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Original Contribution

The durability of operational improvements with rotational patient assignment☆

Stephen J. Traub, MD [a,b,*], Soroush Saghafian, PhD [c], Adam C. Bartley, MS [d], Matthew R. Buras, MS [e], Christopher F. Stewart, MD [a,b], Brian T. Kruse, MD [b,f]

[a] Department of Emergency Medicine, Mayo Clinic Arizona, Phoenix, AZ, United States
[b] College of Medicine, Mayo Clinic, Rochester, MN, United States
[c] Harvard Kennedy School, Cambridge, MA, United States
[d] Division of Health Systems Informatics, Mayo Clinic, Rochester, MN, United States
[e] Division of Health Sciences Research, Mayo Clinic Arizona, Phoenix, AZ, United States
[f] Department of Emergency Medicine, Mayo Clinic Florida, Jacksonville, FL, United States

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ABSTRACT

Introduction: Previous work has suggested that Emergency Department rotational patient assignment (a system in which patients are algorithmically assigned to physicians) is associated with immediate (first-year) improvements in operational metrics. We sought to determine if these improvements persisted over a longer follow-up period.

Methods: Single-site, retrospective analysis focused on years 2–4 post-implementation (follow-up) of a rotational patient assignment system. We compared operational data for these years with previously published data from the last year of physician self-assignment and the first year of rotational patient assignment. We report data for patient characteristics, departmental characteristics and facility characteristics, as well as outcomes of length of stay (LOS), arrival to provider time (APT), and rate of patients who left before being seen (LBBS).

Results: There were 140,673 patient visits during the five year period; 138,501 (98.7%) were eligible for analysis. LOS, APT, and LBBS during follow-up remained improved vs. physician self-assignment, with improvements similar to those noted in the first year of implementation. Compared with the last year of physician self-assignment, approximate yearly average improvements during follow-up were a decrease in median LOS of 18 min (8% improvement), a decrease in median APT of 21 min (54% improvement), and a decrease in LBBS of 0.69% (72% improvement).

Conclusion: In a single facility study, rotational patient assignment was associated with sustained operational improvements several years after implementation. These findings provide further evidence that rotational patient assignment is a viable strategy in front-end process redesign.

1. Introduction

The Emergency Department (ED) front-end (that portion of the visit between patient arrival and the time a provider assumes definitive care of a patient [1]) is an area in which ED administration and personnel generally have a great deal of operational control. As such, it is often an area for innovation and redesign to improve patient flow. Examples of front-end interventions include the use of a fast-track [2], physician in triage [3,4], telemedical triage [5,6], bedside registration [7], virtual patient streaming [8], and split-flow models [9].

Rotational patient assignment is another ED front-end process redesign, in which patients are algorithmically assigned to physicians. This workflow inverts a typical approach of relying on physicians to acquire (or "pick up") new patients at their discretion. Previous work has shown that rotational patient assignment is associated with short-term operational gains [10-15], but the long-term effects of rotational patient assignment on operational metrics are unclear.

Improving clinical operations is an overarching goal of virtually every ED. Operational improvements have the potential to improve clinical care, increase patient satisfaction, and improve financial

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* Corresponding author at: Department of Emergency Medicine, Mayo Clinic Arizona, 5777 E. Mayo Boulevard, Room 1-134A, Phoenix, AZ 85054, United States.
E-mail address: Traub.Stephen@Mayo.edu (S.J. Traub).

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performance. Such improvements can also help to decrease ED crowding, a condition associated with a number of negative patient outcomes [16]. Knowing if an intervention was likely to produce long-term gains might help ED administrators and personnel decide if such an intervention was a worthwhile investment at their facility.

We report long-term operational metrics (years 2–4) in a rotational patient assignment system, with the goal of understanding the durability of improvements over time.

2. Methods

2.1. Institutional review board

This work was part of a quality improvement initiative, and was identified as exempt by our Institutional Review Board process, with a waiver of the requirement for informed consent.

