Emergency Department Rotational Patient Assignment

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Study objective: We compare emergency department (ED) operational metrics obtained in the first year of a rotational patient assignment system (in which patients are assigned to physicians automatically according to an algorithm) with those obtained in the last year of a traditional physician self-assignment system (in which physicians assigned themselves to patients at physician discretion).

Methods: This was a pre-post retrospective study of patients at a single ED with no financial incentives for physician productivity. Metrics of interest were length of stay; arrival-to-provider time; rates of left before being seen, left subsequent to being seen, early returns (within 72 hours), and early returns with admission; and complaint ratio.

Results: We analyzed 23,514 visits in the last year of physician self-assignment and 24,112 visits in the first year of rotational patient assignment. Rotational patient assignment was associated with the following improvements (percentage change): median length of stay 232 to 207 minutes (11%), median arrival to provider time 39 to 22 minutes (44%), left before being seen 0.73% to 0.36% (51%), and complaint ratio 9.0/1,000 to 5.4/1,000 (40%). There were no changes in left subsequent to being seen, early returns, or early returns with admission.

Conclusion: In a single facility, the transition from physician self-assignment to rotational patient assignment was associated with improvement in a broad array of ED operational metrics. Rotational patient assignment may be a useful strategy in ED front-end process redesign. [Ann Emerg Med. 2016;67:206-215.]

Please see page 207 for the Editor's Capsule Summary of this article.

A **podcast** for this article is available at www.annemergmed.com.

INTRODUCTION

Background

Numerous investigators have described strategies to streamline emergency department (ED) patient flow by improving operations, particularly in the "front-end" (the time between patient arrival and the time a provider assumes definitive care of the patient).[1] These redesign efforts, reviewed elsewhere,[1,2] include (among others) placing an advanced provider at triage,[3-5] bedside registration,[6,7] and physically streaming patients through a "fast track."[8,9] Other novel solutions include telemedical triage,[10,11] virtual patient streaming,[12] and complexity-based triage.[13]

Another potential opportunity for ED front-end improvement lies in optimizing the association of physicians with patients. Many departments use a physician self-assignment process, whereby physicians assign themselves to (or "pick up") patients at physician discretion. Physicians may base their decision to pick up a patient on an internal calculation of their perceived capacity to treat another patient, how ill the patient is, the perceived needs of the department

(with respect to whether it is busy or not), how much time is remaining in the shift, and other factors. Physician self-assignment may be superior to a system in which nurses assign patients to physicians,[14] but it may not be an optimal system for patient flow.

Previous work has suggested that a system of rotational patient assignment, in which predetermined criteria are used to assign patients to physicians or teams, may lead to ED operational improvements.[15-18] We report the results of such an intervention at our facility.

Importance

Successful changes to front-end operations are of particular interest in ED process redesign because these operations are usually under the direct control of ED leadership. Changes to other phases of ED care, such as throughput and output, often require the involvement of external stakeholders (laboratory, radiology, or consulting/admitting services) and may be practically or politically more difficult. Novel or infrequently reported front-end

Editor's Capsule Summary

What is already known on this topic
Front-end strategies can improve emergency department (ED) throughput.

What question this study addressed
How do ED throughput metrics change when the process for assigning patients to emergency physicians changes from physician self-assignment to an algorithm-produced rotational assignment?

What the study adds to our knowledge
At a 26,000-visit-per-year ED where attending-level physicians treat a maximum of 1.8 patients per hour, changing to a rotational patient-physician assignment process reduced arrival to provider time by 17 minutes (44% decrease), lengths of stay for discharged patients by 29 minutes (14%), and cases of left before being seen by 3.7 in 1,000 (51%). There was little effect on length of stay for admitted patients or on 72-hour return visits.

How this is relevant to clinical practice
Although unique aspects of this ED may limit the generalizability of results, rotational patient-physician assignment may be worthy of consideration to enhance ED operations.

interventions, such as rotational patient assignment, represent important potential additions to the options for ED process improvement.

Goals of This Investigation

We report the results of transitioning from physician self-assignment to rotational patient assignment at a single facility, with the goal of reporting the operational metrics of length of stay, arrival to provider time, rate of left before being seen, rate of left subsequent to being seen, rate of early (within 72 hour) returns, rate of early returns who are admitted, and complaint ratio. We report these metrics while noting and accounting for several potential confounding variables.

