

Impact of process improvements on measures of emergency department efficiency

Alexander K. Leung, MD*[†]; Shawn D. Whatley, MD[†]; Dechang Gao, MSc[‡]; Marko Duic, MD, MBA[†]

ABSTRACT

Objective: To study the operational impact of process improvements on emergency department (ED) patient flow. The changes did not require any increase in resources or expenditures.

Methods: This was a 36-month pre- and post-intervention study to evaluate the effect of implementing process improvements at a community ED from January 2010 to December 2012. The intervention comprised streamlining triage by having patients accepted into internal waiting areas immediately after triage. Within the ED, parallel processes unfolded, and there was no restriction on when registration occurred or which health care provider a patient saw first. Flexible nursing ratios allowed nursing staff to redeploy and move to areas of highest demand. Last, demand-based physician scheduling was implemented. The main outcome was length of stay (LOS). Secondary outcomes included time to physician initial assessment (PIA), left-without-being-seen (LWBS) rates, and left-against-medical-advice (LAMA) rates. Segmented regression of interrupted time series analysis was performed to quantify the impact of the intervention, and whether it was sustained.

Results: Patients totalling 251,899 attended the ED during the study period. Daily patient volumes increased 17.3% during the post-intervention period. Post-intervention, mean LOS decreased by 0.64 hours ($p < 0.005$). LOS for non-admitted Canadian Triage and Acuity Scale 2 (-0.58 hours, $p < 0.005$), 3 (-0.75 hours, $p < 0.005$), and 4 (-0.32 hours, $p < 0.005$) patients also decreased. There were reductions in PIA (43.81 minutes, $p < 0.005$), LWBS (35.2%, $p < 0.005$), and LAMA (61.9%, $p < 0.005$).

Conclusion: A combination of process improvements in the ED was associated with clinically significant reductions in LOS, PIA, LWBS, and LAMA for non-resuscitative patients.

RÉSUMÉ

Objectif: L'étude visait à examiner l'incidence opérationnelle d'améliorations apportées à différents processus sur le flux des patients au service des urgences (SU). Les changements n'ont exigé ni augmentation de ressources ni accroissement de dépenses.

Méthode: Il s'agit d'une étude de 36 mois, de type avant et après intervention, visant à évaluer l'effet de la mise en œuvre de différentes améliorations apportées à des processus dans un SU d'un hôpital communautaire, et menée de janvier 2010 à décembre 2012. L'intervention consistait en un triage simplifié par le placement des patients acceptés dans des salles d'attente internes immédiatement après le triage. Des processus parallèles se déroulaient au SU et il n'y avait pas de restriction quant au moment de l'inscription ou au type de professionnel de la santé que le patient voyait en premier. Des rapports de charge souples chez le personnel infirmier permettaient à celui-ci d'être réparti autrement et d'être déplacé vers les zones où les besoins étaient les plus grands. Enfin, il y a eu la mise en place d'horaires de travail en fonction de la demande chez les médecins. Le principal critère d'évaluation était la durée de séjour (DS). Les critères d'évaluation secondaires comprenaient le temps écoulé avant la première évaluation médicale (PEM), le taux de départ sans examen médical (DSEM) et le taux de départ contre l'avis du médecin (DCAM). Les auteurs ont procédé à une régression segmentée d'une analyse de séries temporelles interrompues afin de quantifier l'incidence de l'intervention et d'en déterminer la durabilité.

Résultats: Durant la période à l'étude, 251 899 patients ont consulté au SU. Le volume quotidien de patients a augmenté de 17,3 % durant la période après l'intervention. La durée moyenne de séjour durant cette même période a diminué de 0,64 heure ($p < 0,005$). La DS pour les patients non hospitalisés appartenant aux classes 2 (-0,58 heure; $p < 0,005$), 3 (-0,75 heure; $p < 0,005$) ou 4 (-0,32 heure; $p < 0,005$) de l'Échelle canadienne de triage et de gravité a également diminué. Enfin, une diminution a été enregistrée en ce qui concerne le temps avant la PEM (43,81 minutes; $p < 0,005$), le taux de DSEM (35,2 %; $p < 0,005$) et le taux de DCAM (61,9 %; $p < 0,005$).

Conclusion: Les différentes améliorations apportées aux processus au SU ont été associées à une réduction importante, sur le plan clinique, de la DS, du temps avant la PEM, du taux de DSEM et du taux de DCAM chez les patients n'ayant pas eu besoin de réanimation.

Keywords: efficiency, length of stay, patient flow

From the *Department of Family Medicine, Queen's University, Kingston, ON; †Southlake Regional Health Centre, Emergency Services Program, Newmarket, ON; and ‡Department of Statistics, University of Toronto, Toronto, ON.

Correspondence to: Alexander Leung, Department of Family Medicine, Queen's University, 101-115 Clarence Street, Kingston, ON K7L 5N6; Email: alexander.kh.leung@gmail.com

INTRODUCTION

Emergency department (ED) crowding occurs when demand for emergency services exceeds care capacity. When EDs cannot deliver timely and patient-centered care, quality of care suffers.¹⁻³ The negative impacts of ED crowding are well known, including prolonged wait times,^{1,3-5} increased hospital admission rates,⁶ increased health-care costs,⁷ and mortality.⁸⁻¹⁰ The problem of crowding is prevalent internationally and continues to be recognized as a health care priority.^{8,11-13} In Ontario, the Pay-for-Results program was established in 2008 to provide financial incentives for improving measures of ED quality and efficiency.¹⁴ Our hospital, Southlake Regional Health Centre, started participating in the Pay-for-Results program in 2008.

