**Appendix 1: Appendix for ‘Impact of process improvements on measures of emergency department efficiency’**

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**Appendix 1: Table of Contents**

Section 1.0. Detailed background information about study setting 3

Section 1.1. ED Layout

Section 1.2. Nursing staff

Section 1.3. ED physician staffing

Section 1.4. The impact of implementing change at the study setting

Section 1.5. The impact of remuneration model

Section 2.0. Detailed description of study intervention 11

Section 2.1. Streamlining triage

Section 2.2. Parallel processes

Section 2.3. Flexible exam spaces

Section 2.4. Flexible nurse-patient ratios

Section 2.5. Flexible demand-based scheduling

Section 3.0. Detailed statistical analysis 19

Section 3.1. Outcomes of statistical analysis

Section 3.2. Complete results of segmented regression of interrupted time series analysis

Section 3.3. Left-without-being seen rates (LWBS) and Left-against-medical-advice rates (LAMA)

Section 3.4. Step-change mean LOS for non-admitted CTAS 5 patients

Acknowledgements 23

**1.0. Detailed background information about study setting**

The following information describes relevant baseline characteristics of our ED during the pre-intervention and post-intervention period.

**1.1. ED Layout**

The ED was divided into the following areas: Acute, Sub-acute, and Ambulatory. Acute was composed of 18 beds. 3 of these beds were designated as resuscitation beds or areas. Sub-acute was composed of 14 beds divided into 4 mental health beds, and 10 non-mental health beds. There was a total of 32 beds in the ED department. These beds did not change in number or placement after the intervention. Ambulatory was subdivided into Yellow Zone and Fast Track. Fast Track was open from 1000h to 0100h every day. Prior to the intervention there were 6 exam tables in Yellow Zone, 9 exam tables in Fast Track.

A long hallway starting from the entrance of the ED (where triage is located) connected, in the following order, Fast Track, Yellow Zone, Subacute and Acute. This hallway wrapped around through Acute to Subacute before forming a complete circuit near Fast Track. Each area contained a centralized nursing station where physicians could access patient data, results, and imaging on computers. The term ‘centralized’ referred to the nursing station being surrounded by patient rooms, thereby allowing health care personnel with direct and rapid access to any patient room within the area. The psychiatry rooms (within Subacute) were staffed by ED physicians only. There were no regular psychiatrists or residents in the ED.

The waiting area during the pre-intervention period in 2011 was composed of chairs in a ‘waiting room’ outside of the triage area at the front of the ED. There were approximately 20 chairs, but more than 20 patients often waited in the waiting room. After the intervention started in 2011, new waiting areas within the ED were created outside of Fast Track (16 chairs), and Yellow Zone (14 chairs). 19 chairs remained outside of triage in the former ‘waiting room’. From 2011 to 2015, only the number of chairs in the Fast Track waiting area grew from 16 to 20 chairs. The waiting areas were found along the main ED hallway, and physically adjacent to their associated treatment area.

**1.2. Nursing staff**

The generic schedule for nursing on any given 24-hour period in the ED follows in **Appendix Table 1**. This schedule did not change during the study period.

**Appendix Table 1**: Nursing counts over a 24-hour period in our ED during the study period

|  |  |  |  |
| --- | --- | --- | --- |
| **Registered Nurses (RN)** | | | |
| Shift | Hours | Number of Nurses | Notes |
| Day | 0730 to 1930 | 13 | 1 acting as Charge Nurse |
| Day-1 | 0900 to 2100 | 1 |  |
| Evening-1 | 1000 to 2200 | 1 |  |
| Evening | 1100 to 2300 | 7 |  |
| Night | 1400 to 0200 | 1 |  |
| Night-1 | 1930 to 0730 | 13 | 1 acting as Charge Nurse |
|  |  |  |  |
| **Registered Practical Nurses (RPN)** | | | |
| Evening-1 | 1100 to 2300 | 1 |  |

The ED department had 110 RNs and 4 RPNs employed in the ED. The level of RN to physician staffing did not change during the study period. According to our nurse schedulers, the total number of RNs did not appreciably change during the study period. Since 2009, the annual nursing turnover at our ED remained consistently around 7-8%. Our hospital set a maximum target turnover rate of 8%.