MATERIALS AND METHODS
Study Design and Setting

This is a retrospective before-and-after observational study in which we analyzed routinely gathered ED operational data. This project was part of a quality improvement effort, and our institutional review board process identified it as exempt with a waiver of the requirement for informed consent.

The Mayo Clinic Arizona Emergency Department is located in a tertiary care teaching hospital in Phoenix, AZ. There are 24 rooms, with the capacity to use up to 9 hallway spaces. Hallway spaces are used when volume necessitates, stretchers are physically available, and nurse staffing permits. The annual ED census during the study period was approximately 26,000 patients (with significant seasonal variation), and the admission rate was approximately 30%. The ED is staffed 24 hours per day with board-certified emergency physicians and, during the 2-year study period, had 52 to 54 hours of physician coverage per day on days of historically lower census and 61 to 62 hours per day on days of historically higher census. There is no emergency medicine residency training program, although residents from other services rotate through the department and assist in the evaluation of approximately 5% of ED patients.

The physician labor pool was relatively constant throughout the study period. Of the 24 physicians who worked during any part of the 2-year study period, 20 worked during part of both the physician self-assignment period and the rotational patient assignment period, including 16 who worked during the entirety of both periods. All 24 physicians had 3 years or more of postresidency emergency medicine experience.

Throughout the study period, the ED used both the Cerner (Kansas City, MO) electronic medical record and the Cerner FirstNet electronic tracking board. There were no significant changes in electronic processing (including major software updates) or physical patient processing in either the ED or on the part of key ancillary services (laboratory and radiology) during the study period.

Selection of Participants

There were 366 days (including February 29, 2012) in the last year of physician self-assignment and 365 days in the first year of rotational patient assignment.

On 23 of the busiest days in the last year of physician self-assignment (Mondays and Fridays during winter), we used a separate front-end intervention, a physician-nurse team in triage, in an attempt to increase throughput. To minimize confounding of our current data, we eliminated those 23 days from consideration. Because Mondays and Fridays during winter are qualitatively different from other days, with higher daily volume, we identified and eliminated a corresponding set of 23 matched days from the first year of rotational patient assignment as well. We identified a matched day in the first year of rotational patient assignment as the day that was on the same day of the week and within 2 calendar days of the

eliminated day in the last year of physician self-assignment. For example, because we eliminated Friday, February 24, 2012, from the last year of physician self-assignment, we eliminated Friday, February 22, 2013, from the first year of rotational patient assignment; because we eliminated Monday, March 5, 2012, from the last year of physician self-assignment, we eliminated Monday, March 4, 2013, from the first year of rotational patient assignment. We followed this pattern for all 23 days.

All visits from the remaining 343 days in the last year of physician self-assignment and 342 days in the first year of rotational patient assignment were available for analysis.

Interventions

During both periods, patients generally underwent quick registration and nursing triage in a dedicated area or at bedside, at which time an encounter record and patient chart were generated. There were no changes in the triage process during the study period.

During the physician self-assignment period (June 12, 2011, at 5:30 AM to June 12, 2012, at 5:29 AM), the team lead (charge nurse) placed charts into one queue ("rack") to signal readiness for evaluation and positioned them in that rack in the order in which he or she thought they should be seen. Physicians then picked up charts at their discretion.

During the rotational patient assignment period (June 12, 2012, at 5:30 AM to June 12, 2013, at 5:29 AM), a computer algorithm electronically assigned patients to a physician 60 seconds after registration (a delay put in place to exclude information that was erroneously entered and immediately deleted). Software then placed this assignment on the electronic tracking board, which was visually available to the entire department. After initiation of the rotational patient assignment system, each physician had his or her own rack, into which charts for his or her patients were placed. Physicians then evaluated these patients at their own pace, with the understanding that they must see and evaluate all patients assigned to them. Physicians noted the time of evaluation by actively "claiming" the patient on the electronic tracking board. The time at which this happened was recorded as the provider time, and this workflow did not change during the study period.

The assignment algorithm worked as follows: fifteen minutes before the beginning of each shift (30 minutes for the shifts starting at 6 AM and 11 PM), the algorithm assigned 3 consecutive patients to the oncoming physician. After the initial group of patients was assigned, the algorithm placed physicians into a queue and assigned patients to them on a rotating basis. The algorithm did not assign new patients to a physician within 90 minutes of the end of the shift. If the algorithm assigned a physician a total of 16 patients in a 9-hour

shift, the physician was removed from the queue, did not receive any more patients, and was tasked only with completing the ED encounter on patients assigned to him or her. Although we have subsequently made changes to this algorithm, we made those changes after the study period ended.