Interventions to decrease incidence of ED crowding are well known and have been shown to decrease wait times to varying degrees.¹⁵⁻²³ However, many of these interventions involved adding additional ED resources.^{15,19,21,24-28} We sought to improve wait times through process improvements (i.e., without new staff, ED renovation, or operational costs). After re-evaluating the typical sequence of front-end operations,¹⁵ we hypothesized that a multifaceted process of reorganization designed to target triage, patient inflow, and ED staffing patterns would lead to significant improvements in patient flow and decrease wait times.

The objective of this study was to examine the impact of simultaneous process improvements on length of stay (LOS) according to patient acuity and disposition. Secondary objectives included examining the impact of the intervention on physician-initial-assessment (PIA) times, left-without-being-seen (LWBS) rates, and left-against-medical-advice (LAMA) rates.

METHODS

Setting and population

Southlake Regional Health Centre (Southlake) is a 400-bed community hospital in Newmarket, Ontario. It provides regional tertiary care programs, including cardiac, child and adolescent mental health, oncology, and thoracic surgery. From January 1, 2010 to December 31, 2012, the ED received over 251,000 patients, with an admission rate of 11.2%. We conducted a retrospective 36-month pre- and post-intervention study to examine the impact of our

process improvements. The Southlake Research Ethics Board provided ethics approval.

Design

Process improvements without new staff, ED renovation, or operational cost were implemented at Southlake on June 6, 2011. The overall intervention comprised 1) streamlining triage, 2) implementing parallel processes, 3) flexible nurse-patient ratios, 4) flexible exam spaces, and 5) flexible physician scheduling. Each process will be described briefly. Further details and rationale behind the design have been described in the Supplementary Material, and elsewhere.^{29,30} During the month prior to the intervention start-date, meetings between physicians and other ED health care providers were held to describe and review what impact the intervention would have on the ED, and to address any questions. Formal training was not required.

Streamlining triage

Triage remained the first step for all arriving patients. Nurses determined the presenting complaint, assigned a Canadian Triage and Acuity Scale (CTAS) level, and determined the most appropriate location for care within the ED. However, all patients were immediately accepted inside the ED, and there was no "waiting room" at the front of the ED. Accordingly, triage nurses were re-deployed into the ED to provide direct patient care, and subsequent ED processes occurred in parallel.²⁹

Parallel processes

In the traditional ED, patient flow followed a sequential process.^{15,31} In contrast, parallel processing would allow multiple processes to occur simultaneously to reduce waits and bottlenecks.¹⁵ For example, this occurs when CTAS 1 (resuscitative) patients arrive. Physicians and nurses immediately converge to provide care, and registration occurs later. We applied this principle to all patients, regardless of acuity, and eliminated sequential processes which lead to bottlenecks.²⁴ There was no restriction on when registration occurred or which health care provider that a patient saw first.²⁹

Flexible exam spaces

Stable patients without threat to life or limb comprise the majority of patients in the ED.^{32,33} This was the

case at our institution, and we believed that these patients could sit inside the ED. With flexible exam spaces, health care providers called these patients into nearby exam rooms. Patients were in exam rooms only if required for examination. This facilitated a rapid turnover of rooms and maintained patient flow. Patients moved to chairs for IV treatments, or waited for imaging and test results. As a result, non-acute patients collected in areas that in practice could hold a large number of patients.²⁹

Flexible nurse-patient ratios

There was no fixed nurse-to-patient ratio in the care areas described. Because patients were always accepted into the ED after triage, nurse-to-patient ratio could rise above the traditional 4:1 or 5:1.³⁴ By having flexible nursing teams without rigid assignments, resources could be moved to areas with the highest demand.²⁹

Flexible demand-based scheduling

Rigid physician scheduling with defined start and stop hours was changed to a meet unscheduled and fluctuating demand. This demand-based scheduling incorporated the efficiency of each physician, and estimated patient-volume per day to provide approximate shift start times. Prior to the shift, physicians would call and speak to the charge ED physician to negotiate start times based on current wait times. This method prevented overstaffing the ED and did not require the addition of any physician shifts.²⁹

Outcome measures

ED performance measures according to provincial standards and the literature were not identical.¹⁴ Therefore, we summarized ED performance measures in multiple ways. The primary outcome measures were mean and 90th-percentile LOS for CTAS 2-5 patients, and mean LOS for non-admitted (i.e., discharged) patients according to acuity. LOS was calculated as the difference between the earlier of triage or registration time and the time that the patient physically left the ED or was admitted and physically left the ED.

Secondary outcome measures included 90th-percentile PIA, mean PIA, LWBS, and LAMA. PIA was calculated as the difference between the earlier of

triage or registration time to the start of emergency physician assessment. LWBS, a common measure of safety and satisfaction, was calculated as a percentage of daily ED volume.³⁵ We also studied LAMA patients, because they have been associated with increased re-admission rates and risk of emergent hospitalization.^{36,37} LAMA patients were calculated as a percentage of daily ED volume.