**1.3. ED physician staffing**

The total number of staff physicians with privileges at our ED was 28. Within this number included physicians who no longer worked (small minority), worked part-time, and full-time. During the study period the number of staff physicians with privileges expanded by 1. This physician initially worked on a part-time basis at our institution. The number of full-time physicians remained relatively unchanged during the study period.

As noted in the main text, there was no significant difference in the number of physician shifts per day and physician hours per day before and after the intervention (see main text, Table 1). This was also observed during the creation of monthly physician schedules. During the pre-intervention period, the physician scheduling process involved up to 225 shifts available each month (usually 6 to 8 shifts per day). Physicians would be assigned shifts with defined start and end times, typically 6 to 8h in duration. There was also an assigned on-call physician who would be on-call and available throughout the day. Post-intervention, the scheduling process and structure was modified to follow a demand-based schedule. The total number of available shifts remained the same at around 225 shifts post-intervention, in June 2012 (usually 6 to 8 shifts per day). However, based on demand-based scheduling, not all of the available shifts needed to be filled. This will be explained further in **Section 2.5**. Accordingly, the scheduling of on-call physicians was changed to a system that could, in rare circumstances, accommodate 2-3 physicians being called in at the same time (so if the slowest physician in the department was the first to be called, another one could be called in also). To our knowledge, we have never used a system with split-shifts in our ED.

Under the new scheduling method, each shift was composed of a “core time.” This was the time frame that the physician can expect to work on a normal day where there were no demand-modifying events (similar to the basic pre-intervention scheduling model). In addition, each shift had an “on-call time.” This was usually a 3-hour time period prior to the beginning of “core time.” The “on-call time” represented the period of time that the physician must be available to go to the ED if they were called-in by the physician currently staffing the ED.

With demand-based flexible scheduling, a physician might need to increase their shift hours by the total number of hours in the “on-call time” period (i.e. up to 3 hours). Alternatively, on a day with decreased patient volumes, an incoming physician could be asked to delay their attendance in the department by up to 3 hours into their core time. Thus, most shifts could be flexed up or down by 3-6 hours of physician manpower, in essence being a minimum of 3 hours and a max of 11 hours long. These minima and maxima were hardly ever used, and most shifts remained 8 hours in duration, but once in a while a shift could be very long or very short if patient demand was unusually high or low. However, on a month-to-month basis, available records showed that the net effect of demand-based scheduling had a neutral effect on total physician hours per month. This is reflected by the lack of significant difference in total physician hours per day pre- and post-intervention (see main text, Table 1). Additional details about the demand-based scheduling method follows in **Section 2.5**.

**1.4. The impact of implementing change at the study setting**

To summarize, the intervention did not require the addition of any resources or personnel. There were no changes in overall staffing of other health care providers. Our ED did not have any scribes or physician assistants. The same number of family medicine residents rotated through our ED every year during the study period (i.e. there was no expansion in the family medicine program based in our community). As a result, the overall ratios of nurses to physicians remained unchanged. The ratio of nurses to patients, similar to ratio of physicians to patients (see main text, Table 1), increased after the intervention as our ED received increased patient volumes.

Despite the preparatory meetings prior to the study start-date, everybody in the ED knew that change would be difficult. This was a message that was disseminated time and again. We understood that the initial stages of the intervention would be relatively challenging. Thankfully, the results of those changes became quickly noticeable. Although, we did not formally measure rates of satisfaction with the intervention, we believe that satisfaction rates were high based on feedback and anecdotal evidence from numerous sources within the department.