Our physician compensation model is salaried, with no component for clinical productivity. Our group operational culture includes an expectation that patient encounters will generally be complete or near complete (including disposition) before the physician leaves. Neither of these workplace characteristics changed between periods.

Methods of Measurement

We extracted data for age; sex; Emergency Severity Index score; ED volume; length of stay; arrival to provider time; and rates of left before being seen, left subsequent to being seen, early returns, and early returns with admission from the electronic medical record. We extracted complaint ratio data from an internal database that is specifically designed to record this information. We extracted emergency physician staffing data from an electronic scheduling tool (Tangier; Peake Software Labs, Sparks, MD). We extracted ED nurse staffing data before April 20, 2012, from handwritten logs and for subsequent dates from an electronic staffing tool (ANSOS One Staff; McKesson, San Francisco, CA). We obtained data to calculate effective hospital occupancy and degree of ED holding from a daily log of nursing operations.

The primary author (S.J.T.) and a trained, undergraduate-level research assistant (R.L.) were responsible for data abstraction.

We defined length of stay as the interval between when the patient registered in the department and when he or she either left the department or was placed into ED holding status; patients were generally placed into ED holding status 4 hours after a bed was requested if no inpatient bed was available. We defined arrival to provider time as the interval between when the patient registered in the department and the time at which the physician claimed the patient on the electronic tracking board. We report length of stay and arrival to provider time in minutes. We defined left before being seen as leaving before evaluation by a physician. We defined left subsequent to being seen as beginning treatment, but leaving before treatment was complete. We defined early return as returning to the ED within 72 hours of discharge. We defined early return with admission as returning to the ED within 72 hours of discharge and being admitted. We defined complaint ratio as the number of visits (per 1,000) for which there was contact with departmental administration expressing dissatisfaction or concern with the visit. We report left before being seen, left subsequent to being

seen, early returns, early returns with admission, and complaint ratio as frequencies or percentages. Our definitions for arrival to provider time, left before being seen, left subsequent to being seen, and complaint ratio are generally consistent with previously published definitions of these terms.[19,20]

We also collected data for potential confounding variables (variables that may correlate with both the dependent and independent variables being studied). The confounding variables we identified were the patient demographics of age, sex, and acuity, as well as the operational metrics of daily ED volume, physician staffing, nursing staffing, effective hospital occupancy, ED holding, day of week, and month of year.

We measured age in integral years on the day of arrival. We assigned sex according to patient declaration. We measured acuity through the Emergency Severity Index score, which the nursing staff assigned in standard fashion (1 to 5).

We defined daily ED volume as the number of patients who registered between 5:30 AM on the day in question and 5:29 AM the next morning.

We measured daily emergency physician staffing in patients per hour and defined it as daily ED volume divided by the number of physician staffing hours. We defined the number of physician staffing hours as the number of scheduled hours for a 24-hour period, beginning with the first shift (6 AM) of the calendar day. If a physician stayed late (a relatively common event) or left early (a relatively uncommon event), this number was not adjusted.

We measured daily ED nurse staffing in patients per hour and defined it as daily ED volume divided by the number of nurse staffing hours. We defined the number of nurse staffing hours as the number of actual hours worked during a 24-hour period, starting with the first shift (7 AM) of the day. Nurse staffing hours were tabulated only for clinical nurse personnel and excluded ED nursing management, clerical help, nursing aides, and technicians. Full or partial absences from scheduled shifts were not counted in the tabulation of nurse staffing hours.

We defined effective hospital occupancy for a given day as the ratio of occupied hospital beds at 6 AM to the total number of staffed hospital beds and report it as a percentage.

We assessed the presence or absence of ED holding daily; criteria for placing patients into ED holding status did not change between periods. We used ED holding (rather than ED boarding as conventionally defined[20]) as our measure of ED crowding because we lacked sufficiently accurate data to determine ED boarding for a significant portion of the study period.

Primary Data Analysis

We report age, daily ED volume, emergency physician staffing, ED nurse staffing, effective hospital occupancy, and degree of ED holding as medians with interquartile range and note means and standard deviations (SDs) for comparison. We report sex as the percentage of female patients. We report Emergency Severity Index scores as counts and percentages for each level.