Data extraction

The study used a computerized ED information system, which integrates patient tracking and patient charted data (STAR McKesson, McKesson, San Francisco, CA, and Med2020, MED2020 Health Care Software Inc., Orleans, ON). Database queries with Microsoft Access (Microsoft Corporation, Redmond, WA, USA) collected patient demographic information, clinical data, patient flow time stamps, and disposition for all patients received in the ED from January 1, 2010 to December 31, 2012.

The following patients were collected but excluded from regression analysis: critically ill or required resuscitation (CTAS 1), died or were dead on arrival in the ED, direct admissions to a service, and transferred to another facility. These patients were excluded because they either bypass or are accelerated through the usual ED intake processes, and would not be impacted by our intervention. If they were included in aggregated metrics, it would artificially decrease wait times. Furthermore, we knew that the excluded patients usually do not represent a substantial burden to ED throughput at our institution. Administrative records of ED physician staffing schedules were used to determine the total number of physician hours per day, including the activation of any ED backup physicians. For each patient, LOS and PIA were calculated. These values were used to produce monthly values for each metric and determine the primary and secondary outcome measures.

Statistical analysis

We divided our data into pre-intervention and post-intervention intervals starting on June 6, 2011. T-tests were used to compare descriptive statistics for patients before and after the intervention. Segmented regression of interrupted time series (ITS) analysis was performed to assess whether our intervention had an impact on

primary and secondary outcomes immediately, and over time. The outcomes of ITS analysis were changes in the outcome level immediately after the intervention (step-change), and changes in the pre-intervention and post-intervention slopes (trend-change) to determine whether the impact of the intervention was sustained with time.³⁸ ITS analysis was performed on secondary data sets generated by bootstrap simulations, and to calculate standard error and confidence intervals. Additional details regarding the statistical analysis are provided in the Supplementary Material.

The level of statistical significance was $\alpha = 0.05$. A Bonferroni correction was made to control for type 1 error inflation. Missing data were excluded from statistical analysis. ITS analysis was performed using R version 3.2.1 (R Foundation for Statistical Computing, Vienna, Austria). All other analyses were performed using IBM SPSS version 20.0 (IBM Corp., Armonk, NY, USA).

RESULTS

The ED received 251,899 patients during the 36-month study period. The following met exclusion criteria: 1468 CTAS 1 patients, 621 transfers to another facility,

329 direct admissions, and 263 dead on arrival or expired in the ED. During the post-intervention period, there was no clinically meaningful change in the mean age or daily proportion of patients assigned CTAS 2 to 5 acuity scores. There was a significant increase in daily patient volume (210.66 v. 247.20, $p < 0.003$), and mean number of patients to physicians (32.33 v. 37.78, $p < 0.003$). No other descriptors differed significantly. The final sample included 249,258 patients over 521 days pre-intervention, and 575 days post-intervention (Table 1).

Prior to the intervention, there were significant trends for overall mean LOS (-0.011 hours/month, $p < 0.005$), and 90th-percentile LOS (-0.033 hours/month, $p < 0.005$) (see Supplementary Material). After the implementation of process improvements, there were step-changes or reductions of 0.64 hours in mean LOS ($p < 0.005$), and 0.81 hours in 90th-percentile LOS ($p < 0.005$) for CTAS 2 to 5 patients. When separated by acuity and disposition, there were significant reductions for mean non-admitted LOS for CTAS 2 to 4 patients (Figure 1). After Bonferroni correction, there was no significant reduction for non-admitted CTAS 5 patients. There were small and significant increases in trend of 0.012 hours/month ($p < 0.005$) for

Table 1. Emergency department characteristics during pre-intervention period (1 January 2010 to 5 June 2011) and post-intervention period (6 June 2011 to 31 December 2012)

Characteristic, mean (SD)	Pre-intervention	Post-intervention	<i>p</i> value*
No. of patients	109 757	142 142	
No. of patients per day	210.66 (19.71)	247.20 (24.59)	<0.003
Age (yr.), mean (SD)	41.04 (1.96)	41.54 (1.88)	<0.003
Sex (% of daily volume)			
Male	48.67	48.98	0.141
Female	51.33	51.02	
No. of patients to physicians per day	32.33 (3.93)	37.78 (5.01)	<0.003
Physician shifts per day	7.01 (0.79)	6.95 (0.71)	0.189
Physician hours per day	52.44 (4.10)	52.94 (5.72)	0.093
No. of patients by CTAS score per day			
1	1.35 (1.23)	1.33 (1.19)	0.758
2	44.62 (8.33)	46.71 (9.64)	<0.003
3	92.93 (12.31)	108.84 (14.70)	<0.003
4	67.68 (13.25)	84.75 (16.88)	<0.003
5	4.06 (2.97)	5.58 (4.08)	<0.003
Admissions (% of daily volume) per day	11.14 (3.51)	11.26 (2.29)	0.494
Direct admissions per day	0.31 (0.58)	0.30 (0.57)	0.785
Transfer to another facility per day	0.52 (0.78)	0.61 (0.80)	0.770
Died on arrival or expired in ED per day	0.26 (0.52)	0.21 (0.48)	0.121

CTAS = Canadian Triage and Acuity Scale; ED = emergency department; SD = standard deviation.
*Statistical significance at $p < 0.003$ level after Bonferroni correction for multiple comparisons.