2.2. Study design and setting

This was a retrospective, single-site analysis of routinely gathered operational data.

The Mayo Clinic Arizona ED is located in tertiary care teaching hospital in Phoenix, Arizona. The average yearly census during the 5 year period was 28,135 (range: 25,651–32,224), and the average admission rate was 31%. The ED has 24 rooms, and 9 hallway bays. The ED is staffed 24 h per day with board-certified emergency physicians. There are no advanced practice providers (nurse practitioners or physician assistants), and there is no fast-track. There is no Emergency Medicine training program, although residents from multiple services rotate through the department as learners and are involved in the evaluation of approximately 5% of visits. Residents acquire patients *ad libitum*, without having patients assigned to them, and may see patients assigned to any attending physician.

2.3. Selection of participants

We electronically reviewed all patient visits identified by our electronic medical record (EMR; Cerner®; Kansas City) within a five-year period (June 12, 2011–June 11, 2016) that included our last year of physician self-assignment and the first four years of rotational patient assignment.

We have previously reported a comparison of operational metrics for our last year of physician self-assignment (June 12, 2011 to June 11, 2012) and our first year of rotational patient assignment (June 12, 2012 to June 11, 2013) [14]. We include data from our original publication herein for reference and as a part of a regression analysis, but note that these are not novel data.

2.4. Interventions

For the entirety of the five year period, virtually all ambulance patients were roomed immediately and registered at bedside. Ambulatory patients underwent quick registration and nursing triage, in a dedicated triage area or at bedside.

In the last year of physician self-assignment, there was one queue ("rack") into which the charge nurse placed all charts, in the order that she or he thought they should be evaluated. Physicians then picked up patients at their discretion.

After implementation of rotational patient assignment, a computer algorithm electronically assigned patients to physicians 60 s after registration. In the first iteration of this system, physicians were assigned 3 consecutive patients at the beginning of their shift, were not assigned any patients in the last 90 min of their shift, and were not assigned more than 16 patients per shift. In its current iteration, physicians are assigned 4 consecutive patients at the beginning of their shift, are not assigned any patients in the last 120 min of their shift, and are not assigned more than 18 patients per shift.

In all iterations, after the initial allocation of patients physicians are placed into a strict rotation with other on-duty physicians. Assignments are made based solely on arrival time, without consideration of patient demographics, chief complaint, Emergency Severity Index score, provider patient load, or acuity of patients recently assigned to the provider.

The typical shift length is 9 h. A more detailed discussion of the first iteration of this system has been reported previously [14].

2.5. Methods and measurements

We defined LOS as the time interval (in minutes) between registration and the end of the ED visit. The end of the ED visit was defined as leaving the department or being placed into holding status, which generally occurred if a bed had not been assigned to an admitted patient 4 h after a bed request was placed. We defined APT as the time from registration until the time that a physician electronically "claimed" the patient (an event that occurred after, and independent of, the patient being assigned to a certain physician). LBBS was defined as leaving before evaluation by a physician. None of these working definitions or parameters changed during the five year period.

Total nurse staffing hours was defined as the number of hours worked by clinical nurse staff (excluding nurse administrators, nursing aides, and technicians) starting with the 7 AM shift, which was the first shift of the day. Nursing workload was defined as daily ED census/total nurse staffing hours. Total physician staffing hours was defined as the number of scheduled physician hours, beginning with the 6 AM shift, which was the first shift of the day. Physician workload was defined as daily ED census/total physician staffing hours. ED holding is expressed as number of days in which any ED holding occurred. Effective hospital occupancy was defined as the hospital census divided by the number of staffed beds (expressed as a proportion) at 6 AM.

Data for LOS, APT, LBBS and daily ED census were retrieved from the EMR. Data for nurse staffing were retrieved from handwritten logs and ANSOS One Staff® (McKesson, San Francisco, CA). Data for physician staffing were retrieved from Tangier® (Peake Software Labs, Sparks, MD). Data for effective hospital occupancy and ED holding were retrieved from a customized hospital operations report.