In the primary analysis, we report length of stay and arrival to provider time as medians with interquartile ranges, and report them in minutes. We note means and SDs for comparison. We present left before being seen, left subsequent to being seen, early returns, early returns with admission, and complaint ratio as frequencies, ratios, or percentages. Length of stay and arrival to provider time were compared by differences in mean and median minutes; all other metrics were compared by differences in proportions.

In the secondary analysis, we used regression models to control for patient and ED characteristics, day of the week, and month of the year for the encounter. We applied a log transformation and used a linear regression on length of stay and arrival to provider time to measure improvement in geometric means. All other outcomes were modeled with log-binomial regression to measure relative risk. Because ED characteristics were aggregated and assigned to all patients treated during a 24-hour shift, we used generalized estimating equations[21] with an exchangeable covariance structure to account for clustered observations. We also stratified the results for length of stay by admitted and discharged patients. Emergency Severity Index score was categorized as high (1 or 2) versus low (3, 4, or 5) for all regression models.

RESULTS
Characteristics of Study Subjects

In the last year of physician self-assignment, there were 23,726 patient visits during 343 days (including February 29, 2012). In the first year of rotational patient assignment, there were 24,370 visits during 342 days.

For 212 visits in the period of physician self-assignment and 258 visits in the period of rotational patient assignment, data for Emergency Severity Index score were missing, and we excluded these visits from all subsequent analyses.

For 6 visits in the period of physician self-assignment and 6 visits in the period of rotational patient assignment, we could not reasonably determine length of stay and thus excluded these visits from length of stay analysis. In all of these cases, the documented length of stay was zero or less than zero.

For 386 visits in the period of physician self-assignment and 523 visits in the period of rotational patient assignment, we could not reasonably determine arrival to provider time and thus excluded these visits from arrival to provider time analysis. Reasons for exclusions included failure of the physician to assign himself or herself to the patient (resulting in absence of arrival to provider time), arrival to provider time of less than zero, and arrival to provider time greater than length of stay.

We audited the records of all 4 patients with length of stay greater than 6,000 minutes (100 hours). Three of these patients had a plausible length of stay reported (all were awaiting placement at a psychiatric facility). For one patient in the physician self-assignment period, the documented length of stay of greater than 20,000 minutes was inconsistent with the medical record, which documented discharge on the same calendar day as presentation. Because we had insufficient information to accurately determine length of stay for this patient, we excluded this visit from length-of-stay analysis.

Main Results

We report patient characteristics (age, sex, and Emergency Severity Index score) in Table 1 and operational confounders (ED daily volume, physician staffing, nursing staffing, effective hospital occupancy, and holding) in Table 2.

We report unadjusted outcomes in Table 3. During the period of rotational patient assignment, length of stay (for all patients, as well as for the subgroups of admitted and discharged patients), arrival to provider time, rate of left before being seen, rate of early returns, and complaint ratio were all lower. There were no significant changes with respect to left subsequent to being seen or early returns with admission.

We report our regression analysis results in Table 4. Regression analysis confirmed that rotational patient assignment was associated with a decrease in length of stay for all patients and discharged patients, but found no significant

Table 1. Patient characteristics.

Demographic	Physician Self-assignment, N=23,514	Rotational Patient Assignment, N=24,112
Sex (%)		
Female	12,544 (53.3)	12,627 (52.3)
Age, y		
Mean (SD)	58.4 (21.2)	58.6 (21.0)
ESI score (%)		
1	152 (0.6)	203 (0.8)
2	2,261 (9.6)	3,252 (13.5)
3	16,992 (72.3)	16,887 (70.0)
4	3,921 (16.7)	3,586 (14.9)
5	188 (0.8)	184 (0.8)

ESI, Emergency Severity Index.

Table 2. Operational confounders.

