

Continuous Quality Improvement Program, Based on Lean Concepts, Allows Emptying of Emergency Department Corridors

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ABSTRACT

Objectives: To assess the impact on an emergency department (ED) and the sustainability of a multifaceted continuous quality improvement (CQI) program based on Lean concepts.

Study Design: A prospective interventional 6-year study was conducted.

Methods: Interventions included managerial, organizational, and architectural features. Evaluation was conducted using pre-/post intervention ANOVA comparisons and interrupted time series (ITS) analysis.

Results: We analyzed 413,392 attendances. During the study period, significant ($P < .001$) trends were found for decreased length of stay (LOS) (−191 minutes; 95% CI, −280 to −101), waiting time before seeing an ED provider (−142 minutes; 95% CI, −225 to −66), and for increased percentage leaving ED in less than 4 hours (+24%; 95% CI, 12%–38%). ITS analysis demonstrated that the initial quality improvement step and having an ED medical coordinator had a significant impact on LOS, whereas the policy of having 0 patients in ED corridors led to significant improvements in LOS in the percentage of patients leaving the ED in less than 4 hours, and in the waiting time before seeing a medical provider. Fast-track pathways were implemented for low- and very low-complexity patients.

Conclusions: Our results indicate that a CQI program based on Lean concepts—including successive interventions and a “fast track” for low- and very low-complexity patients—allows for the emptying of ED corridors and the enhancement of time-intervals measurements/quality indicators.

Emergency department (ED) overcrowding has a negative impact on the quality of care and on patient and staff satisfaction.^{1,2} Operational performance measures have been suggested and various time intervals have been proposed as quality and performance indicators, or crowding markers, in the ED. Longer ED length of stay (LOS) has been associated with a greater risk of death in the short term.^{3,4} The percentage of patients leaving the ED in less than 4 hours,⁵ the time spent waiting to see a medical provider,⁶ and the time spent waiting for a triage nurse⁷ have all been proposed as time-interval measurement/quality indicators (TIMQIs).

Various strategies to improve ED patient-flow management, performance, and quality of care have been proposed.^{8,9} Continuous quality improvement (CQI) is probably the most established approach,¹⁰ with “Lean thinking”—first implemented in manufacturing, later extended to healthcare organizations including EDs¹¹—as one approach to CQI. Various other tools have been proposed to improve the quality of the EDs,¹² including fast-track¹³ triage area organization,¹⁴ reorganization of patient flow, and clinical information system and process redesign. However, evaluations of their success were frequently carried out by using short-term pre-/post intervention measurements.¹⁵ The long-term impact of interventions is difficult to evaluate in quality improvement evaluations. However, a central idea in improvement is to make changes incrementally, by learning from experience.¹⁶ We have found very few studies that have reported a continuous evaluation over time.¹⁷

Move to ED provisional structure—0 patients in the ED corridors (June 11, 2007)

- A new quality objective is defined—“0 patients in the ED corridors”—without specifying a process to achieve it. The aim of the staff and ED provider coordinator is to stick to the new policy of “not accepting a single patient in the corridors” under any pretext nor for whatever reason.
- On arrival, the patients are lifted by triage nurse if their clinical condition allows, even if they arrived by ambulance.
- Immediate rooming by triage nurse for acuity levels 1 to 4; we added a new level. The Red area receives bedded patients whereas the Blue area is for able-bodied patients or patients in a wheelchair. Patients who are mobile after care in the Red and Blue sectors are orientated to seated areas.
- The triage sector bay is dedicated for the management of level 5 acuity patients (fast-track for very low complexity patients) but no physician is dedicated to this role.
- The old premises were located on the first basement of the main tower; provisional was located on the first floor (radiology was located on the first basement). The total surface area was reduced by 20%. The change in number of places is: Triage nurse: 2 bays, plus 1 medical bay; Red area: 9 beds (+1), plus 6 lying-down waiting places (+0); Blue area: 7 beds (–1), plus 5 lying-down waiting places (+0) and 5 seated waiting places (+0); OU remains located on the 13th floor (21 rooms).

ED move to permanent structure—fast track for very low-complexity patients (June 15, 2009)

- The observation unit staff is merged with the ED staff and can be redeployed in terms of patient flow in the observation unit or in the ED areas (pods). The teams were very motivated by their new premises, which had more secure access, were more comfortable for the patients, and had a more spacious waiting room for receiving families.
- Streaming of patients into 3 pods based on triage nurse: Red, Blue, and Fast-track. Patients with acuity levels 1 to 3 are installed lying down (Red area), and level 4 are standing or in a wheelchair (Blue area). Level 5 are standing and wait-seated in a waiting room. Information for families in the waiting room is reinforced and forms part of the handover process.
- Definitive structure is situated on the first basement of the main tower, over a surface area of +20% compared with the old structure (+40% compared with provisional structure). It includes: Triage area: 2 bays (+0) and 1 medical bay (fast-track for very low-complexity patients without dedicated doctor); Red area: 16 beds (+7) and 5 lying-down waiting places and 6 seated waiting places; Blue area: 8 beds (+1) and 6 seated waiting places. The observation unit is located on the same floor in immediate proximity to the ED. It has 24 beds (+3).

