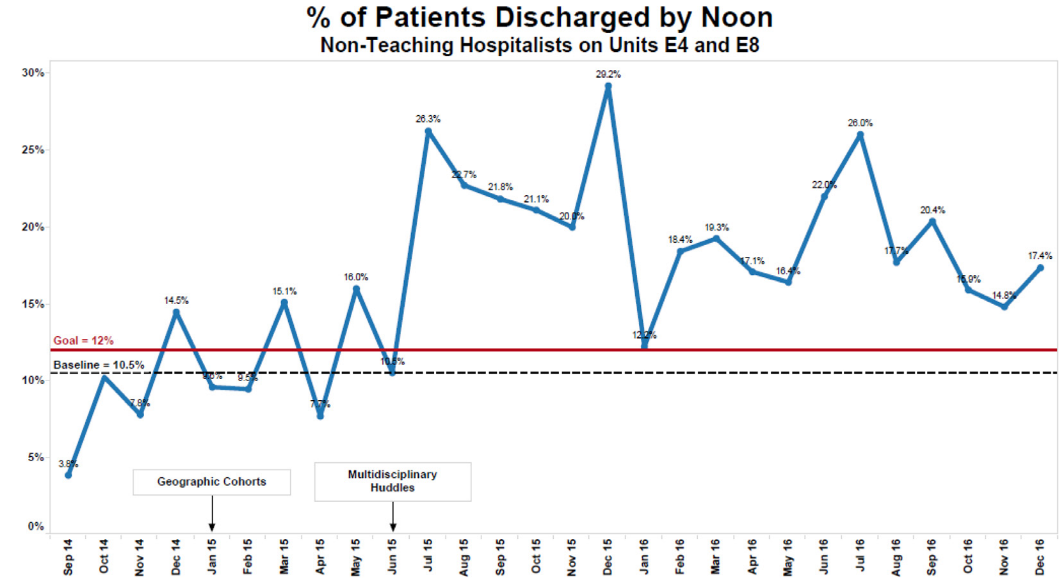


**Figure 5:** This statistical process control chart demonstrates marked improvement in the percentage of patients physically discharged by noon. Geographic cohorts were implemented on January 1, 2015, and multidisciplinary huddles were implemented on June 1, 2015.

in the ED to admission was 481 minutes (vs. 466 minutes during the baseline period).

## DISCUSSION

Despite reports of successful and sustainable early discharge initiatives in the literature, many hospitals continue to have institution-specific barriers that prevent early discharge initiatives from taking hold. A "one size fits all" approach may not be fruitful, and the strategies that prove effective for one institution may not lead to meaningful results for another.

We used LSS DMAIC process methodology as a structured framework to design a discharge initiative to overcome barriers unique to our institution. This allowed us to focus on problems at our institution, such as medication reconciliation. Our results support this approach, as we saw significant improvements in discharge order release time and physical discharge by noon, with marked improvement when compared to those services not taking part in the intervention.

Our primary process metric was the discharge order entry time, and physician and staff engagement were integral drivers of this process. Staff members who are given encouragement, training, and time to make meaningful improvements in how the work is done are unlikely to want to retreat to an earlier period when formalized effort to improve existing processes was outside their domain of responsibility.[17] One reason our discharge initiative had been unsuccessful in the past was a lack of physician engagement, and one of the challenges we experienced was integration of new hires who had not been involved in the original process. This was supported by the observed dips in discharge order release time noted at the time of new physician onboarding. These findings parallel those reported by Patel et al. (who also showed dips in performance when new house staff picked up the service)[12] and underscore the importance of physician and staff engagement as primary drivers of this particular process metric.