Confounder	Physician Self-assignment, N=343	Rotational Patient Assignment, N=342
ED daily volume		
Median (IQR)	68 (61–76)	71 (63–78)
Mean (SD)	69.3 (10.7)	71.4 (11.0)
Physician staffing		
Median (IQR)	1.37 (1.22–1.50)	1.31 (1.17–1.41)
Mean (SD)	1.37 (0.19)	1.30 (0.17)
Nurse staffing		
Median	0.33 (0.29–0.36)	0.32 (0.29–0.34)
Mean (SD)	0.33 (0.05)	0.32 (0.04)
Effective hospital occupancy, %		
Median (IQR)	91.8 (84.5–96.6)	83.2 (76.5–90.3)
Mean (SD)	90.6 (8.3)	82.9 (9.7)
ED holding, days (%)		
No	312 (91.0)	336 (98.2)
Yes	31 (9.0)	6 (1.8)

IQR, Interquartile range.

change in the length of stay for admitted patients. Regression analysis confirmed the qualitative findings that rotational patient assignment was associated with a decrease in arrival to provider time, rate of left before being seen, and complaint ratio. We also confirmed that there was no significant change in left subsequent to being seen or early returns with admission. The finding of a decrease in early returns, noted in the primary analysis, was not confirmed by the regression analysis.

A 3-year plot of length of stay by month, including the last 2 years of physician self-assignment and the first year of rotational patient assignment, is shown in Figure 1. Physician-specific data for length of stay in each period for all physicians who worked during the entire 24 months of the study period are shown in Figure 2.

LIMITATIONS

We report findings of correlation and not causation given that we present before-and-after data.

Although our regression analysis attempts to account for multiple confounding variables, such an attempt does not guarantee that all key factors were incorporated into the model. Many physician-level decisions that we did not consider, such as obtaining advanced imaging studies,[22] ordering blood tests,[23] and obtaining consultations[24] may play a role in ED operational outcomes such as length of stay. Because our core physician group underwent little change between these 2 periods, however, we did not attempt to control for these variables.

Although we believe that many of the problems we face at our facility are common, there are factors (in addition to our single-site setting) that may limit the generalizability of our results. Our staffing was more robust and our rate of

Table 3. Unadjusted patient outcomes.*

Outcome	Physician Self-assignment, N= 23,514	Rotational Patient Assignment, N=24,112	Difference	95% CI
LOS, min				
All patients				
Median (IQR)	232 (156-322)	207 (136-295)	25	23 to 28
Mean (SD)	253.4 (220.8)	229.2 (165.6)	24.2	20.7 to 27.7
Admitted				
Median (IQR)	304 (231-393)	283 (216-364)	21	17 to 26
Mean (SD)	320.9 (139.3)	298.5 (124.9)	22.4	18.1 to 26.4
Discharged				
Median (IQR)	199 (133-277)	170 (112-246)	29	26 to 31
Mean (SD)	220.0 (238.0)	191.5 (139.8)	28.5	24.2 to 32.7
APT, min				
Median (IQR)	39 (22-71)	22 (12-40)	17	16 to 17
Mean (SD)	53.9 (46.9)	31.4 (31.1)	22.5	21.8 to 23.2
LBBS	171 (0.73)	86 (0.36)	0.37%	0.24 to 0.51%
LSBS	98 (0.42)	115 (0.48)	−0.06%	−0.18 to 0.06%
72R	1034 (4.40)	970 (4.02)	0.37%	0.01 to 0.74%
72R/A	340 (1.45)	321 (1.33)	0.11%	−0.1 to 0.32%
CR	9	5.4	3.6	2.1 to 5.2

CI, Confidence interval; *LOS*, length of stay; *APT*, arrival to provider time; *LBBS*, left before being seen; *LSBS*, left subsequent to being seen; *72R*, early return; *72R/A*, early return with admission; *CR*, complaint ratio.
*LBBS, LSBS, 72R, and 72R/A are reported as frequencies (%). CR is reported as frequency per 1,000 patients.

ED holding was lower than is typical in many ED settings. However, this also means that our results are less likely to be clouded by issues of excessive holding or understaffing, possibly leading to a better understanding of the actual effect of any given throughput intervention.

We focus primarily on operational metrics and did not attempt to rigorously study variables addressing quality or provider satisfaction (among emergency physicians, consulting physicians, or ED nurses). Although we report anecdotal nurse and physician sentiment in our discussion, it is possible that a methodical assessment of nursing or physician attitudes would reveal results that were not apparent in subjective interviews.

Table 4. Adjusted patient outcomes.