Non-parametric 95% bootstrap confidence intervals were produced to evaluate the differences between the means and medians for LOS and APT and the differences in percentage for LBBS. In each case we performed 1000 replications and calculated the 2.5th percentile and the 97.5th percentile to provide the lower and upper limits (respectively) of the 95% confidence intervals. Statistical significance was defined as a bootstrap confidence interval that did not include zero.

We performed a multiple linear regression to determine the change in LOS in the 4 years of rotational patient assignment vs. the last year of physician self-assignment after accounting for confounders. We used a simplified model incorporating those variables (ED holding, effective hospital occupancy) that changed in a direction that might independently decrease LOS, and did not incorporate potential confounders that showed little or no change (such as physician and nurse staffing) or changed in a manner that would tend to increase LOS (such as ED volume).

Statistical analysis was performed with SAS version 9.3 (SAS Institute Inc., Cary NC).

3. Results

3.1. Patient and site characteristics

There were 140,673 visits over the 5 year period. We eliminated 1,772 visits (1.3%) with APT or LOS values that were missing or illogical (such as APT or LOS of less than zero). This left 138,901 visits eligible for analysis.

Yearly ED volumes and yearly study subject characteristics are presented in Table 1. There was little change in age or gender over the 5 year period, and a slight increase in acuity (manifesting primarily as

Table 1
ED volume and patient characteristics.

Characteristic	Physician self-assignment	Rotational patient assignment			
	Last year	Year 1	Year 2	Year 3	Year 4
Volume	25,651	26,381	26,804	29,613	32,224
Age (years)					
Median (IQR)	62 (44, 76)	62 (44, 76)	62 (44, 76)	62 (44, 75)	61 (43, 75)
Mean (SD)	58.6 (21.2)	58.8 (20.9)	59 (20.8)	58.7 (20.7)	58.1 (21)
Sex (percent female)	53.2	52.4	53.4	52.9	53.8
ESI Score (percentages)					
Level 1	0.6	0.9	0.9	0.8	0.8
Level 2	9.7	13.6	13.9	13.6	14.6
Level 3	72.0	69.9	72.3	74	73.4
Level 4	16.8	14.9	12.3	11.1	10.6
Level 5	0.8	0.8	0.7	0.6	0.6

IQR, interquartile range; SD, standard deviation; ESI, emergency severity index.

an increase in ESI level 2 patients and a decrease in ESI level 4 patients) in all four years of rotational patient assignment vs. the last year of physician self-assignment.

Daily departmental and facility characteristics are presented in Table 2. There was little change in physician or nurse workload over the 5 year period, but notable fluctuations in ED holding and effective hospital occupancy.

3.2. Main results

Data for LOS, APT and LBBS are presented in Table 3. LOS, APT and LBBS improved in every year of rotational patient assignment vs. the last year of physician self-assignment.

In a multiple linear regression analysis incorporating ED holding and hospital occupancy, LOS improvements remained statistically significant (Table 4).

4. Discussion

4.1. Limitations

Our long timeline of data acquisition (5 years) is central to our analysis and conclusions, but raises concerns about confounding by operational drift (improvements or declines in operations over time unrelated to the change being evaluated). We made no operational changes during the study period similar in scope to rotational patient assignment, made no significant changes in laboratory or radiology processing, introduced no significant changes to the Electronic Medical Record (EMR), and did not implement any significant hospital flow changes (such as smoothing of elective surgeries). Nonetheless, we cannot exclude the possibility that unmeasured or unintended changes contributed to the lower LOS that we found during follow-up.

We report simple comparisons, when ED LOS may depend on myriad factors. We confirmed the directionality of our results for LOS with a regression analysis incorporating ED holding and effective hospital occupancy, which both changed in a manner that would tend to improve LOS. However, we neither measured nor accounted for other variables that might affect LOS, such as ICU census [17] or daily percentage of ED patients who are admitted [17,18].