From a data standpoint, we can only provide indirect measurements of health care provider satisfaction. As mentioned before, our nursing turnover rates remained within the hospital target of 8%. We were not aware of any staff that left as a direct result of the intervention. The size of our physician staff group did not change in size. We would emphasize that the intervention itself was simple to implement. There were no physical re-organization or renovation required in the ED for the intervention. The other medical and surgical specialties who frequented the ED and provided patient care were not affected by the intervention. Finally, as this was a purely departmental matter and solution, this intervention did not require the support of extra-departmental administrators. (Nonetheless, we took steps to readily inform hospital administration of the progress being made and impact of our intervention.) The point being illustrated is that it would have been very simple to revert back to the original ED system if rates of satisfaction were low. As the impact of the intervention solidified over the post-intervention period, we were eager to keep the process improvements permanently.

From a numeric perspective of patient to provider ratios, the intervention appeared to result in increased work load for all ED staff. However, we believe that this perspective is short-sighted and does not accurately capture the impact of the process improvements. From the onset, the intervention led to clinically significant reductions in wait times and LOS. This was noticeable to everyone within the department. It allowed health care providers to see more patients and to focus on providing value-added healthcare activities. If enhanced patient flow shortened mean LOS by 30 minutes, the total daily ED workload (with over 200 patients seen per day) decreases by over 100 hours. Furthermore, there was less time spent on non-value added activities like waiting for patients to reach areas of care within the ED, get discharged or admitted. Similarly, there were fewer requests of nurses for a physician’s estimated time for first assessment (i.e. ‘when will I see the doctor’), requests from patients for help to go to the bathroom, or find the cafeteria because patient LOS was shorter and the total number of patients at any given time in the ED was less than before the intervention. Physicians and nurses were no longer dealing with the former volume of upset patients and families concerned about how long they have waited. Similarly, the disruptions in patient flow associated with patients who leave-without-being seen or leave-against-medical-advice decreased. Therefore, by decreasing LOS, the overall number of patients in the ED at any one time dropped, and reduced the number of non-value added request from patients. We believe the intervention did not actually “add” work for ED staff.

For physicians, there was a degree of adjusting required to the new demand-based scheduling system. However, the benefits for the physician were obvious. With improvements in patient flow, each physician on average would see significantly more patients within the same amount of time, and without compromising quality of care. This was a significant incentive for physicians to remain in our physician group. Although there were often fluctuations on start and stop times based on patient demand, these were almost always limited to time periods of an hour (i.e. physician is requested to leave, stay, or come in early by 1 hour of their usual “core time”). During the post-intervention period we only recorded 4 instances where a physician was called-in for the full 3-hour “on-call time” prior to their core-shift start time, or asked to continue assessing new patients 3 hours after the end of their usual core-shift. According to our physician scheduler, we estimated the monthly net effect of flexible start and end times was essentially 0 hours of added physician time spent in the ED.

We also recorded only 3 instances (2 during the pre-intervention period, and 1 during the post-intervention period) where a back-up (or non-scheduled) physician had to be contacted to replace a physician who was unable to attend to a shift at short notice.

**1.5. The impact of remuneration model**

Our ED operates with a fee-for-service remuneration model which encourages productivity. We believe that any alternate funding arrangement (AFA) model that also encourages productivity would be just as appropriate. We would argue against any misconception that physicians at our institution would work for the maximum 11h when there were no demand-modifying events, or beyond the 11h maximum on a given shift. The focus was on maximizing productivity during the time that a physician was working in the ED. As an aside, the realization of demand-based scheduling underscored the collaborative nature that existed within our physician group without which the process improvements would not have been possible.

Nevertheless, this model turned out to be very popular with our nurses also, and they have no productivity incentives.

**2.0. Detailed description of study intervention**

The following section is a detailed description of the individual process improvements which make up the intervention to improve patient flow. It summarizes the changes that occurred at our ED as a result of the intervention. Within the main text we also included references to 2 resources which provide an even more extensive look behind our process improvements. Both resources are descriptive in nature and focus on the theory and arguments behind implementing process improvements in the ED.1,2 Accordingly, the in-depth statistical analysis we employed to demonstrate the impact of our intervention and the resulting data are novel.