Outcome	Physician Self-assignment*	Rotational Patient Assignment*	Effect†	95% CI
LOS				
Admitted	276.96	271.72	1.89	−0.49 to 4.22
Discharged	179.83	160.15	10.95	8.6 to 13.21
Overall	219.68	201.99	8.05	5.91 to 10.15
APT	30.72	19.55	36.34	32.61 to 39.88
LBBS	0.22	0.14	0.64	0.44 to 0.94
LSBS	0.43	0.41	0.95	0.63 to 1.44
72R	3.73	3.39	0.91	0.80 to 1.03
72R/A	1.60	1.39	0.87	0.70 to 1.09
CR	7.9	5.2	0.66	0.48 to 0.91

*LOS and APT are reported as geometric means in minutes. LBBS, LSBS, 72R, and 72R/A are reported as percentages. CR is reported as rate per 1,000 patients.
†LOS and APT are reported as percentage change. LBBS, LSBS, 72R, 72R/A, and CR are reported as relative risk of rotational patient assignment versus physician self-assignment.

Physician turnover may affect the results of a study such as this. Although our staffing during the study period was relatively constant, with 20 of 24 physicians working during part or all of both the physician self-assignment and rotational patient assignment periods, there was some variation: 1 physician left during the physician self-assignment period and 3 physicians were hired during the rotational patient assignment period. We believe that minor variations such as this are relatively common, however, and are consistent with changes observed over time in many EDs.

We report complaint ratio but not patient satisfaction scores. Because our organization changed patient satisfaction vendors midway through the study period, meaningful comparison of patient satisfaction between periods was not possible.

We report reduced arrival to provider time as a major benefit of this intervention. However, our arrival to provider time in the physician self-assignment period was relatively long, suggesting that there was significant potential for improvement regardless of intervention. The assignment process alone may also have changed the way in which arrival to provider time was recorded. In the physician self-assignment period, there was little or no reason for a physician to electronically claim a patient in the waiting room; in the rotational patient assignment period, physicians may have claimed such patients before treating them to reinforce their responsibility for them. If so, this might account for some of the observed difference in arrival to provider time. It would not, however, account for any of the observed difference in length of stay.
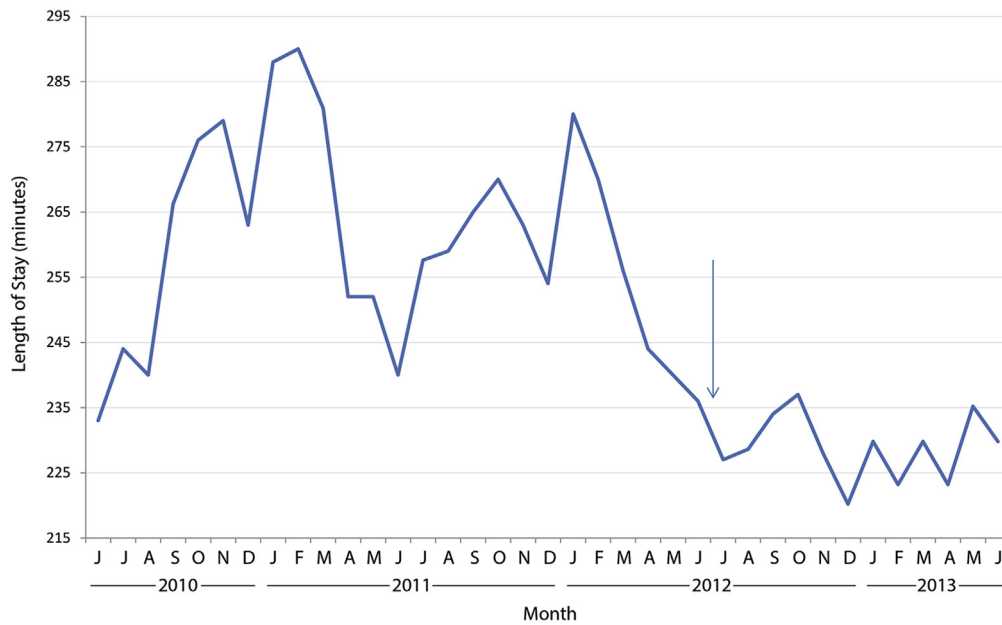
Figure 1. Monthly length of stay, June 2010 to June 2013. Arrow indicates the initiation of rotational patient assignment.

Although there was no formal discussion of a plan to publish the results of this particular intervention at initiation, the ED staff was generally aware of the investigators' interest in operational improvements. Although we do not believe that staff altered their practice with a goal of showing improvement with rotational patient assignment, we cannot rigorously exclude this possibility.