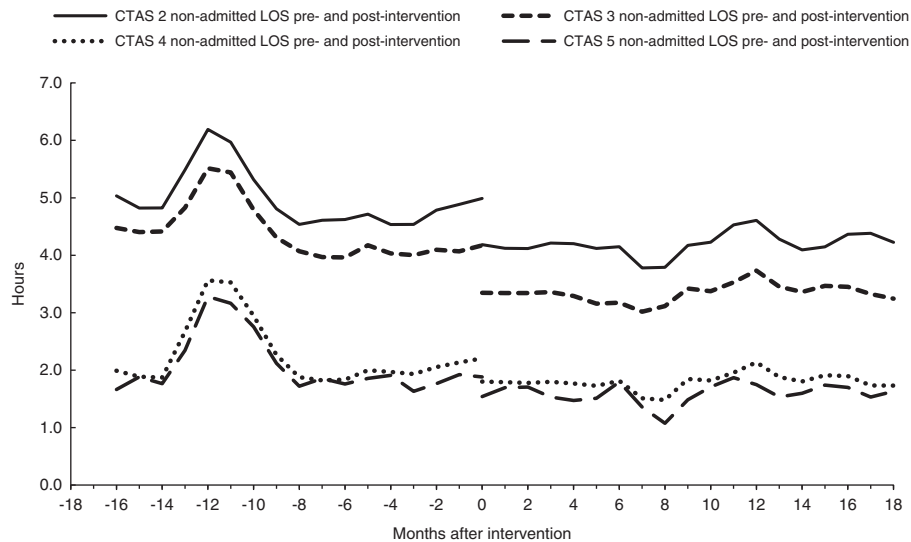


Figure 1. Two-month moving mean of emergency department length of stay (LOS) for non-admitted CTAS 2, 3, 4, and 5 patients before and after the intervention.

Table 2. Changes in emergency department length of stay (LOS) in hours, physician initial assessment (PIA) in minutes, left-without-being-seen (LWBS) rates, and left-against-medical-advice (LAMA) rates after the intervention

Emergency department efficiency metric	Parameter	Mean (95% CI)
Mean LOS (CTAS 2 to 5)	Step-change after intervention	-0.64 (-0.95 to -0.33)*
	Trend-change after intervention	0.009 (0.002 to 0.017) [†]
90th-percentile LOS (CTAS 2 to 5)	Step-change after intervention	-0.81 (-1.49 to -0.08)*
	Trend-change after intervention	0.040 (0.020 to 0.058)*
Mean PIA	Step-change after intervention	-43.81 (-53.70 to -34.46)*
	Trend-change after intervention	0.086 (-0.13 to 0.29)
90th-percentile PIA	Step-change after intervention	-91.39 (-110.66 to -72.22)*
	Trend-change after intervention	0.24 (-0.20 to 0.65)
Mean CTAS 2 (non-admitted) LOS	Step-change after intervention	-0.58 (-0.83 to 0.034)*
	Trend-change after intervention	0.012 (-0.0064 to 0.019)*
Mean CTAS 3 (non-admitted) LOS	Step-change after intervention	-0.75 (-1.02 to -0.49)*
	Trend-change after intervention	0.014 (0.0079 to 0.021)*
Mean CTAS 4 (non-admitted) LOS	Step-change after intervention	-0.32 (-0.51 to -0.13)*
	Trend-change after intervention	0.0081 (-0.0027 to 0.015)
Mean CTAS 5 (non-admitted) LOS	Step-change after intervention	-0.24 (-0.41 to -0.068) [†]
	Trend-change after intervention	0.0037 (-0.0003 to 0.008)
LWBS	Step-change after intervention	-1.27 (-1.77 to -0.72)*
	Trend-change after intervention	0.015 (0.0020 to 0.028)
LAMA	Step-change after intervention	-0.91(-1.20 to -0.63)*
	Trend-change after intervention	-0.0070 (-0.014 to -0.0003) [†]

CI = confidence interval; CTAS = Canadian Triage and Acuity Scale.
 *Statistically significant at $p < 0.005$ level after Bonferroni correction for multiple comparisons.
[†]Statistically significant at $p < 0.05$ level.

non-admitted CTAS 2, and 0.014 hours/month ($p < 0.005$) for non-admitted CTAS 3 patients (Table 2). The resulting post-intervention segment trend for non-admitted CTAS 2 and 3 patients were 0.003 hours/month and 0.002 hours/month, respectively (see Supplementary

Material). These findings were similar to the results from a separate analysis that examined patients separated by acuity only (data not shown).