Our analysis is of a single site, which limits generalizability. Of note, we show durability of improvements only to a volume of approximately 32,200; the translation of our model to larger volume facilities is unknown. We also do not use advanced practice providers, and cannot comment about how to integrate advanced practice providers into a model such as this. In addition, staffing at our facility is relatively robust, and holding relatively rare. We note, however, that these factors may also make it easier to determine the effect of an intervention such as ours, without concern for confounding by staffing or holding concerns.

In previous work, we found statistically significant improvements in LOS for both admitted and discharged patients in an unadjusted primary analysis, but only for discharged patients in a secondary analysis which was adjusted for operational confounders [14]. These findings may be important when facilities with admission rates different than ours (31%) consider rotational patient assignment as an intervention.

We do not report patient satisfaction data, nor do we report surrogate data such as complaint rate. An institutional change in vendors during the study period precluded any meaningful longitudinal analysis of patient satisfaction data. Our methodology for identifying and cataloging patient complaints also changed during the period of follow-up, precluding meaningful analysis of that data as well.

We focus on ED operational data without considering non-LOS quality outcomes. Unfortunately, such quality outcomes are difficult to identify and quantify, particularly in studies such as this. There is substantial debate as to whether readily available metrics (such as returns to the ED within 72 h or returns to the ED within 72 h resulting in admission) are clear markers of quality [19-21].

We rely heavily on systems-generated data. We excluded unlikely or illogical data (i.e. LOS of zero or less than zero). Although we accepted

Table 2
Daily facility characteristics.

Characteristic	Physician self-assignment	Rotational patient assignment			
	Last year ($n = 366$)	Year 1 ($n = 365$)	Year 2 (n = 365)	Year 3 (n = 365)	Year 4 (n = 366)
Physician workload	1.36 (0.19)	1.30 (0.17)	1.31 (0.18)	1.39 (0.17)	1.37 (0.17)
Nurse workload	0.33 (0.05)	0.32 (0.04)	0.35 (0.05)	0.37 (0.05)	0.35 (0.04)
Effective hospital occupancy	0.90 (0.09)	0.82 (0.10)	0.74 (0.09)	0.69 (0.08)	0.77 (0.15)
ED holding	36 (9.8%)	6 (1.6%)	3 (0.82%)	7 (2.0%)	27 (7.4%)

ED, Emergency Department.
Physician and Nurse workload expressed as mean (standard deviation) of ratio of total patients/total labor hours.
Effective hospital occupancy expressed as mean (standard deviation) of percentage of occupied staffed beds at 6 AM.
ED holding expressed as days (percent of days) in that year during which ED holding occurred.
Mathematical relationships may appear imperfect due to rounding.

Table 3
Main results.

Metric	Physician self-assignment	Rotational patient assignment			
	Last year	First year	Second year	Third year	Fourth year
LOS (minutes)					
Median (IQR)	232 (156–322)	208 (137–296)	213 (143–300)	217 (144–303)	211 (139–295)
Difference of medians (95% CI)		**24** (**22–27**)	**19** (**16–21**)	**15** (**12–17**)	**21** (**19–24**)
Percentage change in medians		**−10%**	**−8%**	**−6%**	**−9%**
Mean (SD)	253 (1501)	230 (163)	235 (156)	238 (230)	232 (187)
Difference of means (95% CI)		**23** (**20–26**)	**18** (**15–20**)	**15** (**12–18**)	**20** (**18–23**)
Percentage change in means		**−9%**	**−7%**	**−6%**	**−8%**
APT (minutes)					
Median (IQR)	39 (22–70)	23 (12–41)	20 (9–41)	23 (11–47)	21 (10–40)
Difference of medians (95% CI)		**16** (**15–17**)	**19** (**18–19**)	**16** (**14–16**)	**18** (**17–18**)
Percentage change in medians		**- 41%**	**- 49%**	**- 41%**	**- 46%**
Mean (SD)	54 (48)	32 (34)	33 (48)	36 (39)	31 (32)
Difference of means (95% CI)		**21** (**21 − 22**)	**21** (**21–22**)	**18** (**17–19**)	**23** (**22 − 23**)
Percentage change in means		**−39%**	**−39%**	**−33%**	**−43%**
LBBS					
Percentage	0.95%	0.51%	0.20%	0.27%	0.30%
Difference of percentages (95% CI)		**0.44%** (**0.30%–0.58%**)	**0.74%** (**0.62%–0.87%**)	**0.67%** (**0.54%–0.80%**)	**0.65%** (**0.52%–0.78%**)
Percentage change in percentages		**−46%**	**−77%**	**−71%**	**−68%**