Changes over time in several confounding variables (such as the level of physician and nurse staffing, which increased; ED holding, which decreased; and effective hospital occupancy, which decreased) would tend to favor operational improvements in the rotational patient

Figure 2. Average length of stay by individual physician before and after the intervention. Each line represents one physician.

assignment group. Although our regression analysis attempts to account for this, we cannot be certain that mathematical modeling alone definitively addresses these biases. Furthermore, we cannot exclude the possibility that other, unidentified changes affected outcomes.

We relied heavily on systems-generated data. Although we audited these data and removed illogical values, the fact that we had to do so raises the possibility that other data, although logical, were imperfect. We believe that this is an inherent problem with any study that relies on large amounts of data because individual chart audits on this scale are not feasible. Because there was no change in electronic data processing or warehousing during the study period, however, we also believe it unlikely that there was an unequal distribution of imperfections between the 2 groups.

Although our statistical analysis accounts for clustering within a 24-hour period, this is an imperfect approach because visits that begin near the end of one 24-hour period may affect those at the start of the next 24-hour period, and vice versa.

We use slightly different mathematical conventions in our primary and secondary analysis for length of stay and arrival to provider time, which may be confusing. In our primary analysis, we use arithmetic means (the sum of *n* numbers divided by *n*) to report length of stay and arrival to provider time because this is a more intuitive value when before-and-after change is assessed. In our secondary analysis, however, we report geometric means (the *n*th root of *n* terms) for these outcomes. Results of linear regression models in which the dependent variable is log transformed
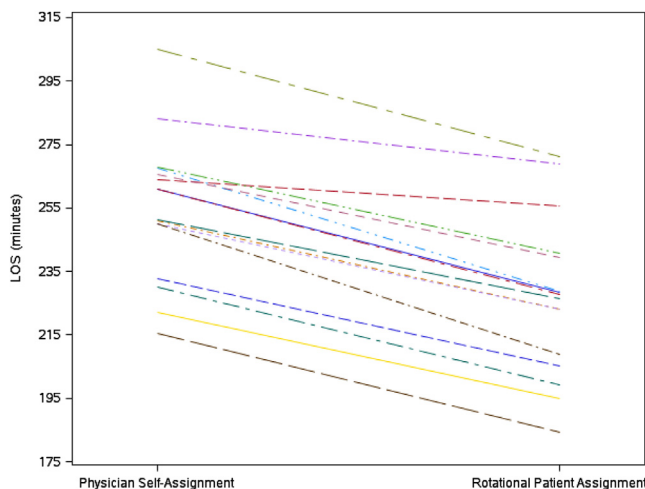
can be used to estimate a relationship between the ratio of geometric means (as opposed to an expected change in arithmetic means). Comparison of arithmetic and geometric means is rarely straightforward because the geometric mean of a data set is almost always less than the arithmetic mean.

DISCUSSION

In a single-facility study, transition from physician self-assignment to rotational patient assignment was associated with significant improvements in a number of ED operational metrics.

Our findings are consistent with the work of other groups in regard to rotational patient assignment in the ED.[15-18] However, these previous studies were performed before the near-universal adoption of electronic patient tracking, which has implications for comparison.

Three groups have previously reported some version of a system in which patients were assigned to alternating teams.[15-17] Two of these groups reported a decrease in arrival to provider time (of 9.5 minutes[15] and 13 minutes[16]), 2 reported an increase in patient satisfaction,[16,17] but none reported changes in length of stay. An older report describes a semicontrolled study in which rotational patient assignment was instituted for residents on the "medical side" of a "medical side/surgical side" ED at a teaching facility. Length of stay improved on the medical side by approximately 15%, whereas length of stay increased on the surgical side.[18]

A visual analysis of our monthly length of stay for a 3-year period (the last 2 years of physician self-assignment and the first year of rotational patient assignment) suggests the general effect of the intervention (Figure 1). In the 2 years before the institution of rotational patient assignment, length of stay had a cyclic nature, with a nadir in the summer, an increase in the fall, a maximum in the winter, and a decline in the spring. This cyclic variation was significantly attenuated or lost altogether in the first year of rotational patient assignment.

After adjusting for confounders, length of stay was improved for discharged patients, but not for admitted patients. Although it is possible that the intervention had a differential effect on admitted versus discharged patients, it is also possible that the greater length of stay or the smaller sample size in admitted patients made it more difficult to show a statistical effect.