For secondary outcomes, there were significant reductions in mean PIA for CTAS 2 to 5 patients

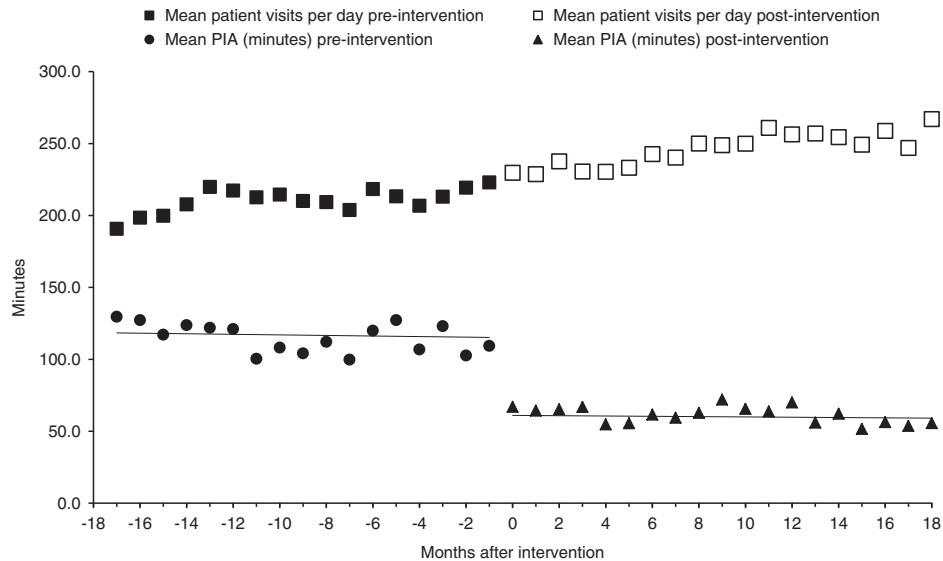


Figure 2. Monthly means of emergency department patient volumes and physician-initial-assessment (PIA) times for CTAS 2 to 5 patients, before and after the intervention.

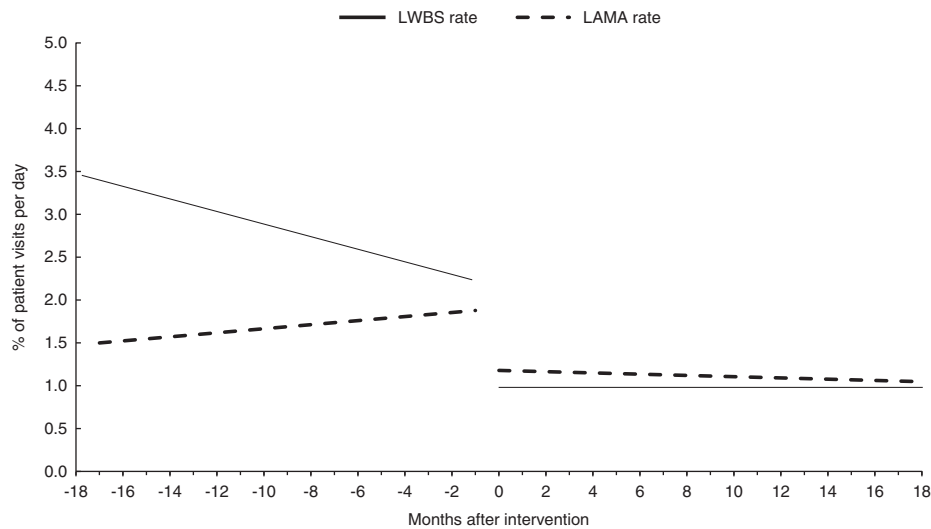


Figure 3. Trend lines of the proportion of emergency department patients who "left without being seen" (LWBS) by a physician, and "left against medical advice" (LAMA) before and after the intervention.

by 43.81 minutes ($p < 0.005$, Figure 2), and 90th-percentile PIA by 91.39 minutes ($p < 0.005$). LWBS and LAMA patients decreased by 1.27% ($p < 0.005$) and 0.91% ($p < 0.005$) of daily patient volume, respectively (Figure 3). This corresponds to a 35.3% and 61.9% decrease from pre-intervention LWBS and LAMA patients, respectively. There were no significant trend changes for secondary outcomes. The full results of ITS analysis are provided in the Supplementary Material.

DISCUSSION

This study shows that an intervention comprising simultaneous ED process improvements can significantly improve overall measures of ED quality and efficiency. This was achieved without cost or additional resources, and sustained despite increases in daily patient volumes by 17.3%. After the process improvements, the average ED physician was more productive and attended to 15% more patients each shift.

For CTAS 2 to 5 patients, we observed a 38.4 minutes (11.1%) reduction in mean LOS, and 43.8 minutes (36.2%) reduction in mean PIA immediately after our intervention was implemented. When patients were separated by acuity and disposition, there were reductions in LOS up to 15.5% of pre-intervention LOS times. For non-admitted CTAS 2 and 3 patients, the reductions in LOS exceeded the 30-minute reduction threshold for clinical significance, a level which has been associated with decreased 7-day mortality,⁷ re-admission of discharged patients,⁷ and LWBS.³⁵ For secondary outcomes, the reduction in 90th-percentile PIA times by over 90 minutes (35.7%) is clinically significant because serious illnesses presenting to the ED, such as myocardial ischemia, require efficient diagnosis and timely care.³⁹ LWBS, commonly associated with prolonged wait times,⁴⁰ decreased by 35.2%. The post-intervention mean LWBS was 0.91% of daily volume, and below the provincial mean of 3%.⁴¹

We did not expect to find clinically significant trend-changes in ED quality metrics. The process improvements were one-time changes meant to improve and maintain patient flow. As a result of the intervention, there were statistically significant increases in trend for LOS. However, the trend-changes and resulting post-intervention trends were small (<1 minute/month). We consider them clinically insignificant and likely caused by increased patient volumes. The absence of clinically significant upward trend-changes indicated that the clinical benefits of our process improvements were sustained during the post-intervention period.