Dedicated physician for very low complexity patients (January 11, 2010)

- A goal of 25% to 30% flow of patients in triage 5 was set. Patients likely to be discharged without any additional exam were placed in triage 5 by triage nurse. A doctor from the Red sector was designated for fast-track level 5 patients.

CQI indicates continuous quality improvement; ED, emergency department; LOS, length of stay; WT, waiting time.

(continued)

The aim of this study was to measure the impact of the reorganization of an ED based on CQI and Lean thinking on TIMQIs. Thus, we used pre- and post intervention comparisons for short-term evaluation. To evaluate the long-term impact of successive interventions, we used interrupted time series (ITS) analysis, assessment technique, developed to analyze work flows and processes within an organization (reengineering).¹⁸

METHODS

Patients and Data Collection

This anonymous data set did not contain any identifiable personal health information, and it is currently used as an ED quality and performance measurement as part of an ongoing emergency activity and performance evaluation. The study was approved by the emergency ethical committee of the Assistance Publique-Hôpitaux de Paris.

Study Design

We report a CQI project conducted over a 6-year period. Specific interventions were introduced in a sequential manner during the study period. To evaluate the impact of each specific intervention, we conducted a prospective pre-/post intervention 1-way analysis of variance (ANOVA),¹⁹ comparing the means of several quality and performance indicators from the 28 days before to 42 days after each intervention.

An ITS analysis was also conducted, which included monthly average values for the performance indicators as a way to evaluate each specific intervention in the overall CQI project. The time series included 72 measured points from January 2006 to December 2011, which spanned a period prior to CQI implementation to 24 months after the last intervention.²⁰

Setting

The study was carried out in an academic hospital (Bichat-Claude

Table 1. Definitions of Specific Interventions (continued)

Move to ED provisional structure—0 patients in the ED corridors (June 11, 2007)
<ul style="list-style-type: none"> A new quality objective is defined—“0 patients in the ED corridors”—without specifying a process to achieve it. The aim of the staff and ED provider coordinator is to stick to the new policy of “not accepting a single patient in the corridors” under any pretext nor for whatever reason. On arrival, the patients are lifted by triage nurse if their clinical condition allows, even if they arrived by ambulance. Immediate rooming by triage nurse for acuity levels 1 to 4; we added a new level. The Red area receives bedded patients whereas the Blue area is for able-bodied patients or patients in a wheelchair. Patients who are mobile after care in the Red and Blue sectors are orientated to seated areas. The triage sector bay is dedicated for the management of level 5 acuity patients (fast-track for very low complexity patients) but no physician is dedicated to this role. The old premises were located on the first basement of the main tower; provisional was located on the first floor (radiology was located on the first basement). The total surface area was reduced by 20%. The change in number of places is: Triage nurse: 2 bays, plus 1 medical bay; Red area: 9 beds (+1), plus 6 lying-down waiting places (+0); Blue area: 7 beds (-1), plus 5 lying-down waiting places (+0) and 5 seated waiting places (+0); OU remains located on the 13th floor (21 rooms).
ED move to permanent structure—fast track for very low-complexity patients (June 15, 2009)
<ul style="list-style-type: none"> The observation unit staff is merged with the ED staff and can be redeployed in terms of patient flow in the observation unit or in the ED areas (pods). The teams were very motivated by their new premises, which had more secure access, were more comfortable for the patients, and had a more spacious waiting room for receiving families. Streaming of patients into 3 pods based on triage nurse: Red, Blue, and Fast-track. Patients with acuity levels 1 to 3 are installed lying down (Red area), and level 4 are standing or in a wheelchair (Blue area). Level 5 are standing and wait-seated in a waiting room. Information for families in the waiting room is reinforced and forms part of the handover process. Definitive structure is situated on the first basement of the main tower, over a surface area of +20% compared with the old structure (+40% compared with provisional structure). It includes: Triage area: 2 bays (+0) and 1 medical bay (fast-track for very low-complexity patients without dedicated doctor); Red area: 16 beds (+7) and 5 lying-down waiting places and 6 seated waiting places; Blue area: 8 beds (+1) and 6 seated waiting places. The observation unit is located on the same floor in immediate proximity to the ED. It has 24 beds (+3).
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CQI indicates continuous quality improvement; ED, emergency department; LOS, length of stay; WT, waiting time.

Bernard [BCB]) located in the Paris metropolitan area. Over the course of the study, there were no significant changes in the number or composition of the medical staff (trainees, residents, or staff emergency physicians); in the paramedical staff; in the hospital policies on admissions; or in access to radiology or laboratories. ED renovation had already been planned, including a temporary move to a provisional structure, and finally, into our permanent structure.