We found that rate of left before being seen and the complaint ratio both improved. One explanation is that patients define their wait to be seen as ending with physician contact. If so, and if that wait plays a part in both left before being seen[25] and patient satisfaction,[26] then an intervention that reduces arrival to provider time could reasonably be expected to improve the rate of left before being seen and the complaint ratio as well.

Our physician-level results (Figure 2) indicate that rotational patient assignment led to improvement of length of stay for all physicians. There was some concern at our facility, voiced before adoption, that rotational patient assignment might have a positive influence on length of stay for some physicians and a negative influence for others. Our results, however, found that this was not the case.

In general, queuing theory suggests that inflexible systems (of which rotational patient assignment might be considered one) lead to decreases rather than increases in efficiency. We and others believe it is unlikely that the ED represents an exception to this rule,[27] and our success might therefore seem counterintuitive. We believe, however, that the incremental rigidity introduced by this system was minor in that all physicians were still available to treat all types of patients. Empirically, it seems that another aspect of the intervention—ensuring that patients were assigned to physicians immediately—outweighed any negative effects.

We suspect that our results are most generalizable to EDs in which attending physicians process patients independently, as opposed to those in which residents or advanced practice providers co-manage patients with attending physicians. However, one academic medical center has reported a throughput benefit with a rotational patient assignment model.[18]

Our intervention is similar to interventions that have proven effective in other industries. Fair, efficient, and skilled-based routing in telephone call centers are well-studied mechanisms that determine the optimal assignment of incoming calls to agents,[28] and data communication networks and manufacturing systems use algorithmic scheduling techniques to ensure efficiency of flow.[29]

Subjective nursing response to this intervention has been positive. In the period of physician self-assignment, there was little clarity of physician responsibility for patients who had been assigned to a nurse but not yet picked up by a physician. With rotational patient assignment, physician ownership is nearly immediate and always unambiguous, allowing nurses to identify a responsible physician when one is needed.

Subjective physician response to this intervention has been mixed. Physicians believe that rotational patient assignment promotes equitable distribution of patients over time and note that it has led to significant and important operational gains. However, day-to-day (or even patient-to-patient) variations can lead to perceptions of workload inequality because the average acuity of patients assigned to

one physician might be higher than that of patients assigned to another. An additional negative aspect of this system from the perspective of the physician is the loss of autonomy in regard to discretion in assuming care for new patients. At our facility, the assignment of patients to providers irrespective of acuity, circumstances, or timing has led to a description of this system as "mercilessly fair."

Physicians have expressed generally negative feelings about having waiting room patients assigned to them because this generates ownership without necessarily providing the immediate resources needed to fully care for patients. Immediate assignment does, however, mean that physicians can identify patients for whom they will be responsible early in the encounter, allowing them to evaluate them in a triage room or place orders toward the beginning of the visit.

To mitigate concerns about patient safety compromise that could potentially arise from loss of physician discretion in assuming responsibility for new patients, we have encouraged providers to "trade" patients with one another if doing so is perceived to be in the best interests of patient care. We do not track or quantify this event, but in our experience it has been rare.

The rate of early returns and early returns with admission (in the adjusted model) did not change after adoption of rotational patient assignment. Although these findings may suggest that our intervention did not adversely affect quality, we note that these metrics are controversial with respect to analyzing ED quality.[30,31]

We implemented a simple rotational framework. Although this was successful at our facility, it is possible that a more advanced assignment algorithm (one taking into account patient Emergency Severity Index score, workload, recent arrivals per provider, etc) would prove superior. Advanced algorithms are commonly used to solve similar problems in other industries, such as routing incoming calls in call centers or assigning data packets to various servers in communications networks. Future research may help to explore this possibility.

Our intervention does not rely on incremental resources for success; rotational patient assignment can be instituted without additional nurses, physicians, or space.

Finally, a rotational patient assignment system is almost assuredly not appropriate for every ED. We believe that this intervention was successful at our institution largely because it brought clarity to the question of which physician should pick up the next patient. In a single-coverage ED, this may not even be a theoretical question. In a larger ED, incentives (financial or otherwise) may have already optimized this aspect of front-end operations. In such cases, the institution of rotational patient assignment would likely be unhelpful at best and counterproductive at worst.

In a single-facility study, rotational patient assignment was associated with significant operational improvements compared with physician self-assignment. Rotational patient assignment deserves consideration as an intervention in front-end ED process redesign.

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