Our results are comparable to similar interventions affecting multiple aspects of ED organization. A multi-faceted redesign by Spaite et al. (2002) resulted in LOS reductions of 27% for admitted patients and 31% for non-admitted patients.⁴² Chan et al. (2005) studied a rapid entry and accelerated care at triage process that facilitated immediate bedding and accelerated test ordering, which resulted in a less than 9% (31 minutes) reduction in LOS and 58.7% reduction in LWBS.⁴³ However, both of the models cost over \$1 million to implement.^{42,43} Ng et al. (2007) applied Lean manufacturing principles to improve the flow of patients throughout the ED. There were reductions in overall LOS for discharged patients from 3.6 to 2.8 hours (22.2%). However, the improvements were mainly limited to low-acuity (CTAS 4 and 5) patients. Mean PIA times decreased from 111 to 78 minutes (29.7%), and mean LWBS from 7.1% to 4.3% (39.4%).²⁵ Our study demonstrates how clinically significant changes

impacting the wait times of higher and lower-acuity patients could be achieved without massive expenditures.

Our intervention did not require the fixed reallocation of physician or nursing resources, a common occurrence in interventions that institute a dedicated area for low and/or medium-acuity patients. These studies have reported reductions in wait times, LOS, and LWBS.¹⁵ However, a mid-track intervention for medium-acuity patients by Soremekun et al. (2013) found that siphoning off medium-acuity patients and assigning physician resources from the main ED to the mid-track area contributed to increases in the LOS of high-acuity patients.⁴⁴

Streamlining triage and accepting all triaged patients into the ED reduced triage complexity. This released triage nurses from triage to provide direct patient care within the ED. By having patients wait inside of the ED, health care providers immediately noticed any increase in patient volume and were able to respond faster to mid-acuity patients who deteriorated while waiting. In addition, traditionally sequential ED processes that occurred in waiting rooms could unfold in parallel within the ED. This approach was distinct from “immediate bedding and bedside registration” interventions which have been implemented only when the ED is not at capacity (i.e., “when possible”).^{31,42,43} Therefore, despite the significant costs to implement and maintain immediate bedding and bedside registration interventions,^{42,43} the impact on ED crowding was likely minimal.¹⁵ Similarly, our concept of simplifying triage went against other operational interventions, which expanded triage, such as physicians-in-triage. Although physician-in-triage interventions have been associated with reductions in overall LOS by 11 to 56 minutes, they required up to 16 hours/day of additional physician coverage, and increases in nursing hours.²⁶⁻²⁸ This led us to question whether the resources could have been better utilized by allowing them to flexibly operate within the ED and respond to fluctuations in patient volumes. In fact, some physicians-in-triage trials were terminated if the main ED was overwhelmed and the triage physician was required for patient care within the department.^{43,45}

We recognized that health care providers needed to be flexible to meet fluctuations in ED demand throughout the day. This involved deploying nurses as flexible teams that did not adhere to traditional ratios of nurses to patients.³⁴ Likewise, abandoning rigid

clock-based scheduling for demand-based scheduling allowed physicians to adapt to changing patient volumes without overstaffing. By using real-time data to make decisions, we felt that it empowered health care professionals to manage patient flow in real-time. The changes empowered frontline staff to take responsibility for managing demand for ED services. To our knowledge, this the first study to describe modifications on physician scheduling as an intervention on patient flow. Indeed, as opposed to creating an additional layer of ED complexity through rigid implementation of novel systems during hours of peak ED demand, our study has shown that clinically significant reductions in LOS and PIA times could be achieved by providing health care providers the flexibility to become responsive to patient demand for timely assessments.⁵

The idea of flexible exam spaces is similar to the more recent concept of “vertical patient flow.” Vertical patient flow eliminates the unavailability of ED beds as a key bottleneck in patient flow by having patients sit in upright chairs while awaiting treatments or tests.²³ In contrast to other studies that limited the idea of being “vertical” to lower-acuity patients,^{23,44} we applied it to all patients who were clinically stable and ambulatory. Our intervention of having internal waiting areas leverage upon this idea, thereby reserving ED beds for clinically appropriate cases only.

Because our process improvements were made without additional investments or significant reorganization, the implementation of these changes did not require institution-wide support or political cooperation from other services. This is in contrast to other operational interventions that increased ED process complexity.^{15,21,24-28} Moreover, research on the cost-benefit of interventions is universally lacking.^{15,16,21} Although these factors may limit the generalizability and implementation of other interventions,^{15,21} they do not apply to our study.

LIMITATIONS

Prior to the intervention, our ED hosted two learning events on Lean principles, but there were no attempts to formally implement a Lean intervention. During the first month of the intervention, all ED staff took time to adapt to the new system. Nonetheless, we were fortunate for the lack of resistance. This was attributed to the preparatory meetings and the belief that our changes would improve quality of care.