*References*

1. Whatley S, Leung A, Duic M. Process Improvements to Reform Patient Flow in the Emergency Department. *Healthc Q*. 2016;19(1):29-35.

2. Whatley, S. No More Lethal Waits: 10 Steps to Transform Canada's Emergency Departments. Toronto, Canada: BPS Books; 2016.

**2.1. Streamlining triage**

Prior to the intervention, triage at our institution was staffed by 4 nurses during the day. From 2009-2010, our ED had increased the number of triage nurses to improve patient flow and process higher patient volumes. This decreased to 1 nurse at night (2300h to 0700h). Triage followed the traditional model of collecting a presenting complaint, assigning CTAS score, and determining best care location. In addition, other pieces of information collected at triage included a brief history and physical, past medical history, screen for influenza-like illness, domestic violence, medications, and allergies. Furthermore, triage nurses advised patients on what to expect during their ED stay, and reassess patients in the waiting room as necessary. The patient was sent to registration after triage.

After streamlining triage, triage was staffed by 2 nurses during the times we expect the majority of patients to arrive in the ED (0900h to 2100h), and 1 nurse at all other hours. When patients entered the ED, they collected numbers at the door and are called to triage in turn. When the number of patients awaiting triage exceeded 3 (i.e. a line starts to form), triage nurses contacted the charge nurse for additional help to process patients who were arriving. Triage itself was pared down and included chief complaint, vital signs, medications relevant to the presentation (e.g. anticoagulant use with a head injury), and a febrile respiratory illness screen. After, all patients were accepted inside the ED.

**2.2. Parallel processes**

Prior to the intervention, there was a fixed number of treatment spaces within the ED. When they were fully occupied, patients would be placed in the waiting room outside triage and monitored by triage nurses. We believed that this required more manpower than what was required just for triage. This also necessitated a greater amount of detail on history and physical to avoid inadvertently placing a high-acuity patient in the waiting room. When a treatment space inside became available, the nurse whose space it was would come to fetch a patient from the waiting room and do a secondary assessment. Only then could the physician see the patient.

With the intervention, patients went directly inside to ED after triage, whether a treatment space was available or not. Either a nurse or a physician could see the patient, depending on who was available first; or they could see the patient simultaneously. This replaced the rigid adherence to having a secondary RN assessment after triage. Since patients were now being seen by physicians sooner, less nursing was needed in the triage area, and the triage assessment did not have to be as detailed.

Prior to the intervention all patients followed the rigid sequence of patient triage followed by registration. Within the process improvement of parallel processes, we placed no restriction on when registration could occur. In general, this applied to all patients assigned to non-Ambulatory areas (i.e. required their own exam space in Sub-acute or Acute). If registration had not already occurred simultaneously with triage, it could happen at any time within the ED. Our priority was getting these patients into the ED for assessment and treatment. Patients assigned to Ambulatory areas typically completed registration prior to entering the ED. During the study period, our registration followed the “Quick Reg” model of limited registration which collects information just necessary to generate a basic chart.

**2.3. Flexible exam spaces**

In our former ED, patients destined for Ambulatory waited to move out of the waiting room and into the ED when an exam space became available. A patient was examined on their exam table, treated on it, and was told to remain on it for the duration of their stay. This allowed the ED to define patient capacity and give a clear sense of limits. In other words, it served as a rigid cap on care capacity.

In the new system, patients who used to sit in the waiting room – those without immediate threat to life or limb – now sat inside the ED after triage. These patients would be seen in the Ambulatory area of our ED. Providers called patients into exam rooms from waiting areas steps away. Sensitive discussion and any care that required privacy occurred in a private exam room with examining tables. Patients did not stay in exam rooms unless a clinician was present. At all other times, patients would spend time in chairs. We did not collect data regarding use of chairs, and often there were multiple uses. For example, a patient awaiting a CT result could also be getting an IV treatment.