Others have shown that increasing early discharges using a structured framework for QI is achievable and sustainable.[10–12] For example, Beck et al. used Lean methods to modify work flow and attain early discharges,[10] and Patel et al. used an Institute for Healthcare Improvement PDSA (Plan-Do-Study-Act) framework to achieve early discharges[12]. A feature common to all these successful interventions is a standardized forum for communication such as a multidisciplinary huddle. Other elements central to the success of these interventions are accurate measurement with data analysis, use of checklists, feedback, and identification of patients the day before discharge. These initiatives were focused on house staff teams, whereas our study involved attending physicians without house staff. In both cases the morning hours were deemed unsuitable for the kind of preparatory work needed to facilitate discharges early in the day; preparation occurred the day before. Our intervention also relied on notable systems changes. Geographically cohorting physicians to our intervention units facilitated effective use of the huddle and brought team members together who were familiar with the process and had worked with each other. Without a critical number of patients on the unit (achieved only through geographic cohorts), physicians would not be able to appreciate efficiencies created through this type of multidisciplinary communication. This was particularly important when starting the intervention, as efficiency and commitment to keeping the huddles short were necessary prerequisites to physician participation. With geographic cohorts resulting in a critical volume of patients to discuss, a platform was created with which to bring in other elements of the huddle—pharmacy technicians to address medication reconciliation problems, physical therapy to address delays in ordering durable medical equipment, case management to address postdischarge needs—all of which occurred at one place and in one sitting. The other disciplines were brought in on the basis of problems identified in our RCA. These disciplines, such as pharmacy, were already stationed on the units (unit-based). Cohorts made it much easier for these disciplines to collaborate with one hospitalist responsible for many of the patients located on the unit. We do not feel that other elements of the intervention bundle could have interacted in an efficient and effective way without cohorting. We saw this when hospitalists crossed over to the control floors (where they probably took their early discharge practices with them), but without the other elements of the huddle we saw a far less robust improvement in the DBN.

We did not see deterioration in upstream measures such as LOS nor downstream measures such as readmission rates. Our results were based on medicine patients admitted almost exclusively through the ED and are in contrast to a more recent analysis that demonstrated that the DBN rate, specifically among medicine patients admitted emergently, was associated with a longer LOS.[19] Our analysis did show that patients with major illnesses were less likely to have their discharge orders by 10:00 A.M., and less likely to be discharged by noon. Counterintuitively, patients aged 65 years and older experienced a shorter LOS, even though they were less likely to be discharged by noon. Older patients may require a greater lead time to arrange for discharge, with resultant discharge later in the afternoon, but still meet discharge criteria by midnight, thereby not affecting the overall LOS. Younger patients probably have fewer needs on discharge, such as extensive medication reconciliation or equipment needs, or they may have been able to transport home without the need of an ambulance or other barriers. These are the patients who likely benefit most from a focus on efficient discharge and the DBN rate.

Although our interventions were focused on two specific units of the hospital, we also saw modest improvement in the discharge order release time and DBN rate in our control units. The early discharge initiative at its inception was hospitalwide, rolled out to the entire health system. All the disciplines—from social services to hospital medicine—were aware of the desire to discharge patients earlier in the day, and the hospitalist group, as a whole, received feedback on the process during the monthly business meetings. Hospitalists crossed over to the control units in subsequent weeks, perhaps taking their early discharge practices with them. This general awareness and institutional desire may have led to some improvement, although far less than with our interventions in place. The early DBN initiative at our institution had not achieved significant results over the years because of an emphasis on physician practice alone. By pursuing a comprehensive structured approach, with an emphasis on staff engagement and systems-level changes, and an established QI framework, we were finally able to achieve significant results.

Satisfaction with the geographic cohorts and multidisciplinary huddles was high and contributed to the initiative's sustainability postintervention. Hospitalists came to appreciate the efficiency of huddles where they could communicate to multiple disciplines about their patients in one sitting and prepare for the discharge process during a less hectic period of the workday, in the early afternoon. There were anecdotal reports that they received far fewer pages as a result of better communication and collaboration, which also contributed to high satisfaction. The other disciplines also felt that communication was greatly improved and coordination of care elevated. In addition to developing familiarity with the hospitalist, it was also much easier for nursing, case management, or the other involved disciplines to relay information about their patients to one physician who covered many of the patients on their unit.