The generalizability of our results is limited by the single-site, non-randomized, and retrospective study design. Nevertheless, it was impractical to host a randomized controlled trial in a complex ED setting where improving clinical outcomes is the priority.⁴⁶ From available 2013-2014 data, although the ED admission rates for Canadian hospitals (est. 10.0%) and ≥ 200 -bed “large” community hospitals in Ontario and Canada (11.5% and 11.9%, respectively)⁴⁷ were similar to our institution’s rate of 10.9% that year, our study intervention and findings may not apply to Canadian < 200 -bed community hospitals and teaching hospitals with markedly different ED admission rates ($< 8.1\%$ and 14.3% , respectively)⁴⁷ and organization. We were not able to isolate the impact of individual components within our intervention. During the study period, we did not exclude the potential of seasonal trends and other unmeasured changes as confounding factors. We did not measure other metrics of ED efficiency, including 72-hour returns of discharged patients, patient satisfaction, or patients returning to a different hospital. Although the study occurred in a fee-for-service remuneration paradigm, we believe that our model could be applied to institutions under alternative funding models.

A combination of process improvements meant to optimize flow in the ED without the addition of resources was associated with clinically significant reductions in LOS, PIA, LWBS, and LAMA for non-resuscitative patients. Future research is required to determine how components from various initiatives to address ED crowding can be integrated.

Acknowledgements: The authors acknowledge and thank Dr. Grant Innis for his contributions to the manuscript.

Competing interests: None declared.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit <http://dx.doi.org/10.1017/cem.2016.382>.

REFERENCES

1. Derlet RW, Richards JR. Overcrowding in the nation’s emergency departments: complex causes and disturbing effects. *Ann Emerg Med* 2000;35(1):63-8.
2. Maa J. The waits that matter. *N Engl J Med* 2011;364(24):2279-81.

3. Bond K, Ospina MB, Blitz S, et al. Frequency, determinants and impact of overcrowding in emergency departments in Canada: a national survey. *Healthc Q* 2007;10(4):32-40.
4. Wait Time Alliance. Wait times in Canada: summary of findings; 2014. Available at: <http://www.waittimealliance.ca/media-centre/public-opinion-wait-times/> (accessed May 2015).
5. InfoFinders. Leading practices in emergency department patient experience; 2011. Available at: <https://www.oha.com/CurrentIssues/keyinitiatives/Patient%20Experience/Pages/EmergencyDepartmentPatientExperience.aspx> (accessed May 2015).
6. Forster AJ, Stiell I, Wells G, et al. The effect of hospital occupancy on emergency department length of stay and patient disposition. *Acad Emerg Med* 2003;10(2):127-33.
7. Krochmal P, Riley TA. Increased health care costs associated with ED overcrowding. *Am J Emerg Med* 1994;12(3):265-6.
8. Bernstein SL, Aronsky D, Duseja R, et al. The effect of emergency department crowding on clinically oriented outcomes. *Acad Emerg Med* 2009;16(1):1-10.
9. Guttmann A, Schull MJ, Vermeulen MJ, et al. Association between waiting times and short term mortality and hospital admission after departure from emergency department: population based cohort study from Ontario, Canada. *BMJ* 2011;342:d2983.
10. Johnson KD, Winkelman C. The effect of emergency department crowding on patient outcomes: a literature review. *Adv Emerg Nurs J* 2011;33(1):39-54.
11. Forero R, Hillman KM, McCarthy S, et al. Access block and ED overcrowding. *Emerg Med Australas* 2010;22(2):119-35.
12. Physician Hospital Care Committee of the Ontario Hospital Association. Improving access to emergency care: addressing system issues; 2006. Available at: <http://www.health.gov.on.ca/en/common/ministry/> (accessed May 2015).
13. Hughes G. Four hour target for EDs: the UK experience. *Emerg Med Australas* 2010;22(5):368-73.
14. Ontario Ministry of Health and Long-term Care. Ontario wait-time strategy. Available at: <http://www.health.gov.on.ca/en/public/programs/waittimes/> (accessed May 2015).
15. Wiler JL, Gentle C, Halfpenny JM, et al. Optimizing emergency department front-end operations. *Ann Emerg Med* 2010;55(2):142-60.e141.
16. Oredsson S, Jonsson H, Rognes J, et al. A systematic review of triage-related interventions to improve patient flow in emergency departments. *Scand J Trauma Resusc Emerg Med* 2011;19(1):43.
17. Burström L, Nordberg M, Örnung G, et al. Physician-led team triage based on lean principles may be superior for efficiency and quality? A comparison of three emergency departments with different triage models. *Scand J Trauma Resusc Emerg Med* 2012;20:57.
18. Lidal IB, Holte HH, Vist GE. Triage systems for pre-hospital emergency medical services – a systematic review. *Scand J Trauma Resusc Emerg Med* 2013;21:28.
19. Pines JM, Pilgrim RL, Schneider SM, et al. Practical implications of implementing emergency department crowding interventions: summary of a moderated panel. *Acad Emerg Med* 2011;18(12):1278-82.
20. McClelland MS, Lazar D, Sears V, et al. The past, present, and future of urgent matters: lessons learned from a decade of emergency department flow improvement. *Acad Emerg Med* 2011;18(12):1392-9.
21. Handel D, Epstein S, Khare R, et al. Interventions to improve the timeliness of emergency care. *Acad Emerg Med* 2011;18(12):1295-302.
22. Handel DA, Ginde AA, Raja AS, et al. Implementation of crowding solutions from the American College of Emergency Physicians Task Force Report on Boarding. *Int J Emerg Med* 2010;3(4):279-86.
23. Liu SW, Hamedani AG, Brown DF, et al. Established and novel initiatives to reduce crowding in emergency departments. *West J Emerg Med* 2013;14(2):85-9.
24. DeFlitch C, Geeting G, Paz HL. Reinventing emergency department flow via healthcare delivery science. *HERD* 2015;8(3):105-15.
25. Ng D, Vail G, Thomas S, et al. Applying the Lean principles of the Toyota Production System to reduce wait times in the emergency department. *CJEM* 2010;12(1):50-7.
26. Holroyd BR, Bullard MJ, Latoszek K, et al. Impact of a triage liaison physician on emergency department overcrowding and throughput: a randomized controlled trial. *Acad Emerg Med* 2007;14(8):702-8.
27. Rogg JG, White BA, Biddinger PD, et al. A long-term analysis of physician triage screening in the emergency department. *Acad Emerg Med* 2013;20(4):374-80.
28. Han JH, France DJ, Levin SR, et al. The effect of physician triage on emergency department length of stay. *J Emerg Med* 2010;39(2):227-33.
29. Whatley S, Leung A, Duic M. Process improvements to reform patient flow in the emergency department. *Healthc Q* 2016;19(1):29-35.
30. Whatley S. *No more lethal waits: 10 steps to transform Canada's emergency departments*. Toronto, Canada: BPS Books; 2016.
31. Morgan R. Turning around the turn-arounds: improving ED throughput processes. *J Emerg Nurs* 2007;33(6):530-6.
32. Saunders CE. Time study of patient movement through the emergency department: sources of delay in relation to patient acuity. *Ann Emerg Med* 1987;16(11):1244-8.
33. Canadian Institute for Health Information. NACRS emergency department (ED) visits: volumes and median length of stay by triage level, visit disposition, and main problem; 2014. Available at: <https://www.cihi.ca/en/types-of-care/hospital-care/emergency-and-ambulatory-care/nacrs-emergency-department-ed-visits> (accessed May 2015).
34. Chan TC, Killeen JP, Kelly D, et al. Impact of rapid entry and accelerated care at triage on reducing emergency department patient wait times, lengths of stay, and rate of left without being seen. *Ann Emerg Med* 2005;46(6):491-7.
35. Mohsin M, Forero R, Ieraci S, et al. A population follow-up study of patients who left an emergency department without being seen by a medical officer. *Emerg Med J* 2007;24(3):175-9.
36. Ding R, Jung JJ, Kirsch TD, et al. Uncompleted emergency department care: patients who leave against medical advice. *Acad Emerg Med* 2007;14(10):870-6.
37. Jerrard DA, Chasm R. Patients leaving against medical advice from the emergency department: how many of them actually