LOS, length of stay; APT, arrival to provider time; LBBS, left before being seen.
Values for LOS and APT rounded to nearest minute.
All differences are vs. last year of physician self-assignment; statistically significant changes in **bold**.
Mathematical relationships may appear imperfect due to rounding.

the remainder of the data as accurate, we cannot be certain that there were no errors in the final data set, or that errors did not affect one group or one variable more than others.

4.2. Main discussion

Improvements in ED operations can yield multiple benefits. A reduction in LOS and the associated improved throughput may reduce waiting times, which correlate strongly and negatively with patient satisfaction [22,23]. Operational improvements often decrease the rate of patients who leave before being seen, which is of benefit with respect to patient care, financial performance, and risk management. Improved ED throughput may also help to reduce ED crowding, which is associated with medication errors [24], negative patient outcomes [25,26], poor patient satisfaction [27] and negative perceptions of care [28].

The front-end of the ED is an area over which the ED often has complete or near-complete operational control, with few external stakeholders. As such, it is an area where changes designed to reduce LOS can be made relatively easily. Accordingly, numerous front-end innovations are described in the literature, including physician in triage, telemedical triage, bedside registration, and the use of a fast-track. These interventions and others are reviewed elsewhere [1,29].

Another front-end intervention is rotational patient assignment. In a system of rotational patient assignment, patients are assigned to physicians based on an algorithm, rather than leaving the decision to acquire new patients to physician discretion. Previous experiences with rotational patient assignment have found that it is associated with decreased arrival to provider time [10,11,14], increased patient satisfaction [11,13], a decrease in complaints [14], and lower overall LOS [12,14,15].

Table 4
Decrease in LOS with rotational patient assignment, by year.

Year	Estimated decrease in LOS	95% CI
1	20.2	15.7–24.7
2	13.4	8.5–18.3
3	9.6	4.0–15.1
4	17.0	12.1–21.9

Change in LOS for each year expressed vs. last year of physician self assignment, in minutes.
Regression model incorporates ED holding and effective hospital occupancy.
CI: confidence interval.

Deciding how or whether to proceed with ED front-end redesign may be challenging. There is scant literature available to help ED personnel decide which front-end redesign (if any) is appropriate for their ED; the before-and-after nature of most operational interventions means that interventions are often compared with a “standard practice” rather than directly with one another. Rarely, fortuitous timing may allow for a comparison between two different front end redesigns [30], but such comparisons are uncommon.

A second challenge lies in the lack of data to determine if changes observed in the immediate post-implementation period persist over time. The published results of most interventions describe the immediate follow-up period, almost always focusing on a period of less than or equal to one year, without reporting long-term results. One exception to this is a report regarding a physician in a triage model, which showed operational improvements that persisted in year 3 after implementation [31].

The lack of robust data regarding the durability of operational gains with front-end redesign strategies may be an impediment to front-end change in and of itself. Organizational change can be extraordinarily difficult [32], with multiple barriers at the level of both formulation and implementation [33]. The lack of follow-up efficacy studies for front-end redesign efforts may give ED management personnel pause when deciding whether to dedicate resources or change management efforts to such projects.