## LIMITATIONS

Although positive results were obtained from both our process metric (discharge order release time) and outcome metric (DBN), there was a significant difference between the two. Our intervention bundle focused on the time orders are written, as well as the downstream discharge process from the unit. Discharge orders can be placed without having final discharge-ready processes in place, and there are many more factors involved in physical discharge from the unit. We saw this when we constructed a Pareto chart and learned that we needed to target our attention to facilitating rides home. There may have been more opportunities to analyze this discrepancy and delineate further areas of increasing engagement with the other disciplines. This also underscores a weakness in focusing on the discharge order release time alone: Ultimately, it may not lead to physical emptying of beds. Because discharge orders can be placed by the clinician without other aspects of discharge in place, a focus on DBN rate as the primary goal would likely be more meaningful in affecting the ED throughput time or in designing incentive programs.

Our analysis revealed that our control and intervention groups had important differences in their demographic profiles. Although we controlled for patient characteristics in our multivariable analysis, there may have been other unmeasured confounders that affected our results. Optimization of medical comorbidities and treatment, or the patient's willingness to leave before noon, are examples of very difficult to control confounders that could have an impact on the DBN rate. The hospital environment tends to be fluid and dynamic, and it can be difficult to create conditions in which precise comparisons can be made. Although statistical modeling was employed, there are limitations with using observational data to draw conclusions.

Prior research indicated that higher DBN rates were associated with admissions from the ED earlier in the day, decreasing boarding time in the ED.[4,9] The ultimate goal of our initiative was to decrease ED throughput time. However, we did not see any improvement in Core Measure ED-1b (ED throughput time) during or after the intervention. Our intervention involved two units of the hospital and focused only on medicine patients on the nonteaching hospitalist service, a relatively small proportion of the total number of patients admitted through the ED. Conceivably, if discharge huddles and geographic cohorts were widespread and utilized by every unit, a significant improvement in ED throughput could be achieved. Indeed, at our institution, attempts are now being made to expand geographic cohorts of physicians to other units with multidisciplinary huddle structures in place.

Our control and intervention groups consisted of nonteaching hospitalists without house staff at a single-site tertiary university medical center. This type of practice is reflective of nonteaching community-based hospital medicine work; however, staffing and workload may vary in university-affiliated and nonaffiliated practices. Further studies and replication will need to demonstrate the effectiveness of this approach in community-based hospitals with different staffing models. In addition, all our hospitalists were experienced clinicians receiving structured support within a flexible framework. It is not clear how effective these interventions would be with learners, or in a more rigid learning-centered framework, where, for example conferences or other structured teaching activities may interfere with huddles. There was considerable investment at the institution level in the Px Department. This project required hiring of additional staff, including an LSS Black Belt and a team to perform real-time data analysis. These efforts are resource intensive and require large capital investments. In addition, our interventions were heavily dependent on geographic cohorts of physicians to a specific unit to be effective, and this may not be achievable on other units/services or other institutions.

## CONCLUSION

We developed a successful strategy of interventions by using LSS DMAIC, a QI process with a proven track record in other industries. Our experience suggests that LSS process improvement methodology has potential to improve care and efficiency—including timeliness of discharge—in a variety of complex health care settings. Our success in achieving our discharge goals was sustained in part by a physician-centric approach, as well as systems changes that were implemented on the basis of an in-depth analysis of barriers to the discharge process. Although our project successfully achieved results in discharging patients earlier in the day, further analysis with more widespread application needs to be conducted. This may help to clarify and support the idea that early discharges lead to a reduction in ED throughput time.

**Acknowledgments.** The authors thank the Performance Excellence Department at UC Davis Medical Center. They also thank Drs. Greg Maynard and Richard Kravitz for their contributions.

**Conflicts of Interest.** All authors report no conflicts of interest.

## SEE THE ONLINE VERSION OF THIS ARTICLE FOR APPENDIX 1. DISCHARGE HUDDLE DASHBOARDS FOR PERCENTAGE OF PATIENTS DISCHARGED BY NONTEACHING HOSPITALISTS ON UNITS EAST 4 (E4) AND EAST 8 (E8) BY NOON AND 10:00 A.M.

## SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jcjq.2018.02.006.

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