- return to continue their evaluation and what are the reasons the others do not? *Ann Emerg Med* 2004;44(4 Supplement): S130-1.
38. Wagner AK, Soumerai SB, Zhang F, et al. Segmented regression analysis of interrupted time series studies in medication use research. *J Clin Pharm Ther* 2002;27(4):299-309.
 39. Schull MJ, Hatcher CM, Guttmann A, et al. Development of a consensus on evidence-based quality of care indicators for Canadian emergency departments. ICES investigative report. Toronto: Institute for Clinical Evaluative Sciences; 2010.
 40. Kennedy M, MacBean CE, Brand C, et al. Review article: leaving the emergency department without being seen. *Emerg Med Australas* 2008;20(4):306-13.
 41. Baibergenova A, Leeb K, Jokovic A, et al. Missed opportunity: patients who leave emergency departments without being seen. *Healthc Policy* 2006;1(4):35-42.
 42. Spaitte DW, Bartholomeaux F, Guisto J, et al. Rapid process redesign in a university-based emergency department: decreasing waiting time intervals and improving patient satisfaction. *Ann Emerg Med* 2002;39(2):168-77.
 43. Chan TC, Killeen JP, Kelly D, et al. Impact of rapid entry and accelerated care at triage on reducing emergency department patient wait times, lengths of stay, and rate of left without being seen. *Ann Emerg Med* 2005;46(6): 491-7.
 44. Soremekun OA, Shofer FS, Grasso D, et al. The effect of an emergency department dedicated midtrack area on patient flow. *Ann Emerg Med* 2014;21(4):434-9.
 45. Subash F, Dunn F, McNicholl B, et al. Team triage improves emergency department efficiency. *Emerg Med J* 2004;21(5):542-4.
 46. Asplin BR, Yealy DM. Key requirements for a new era of emergency department operations research. *Ann Emerg Med* 2011;57(2):101-3.
 47. Canadian Institute for Health Information. NACRS emergency department visits and length of stay by province/territory, 2013–2014. Available at: <https://www.cihi.ca/en/types-of-care/hospital-care/emergency-and-ambulatory-care/nacrs-emergency-department-visits-and-0> (accessed February 2016).