**2.4. Flexible nurse-patient ratios**

Nurses continued to have assignments within our ED. Prior to the intervention, nurses remained in their assignment regardless of what was occurring elsewhere in the ED. We felt that this siloed approach was restrictive to patient flow, and that the potential of charge nurses playing a role in managing patient flow was being underutilized.

When patients went straight inside the ED from triage, surges in patient volume occurred within the ED. This was most noticeable within Ambulatory, where 80-85% of daily patient volume was normally received. Accordingly, nurse-to-patient ratios are flexible, and traditional ratios (i.e. 4:1) no longer applied in this area of the ED. After implementing the overall intervention, the changes to triage freed-up nursing capacity, most often 2 nurses, which were redeployed to other areas within the ED. Therefore, when a group of nurses within an ED area was overwhelmed, they called the charge nurse. The charge nurse coalesced assignments in other areas (similar to what happens when a nurse goes on break), and directed nurses to the overwhelmed area. Similarly, the charge nurse was given the authority to take initiative and pre-emptively reassign nurses under special circumstances like being notified by triage that fast-track was about to receive a sudden increase in patient volume.

**2.5. Flexible demand-based scheduling**

In order for our process improvements to be successful, physicians needed to see patients soon after they arrived in the treatment area. Transplanting waiting crowds from the waiting room to within the ED without modifying physician behaviour would create chaos, not patient flow. Changes to triage paradigms and nursing ratio expectations required physician schedules that reflected and responded to patient inflow rather than clock time.

Prior to our intervention, our physician group valued predictability, defined hours on defined days. ED physicians grew accustomed to crisp schedules with defined times to start and stop. The only exception was the “on-call” physician. Rigid shifts work well in industries where demand is scheduled and predictable. However, we believed that rigid shifts were provider-centred. We realized they failed to meet unscheduled demand and variable workload. Flexible hours were admittedly not an easy sell to the physician group. It was “sold” to our physician group as follows.

Consider the following: EDs could adjust staffing to meet unscheduled and fluctuating demand just as restaurants have done for years. Server schedules would get changed to match expected volumes at high-functioning eateries. If more diners arrived than usual, servers or management would call in more servers. Days staffed with highly efficient wait staff required fewer servers to meet demand, so fewer get scheduled. Days staffed with slower servers required more shifts, or servers would get called in. Customer service and efficient server productivity would be optimized to benefit the customer and the wait staff.

Like waiters, physicians work at different speeds with a finite response to patient arrival rates, especially if patients were out of sight (i.e. outside the ED in waiting rooms). With clock-based shifts, physicians could not adapt to the flux of patient volume and acuity beyond working harder and faster. Using the approach found in other service industries, flexible start and stop times could reflect patient demand. Therefore, on days staffed with highly efficient physicians, there was no need to fill in each available shift – so fewer got scheduled. Days staffed with less efficient physicians required more shifts scheduled. In either case, demand-modifying events could lead to physicians being called in.

Many people are familiar with the production trilemma, “Cheap, good, fast: Pick 2.” If you wanted something done well and fast, it would not be cheap; if cheap and good, it won’t be fast; and if fast and cheap, it won’t be good. Similarly, physician work followed the trilemma: fixed start and stop times, short patient waits, high productivity. With variable workload in the ED, we could not have all three, all the time. Physicians in productivity-incented environments could be tempted to sacrifice short patient waits (to maintain fixed start and stop times, and high productivity), but this was obviously not acceptable to us – it would counteract the very purpose of implementing process improvements to improve patient flow. Patient focused, high-quality care demanded timely assessment. If we could not sacrifice short patient waits, then one of the other two values had to be sacrificed: fixed start and stop times or high productivity. Inevitably, the only way to guarantee timely patient assessment using rigid, clock-based scheduling was to overstaff and sacrifice productivity. Overstaffing wastes ED physician time during periods with decreased patient volume, and something our physician group was staunchly against. If we wanted timely assessment and efficient use of physician time, we needed schedules based on demand, not the clock.