We found that the operational gains in LOS, APT and LBBS that we previously reported in the first year of rotational patient assignment persisted in years 2–4, with approximate average yearly decreases in median LOS of 18 min (8% of baseline), median APT of 21 min (54% of baseline), and LBBS of 0.69% (72% of baseline). Importantly, we found that our improvements remained relatively consistent over the three year follow-up period, and that we did not observe a general trend back towards pre-implementation values. There did appear to be a mild decline in improvements in year 3, but these improvements essentially recovered in year 4. Improvements observed in year 4 were very similar to (and in some cases slightly better than) improvements observed in year 1. We believe that this demonstrates the durability of operational gains with rotational patient assignment.

Importantly, these gains have persisted without significant active management. Once this system was accepted by nurses and physicians (a process that was essentially complete within six months), ED management has performed little or no work to keep it in place. Rotational patient assignment has become an integral and unquestioned part of our group's operating culture.

We note that the institution of rotational patient assignment has abolished all concerns regarding differential productivity. Differential productivity may be a point of contention in any system (such as ours) where physicians are salaried, with no financial incentives for productivity.

Over time, we have made small changes to our underlying algorithm. We changed our initial patient allocation at the beginning of the shift from three patients to four, in order to increase the amount of work physicians perform at the beginning of their shift. We also changed the time of last patient assignment ("cut-off time") from 90 min to 120 min before the end of a shift. We made this change based on an empiric observation that physicians were staying well past the nominal end of their shift with a cut-off time of 90 min. We have a strong group operating culture that limits sign-outs at the end of the shift, however, and note that groups without such a culture might not require such a long cut-off time. In order to increase productivity, we also changed our maximum number of patients per shift to 18 from 16.

We note that our gains persisted despite a significant increase in daily ED volume. Compared to baseline (the last year of physician self-assignment), ED visit volumes in years 1–4 of rotational patient assignment rose by approximately 3%, 4%, 15% and 26%, respectively. During this time, we did not add any additional treatment space. While it is possible that we would have been able to manage this increase in volume without rotational patient assignment, the subjective assessment of ED management was that rotational patient assignment has played a vital role in maintaining throughput, as this system assigned an accountable physician to each patient essentially upon patient arrival.

Although we have demonstrated durable success of rotational patient assignment at our facility, we believe that this intervention would not be appropriate for every ED. For example, if a group has strong financial incentives for productivity, a system such as ours may generate resentment from physicians who lose autonomy in determining their own balance of productivity vs. compensation. Autonomy is a known driver of physician satisfaction [34].

We also note that rotational patient assignment may not be compatible with, or add value to, other successful front-end redesign efforts. The provider in triage model, for example, has demonstrated success at many institutions whether the provider is an attending physician [3,35], a resident physician [36], or a physician assistant [37]. Many of the operational gains associated with provider in triage are believed to accrue to the practice of a provider entering appropriate orders early in the encounter during an initial screening examination.

In rotational patient assignment, physician ownership of patients occurs almost immediately upon registration. As such, physicians have a strong incentive to screen their own patients as soon after registration as possible, even if it means doing so in a triage area. Of note, although our facility noticed a benefit with use of a physician in triage, we elected not to use it concurrently with rotational patient assignment. We were concerned that combining the systems would lead to duplicative work, as data at our facility demonstrated that, after screening by a physician in triage, patients sent to the main ED and evaluated by a second physician had additional imaging or testing ordered over 50% of the time [4]. We felt that the initial screening process was best left to the primary physician, as is the workflow in rotational patient assignment.

In conclusion, we found that rotational patient assignment was associated with operational gains that persisted several years after implementation. While such a system is almost assuredly not appropriate for every department, our findings provide further evidence that rotational patient assignment is a valid and durable approach to ED front-end process redesign.

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