The basic approach to demand-based scheduling was applied by our physician scheduler to all days of the year, and described in detail within **Appendix Figure 1**. We often relied on a year of historic data from our ED to make the necessary calculations (i.e. expected number of patients on any given day, mean number of patients seen per shift by a given physician), and refine our measurements on an annual basis. This was one of the major topics discussed during physician group meetings in May 2011, prior to implementing our process improvements. **Appendix Figure 2** is an example of demand-based scheduling used at our institution.

**Appendix Figure 1**. Example of implementing flexible demand-based scheduling in the emergency department (ED)

Demand-based scheduling works as follows:

1. Determine mean # of patients each ED physician sees / shift.

2. Estimate total ED patient volume / day.

3. Use 1. and 2. to schedule # of physicians required / day.

4. Provide approximate shift start times based on historic ED patient arrivals. Each shift is associated with a 3 hour “on-call time” prior to the beginning of the “core-time.”

5. A few hours before their shift, physicians call and speak to the charge physician to negotiate actual start times based on patient waits.

6. The most recently arrived ED physician functions as charge, monitoring patient wait times.

7. If wait times threaten to exceed targets, the charge physician calls the next incoming physician in early, asks the outgoing physician to leave later, or activates the on-call ED physician. On slow days, the charge physician tells the incoming physician to start later, the outgoing ED physicians to leave earlier, and part or all of a shift may be cancelled later in the day.

Consider the following hypothetical situation:

Assume 180 patients are expected per day. On mean, physicians see 30 patients/shift. Based on usual arrival patterns, approximate shift start times are set at 0700, 1100, 1400, 1700, 1900, 2400. If scheduled physicians are slower on average, they will expect to start earlier and finish later—or the on-call physician will be activated. If a faster physician group is working, they will expect to go in later and leave earlier. If a demand-modifying event occurs, the physician in charge can adjust staffing on a real-time basis. For example, a start time might be delayed if low volumes are expected during the Stanley Cup final, and the later shift started early to address higher post-game volumes.

If low volume physicians are scheduled in sequence, they will have to work longer shifts or arrange for the on-call physician to come in. Trades that involve replacing a high-producer with a low producer are sometimes ill advised. For this reason, all physicians working on a given day should have the opportunity to participate in decisions around proposed switches. In an imbalanced shift trade, the group might ask that two lower-producing EPs be used to replace the high producer so that their hours are not lengthened.

**Appendix Figure 2**. A simplified example of flexible demand-based scheduling at our emergency department

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Expected # patients per day | St. John’s shift | Halifax shift | Montreal shift | Ottawa shift | | Toronto shift | Edmonton shift | Vancouver shift | Victoria shift |
| 240 | A | B | C | D | | F | E |  | M |
| 210 | J | B | I |  | | E | G |  | M |
| 210 | A | B | C | K | | F | G | I | N |
| Core time | 0700-1400 | 1100-1700 | 1400-2000 | 1500-2100 | | 1700-2300 | 1900-0100 | 2400- 0300 | 0100-0700 |
| On-call time | 0400-0700 | 0800-1100 | 1100-1400 | 1200-1500 | | 1400-1700 | 1600-1900 | 1800- 2400 | 2100-0100 |
| Mean # of patients each physician (denoted by letters) seen per shift | | | | | | | | | |
| A: 40 | | | | | B: 20 | | | | |
| C: 30 | | | | | D: 40 | | | | |
| E: 50 | | | | | F: 30 | | | | |
| G: 30 | | | | | I: 30 | | | | |
| J: 50 | | | | | K: 20 | | | | |
| M: 30 | | | | | N: 20 | | | | |

On that note, we would emphasize that our physician group does not penalize individual physicians who are “less efficient”. We did not collect these statistics for purposes of ranking or comparison. We did not promote an environment where “less efficient” physicians are encouraged to achieve higher levels of efficiency. Since a significant proportion of our physician group worked on a part-time basis at our institution, ED physicians were always scheduled based on availability, and were not pressured to abide to any particular scheduling pattern. As mentioned before, there were no significant changes to our ED physician group during the study period. Once our physician group quickly experienced the increase in productivity that resulted from the flexible start and stop times, even the most reluctant physicians embraced it. As an unintended consequence, the negotiation around arrivals and departures built a team spirit and collegiality around managing ED workload.

**3.0. Detailed statistical analysis**

The following is an in-depth description of the statistical methods behind the findings in the study. We will mainly discuss the use of segmented regression of interrupted time series (ITS) analysis to determine the impact of our study intervention.

**3.1. Outcomes of statistical analysis**

For analysis purposes, variables were log-transformed if the assumption of normality was violated. 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). This is summarized in the following equation.1

Yt = β0 + β1\*timet + β2\*interventiont + β3\*time after interventiont + et

β0 estimates the baseline level of the outcome at time 0. β1 estimates the pre-intervention trend at time t from the start of the study period. β2 estimates the step-change where interventiont=0 before the intervention, and interventiont=1 after the intervention. β3 estimates the change in post-intervention trend where *time after intervention* is a continuous variable representing the number of days after the start of the intervention at time t. et, the error term at time *t*, represents all random variations that are not explained by the model. At time t, et consists of a normally distributed random error as well as autocorrelated error with previous or following time points. The trend of the post-intervention segment can be calculated by the sum of β1 and β3.1,2

Parameter estimates (β0, β1, β2, β3) were obtained by performing bootstrap simulations to obtain 10,000 secondary datasets. ITS analysis was performed on the secondary datasets to generate parameter estimates with nonparametric standard errors, 95% confidence intervals and p-values for the original segmented regression model.

*References*

1. 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.

2. Morgan OW, Griffiths C, Majeed A. Interrupted time-series analysis of regulations to reduce paracetamol (acetaminophen) poisoning. *PLoS Med*. 2007;4(4):e105.

**3.2. Complete results of segmented regression of interrupted time series analysis**

A detailed table describing the parameter estimates (β0, β1, β2, β3) is provided in **Appendix Table 2**. The parameters were used to calculate, as described in Section 3.1, the step-changes and trend-changes found in the main text.

**Appendix Table 2**: Parameter estimates from segmented linear regression analysis of emergency department length of stay (LOS) in hours, physician-initial-assessment (PIA) in minutes, rates of left without being seen (LWBS), and rates of left against medical advice (LAMA) before and after the intervention

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Parameters | Coefficient | 95% CI | *p*-value  (p = 0.005) |
| Mean LOS  (CTAS 2-5) | Pre-intervention trend β1 | -0.011 | -0.019 to -0.0055 | <0.005 |
| Step-change post-intervention β2 | -0.64 | -0.95 to -0.33 | <0.005 |
| Trend-change post-intervention β3 | 0.009 | 0.002 to 0.017 | 0.021 |
| Intercept β0 | 5.74 | 5.43 to 6.07 | <0.005 |
| 90th Percentile LOS  (CTAS 2-5) | Pre-intervention trend β1 | -0.033 | -0.049 to -0.015 | <0.005 |
| Step-change post-intervention β2 | -0.81 | -1.49 to -0.08 | <0.005 |
| Trend-change post-intervention β3 | 0.040 | 0.020 to 0.058 | <0.005 |
| Intercept β0 | 11.21 | 10.36 to 11.97 | <0.005 |
| Mean PIA | Pre-intervention trend β1 | -0.17 | -0.37 to 0.036 | 0.81 |
| Step-change post-intervention β2 | -43.81 | -53.70 to -34.46 | <0.005 |
| Trend-change post-intervention β3 | 0.086 | -0.13 to 0.29 | 0.092 |
| Intercept β0 | 120.85 | 112.71 to 128.60 | <0.005 |
| 90th Percentile PIA | Pre-intervention trend β1 | -0.54 | -0.93 to -0.11 | 0.011 |
| Step-change post-intervention β2 | -91.39 | -110.66 to -72.22 | <0.005 |
| Trend-change post-intervention β3 | 0.24 | -0.20 to 0.65 | 0.26 |
| Intercept β0 | 255.69 | 238.10 to 271.39 | <0.005 |
| Mean CTAS 2 (non-admitted) LOS | Pre-intervention trend β1 | -0.0091 | -0.015 to -0.0039 | <0.005 |
| Step-change post-intervention β2 | -0.58 | -0.83 to 0.034 | <0.005 |
| Trend-change post-intervention β3 | 0.012 | -0.0064 to 0.019 | <0.005 |
| Intercept β0 | 5.31 | 5.06 to 5.63 | <0.005 |
| Mean CTAS 3 (non-admitted) LOS | Pre-intervention trend β1 | -0.012 | -0.018 to -0.0057 | <0.005 |
| Step-change post-intervention β2 | -0.75 | -1.02 to -0.49 | <0.005 |
| Trend-change post-intervention β3 | 0.014 | 0.0079 to 0.021 | <0.005 |
| Intercept β0 | 4.83 | 4.56 to 5.16 | <0.005 |
| Mean CTAS 4 (non-admitted) LOS | Pre-intervention trend β1 | -0.0061 | -0.013 to -0.001 | 0.042 |
| Step-change post-intervention β2 | -0.32 | -0.51 to -0.13 | <0.005 |
| Trend-change post-intervention β3 | 0.0081 | -0.0027 to 0.015 | 0.13 |
| Intercept β0 | 2.49 | 2.20 to 2.85 | <0.005 |
| Mean CTAS 5 (non-admitted) LOSa | Pre-intervention trend β1 | -0.0021 | -0.0057 to 0.0011 | 0.22 |
| Step-change post-intervention β2 | -0.24 | -0.41 to -0.068 | 0.008 |
| Trend-change post-intervention β3 | 0.0037 | -0.0003 to 0.008 | 0.078 |
| Intercept β0 | 0.76 | 0.59 to 0.94 | <0.005 |
| LWBS | Pre-intervention trend β1 | -0.018 | -0.03 to -0.0054 | 0.006 |
| Step-change post-intervention β2 | -1.27 | -1.77 to -0.72 | <0.005 |
| Trend-change post-intervention β3 | 0.015 | 0.0020 to 0.028 | 0.27 |
| Intercept β0 | 3.60 | 3.01 to 4.19 | <0.005 |
| LAMA | Pre-intervention trend β1 | 0.0053 | -0.0004 to 0.011 | 0.069 |
| Step-change post-intervention β2 | -0.91 | -1.20 to -0.63 | <0.005 |
| Trend-change post-intervention β3 | -0.0070 | -0.014 to -0.0003 | 0.038 |
| Intercept β0 | 1.47 | 1.23 to 1.73 | <0.005 |

CI, confidence interval; CTAS, Canadian Triage and Acuity Scale; β symbols refer to those in Equation 1

a Data was log-transformed prior to segmented regression of interrupted time series analys*i*s

**3.3. Left-without-being seen rates (LWBS) and Left-against-medical-advice rates (LAMA)**

From Appendix Table 1, we were able to calculate the % change in LWBS and LAMA pre- and post-intervention. Since there were no significant trends during the pre-intervention period after Bonferroni correction, we assume that the intercept is the value of the metric at the end of the pre-intervention period. Therefore, we divide the step-change (β2) by the intercept (β0) and multiply by 100 to produce the % change in LWBS and LAMA after the intervention.

**3.4. Step-change mean LOS for non-admitted CTAS 5 patients**

There were statistically significant reductions in LOS during the post-intervention period for non-admitted CTAS 2 to 4 patients. For non-admitted CTAS 5 patients, we detected a 0.24 hour reduction in mean LOS that reached statistical significance at the p < 0.05 level, but not after Bonferroni correction (p = 0.005, Appendix Table 2). We believe the mean LOS for non-admitted CTAS 5 patients was likely improved. However, the pre-intervention mean CTAS 5 LOS was already quite short (Appendix Table 2), and a smaller sample size limited us from demonstrating a statistically significant step-change.

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