Interventions Description

Each of the interventions included managerial, organizational, and architectural modifications. Briefly, they included: a) initial quality improvement step: the creation of a CQI team project that includes a change of culture promoting performance and quality; b) implementation of an ED medical coordinator responsible for the good functioning of the ward through leadership and formal authority; c) a triage nurse who streams the patients into 2 different sectors according to their acuity level;

d) the move to a provisional ED structure (ED area reduced by 20%) with a new policy of 0 patients in the ED corridors; e) the move to our permanent ED structure (40% larger than original ED area) with all sectors on 1 unique floor, meaning personnel can be deployed according to patient flow in real time; and f) a dedicated physician for fast-tracking low-complexity patients.

Details of each intervention are shown in **Table 1**. We did not evaluate intervention “a”—the initial quality improvement step as a pre-/post intervention—but it was integrated into the ITS model because it represents the first modification to the culture of the service and accompanied the first organizational modifications to our ED.

Measurements

Daily and monthly values for time-interval measurements were extracted automatically in real time from the electronic medical and hospital database records. All visits to the BCB’s ED during the study period were included. The following variables

were studied: number of daily and monthly visits; acuity level; patient's final outcome (ie, not admitted, admitted in our observation ward, admitted to another ward, or transferred to another hospital). Acuity was measured according to the Canadian Triage scale from 1 to 5 (1 = high acuity or complexity, 5 = low acuity or complexity).

Time intervals (minutes) were calculated automatically on a daily and monthly basis and were defined as follows: a) LOS—minutes between the time the patient was identified in the ED and the time the patient left the ED; b) percentage of patients leaving in less than 4 hours—calculated from the LOS for each visit; c) waiting time to triage nurse—minutes between the time the patient was identified in the ED and the time the patient was seen by the triage nurse; d) waiting time to ED provider—minutes between the time the patient was identified in the ED and the time the patient was first treated by the ED provider. The final decision of the ED provider is registered by the ED computer program.

Statistical Analysis

The pre-/post intervention analysis compares pre- and post intervention means of daily time-interval measurements (28 days before and 42 days after each intervention) by using 1-way ANOVA.¹⁹

ITS analysis at multiple time points before and after interventions were conducted in order to detect whether or not the different interventions had a significantly greater effect than any underlying trend.^{20,22} Autoregressive integrated moving average (ARIMA) models, using Box-Jenkins methodology,²⁰ were used to evaluate whether relationships existed between time intervals (LOS, percentage leaving ED <4 hours, wait time to see provider) and the different interventions introduced. Time between interventions were longer than 3 months (with 3 measures points) to guarantee a stable mean, and moving averages were calculated if necessary to correct trend.^{20,22}

The model was identified by determining the ARIMA model orders (p, d, q) using auto-correlation and partial auto-correlation. Finally, the adequacy of the model was checked and statistical significance of the parameters was determined. The best type of impact was evaluated as previously described.^{20,21} The gradual permanent impact was used; gradual permanent pattern includes 2 parameters estimated from the ITS analysis, which allows us to evaluate the level of the disturbance event and its duration. Omega estimates the difference between the data series before and after the intervention; delta indicates the duration of any change and the rate of recovery if present. Then, omega (ω) indicates the overall shift where the sign represents the direction of the change; and delta (δ) represents the speed at which a gradual increase or decay of these initial changes occurred over time. Both parameters should be statistically significant so as not end up with paradoxical conclusions.²¹ Omega and delta asymptotic parameters \pm SD values are presented as well as their 95% CIs.

Statistica software (Statsoft, Tulsa, Oklahoma) was used for analysis. We deemed statistical differences to be significant for $P < .05$.

RESULTS

Characteristics of the Study Subjects

During the 6-year study period, 413,392 attendances were registered in the ED. Monthly ED attendances increased over the study period from 4540 ± 214 in 2005 to 5928 ± 299 in 2011 (+31%; 95% CI, 20%-42%) (Figure). No significant change in admission rate (20.3%), transfer to intensive care (3.2% of the entire population), or patients' typology (medicine [60%], surgery [36%], psychiatric [4%]; patients ≥ 75 years [10.5%]) was found during the study period.

Main Results

The trends for main TIMQIs and monthly number of visits are presented. The chronology of the different interventions studied is indicated as well.

During the 6-year study period, findings included decreases in trends for LOS (-191 minutes; 95% CI, -280 to -101; $P < .001$) and waiting time to provider (-142 minutes; 95% CI, -225 to -66; $P < .001$), and a significant increase in the trend for the percentage of patients leaving the ED in less than 4 hours (+24%; 95% CI, 12%-38%; $P < .001$).

Pre- and Post Intervention Analysis

Table 2 shows the results of ANOVA comparisons for the measured time intervals in the pre-/post intervention analysis.

Having an ED medical coordinator significantly reduced ED LOS, notably for high-acuity patients. The interventions of having a dedicated physician for fast-tracking what is considered to be low-complexity also significantly improved the percentage of patients leaving the ED in less than 4 hours.

Interrupted Time Series Analysis

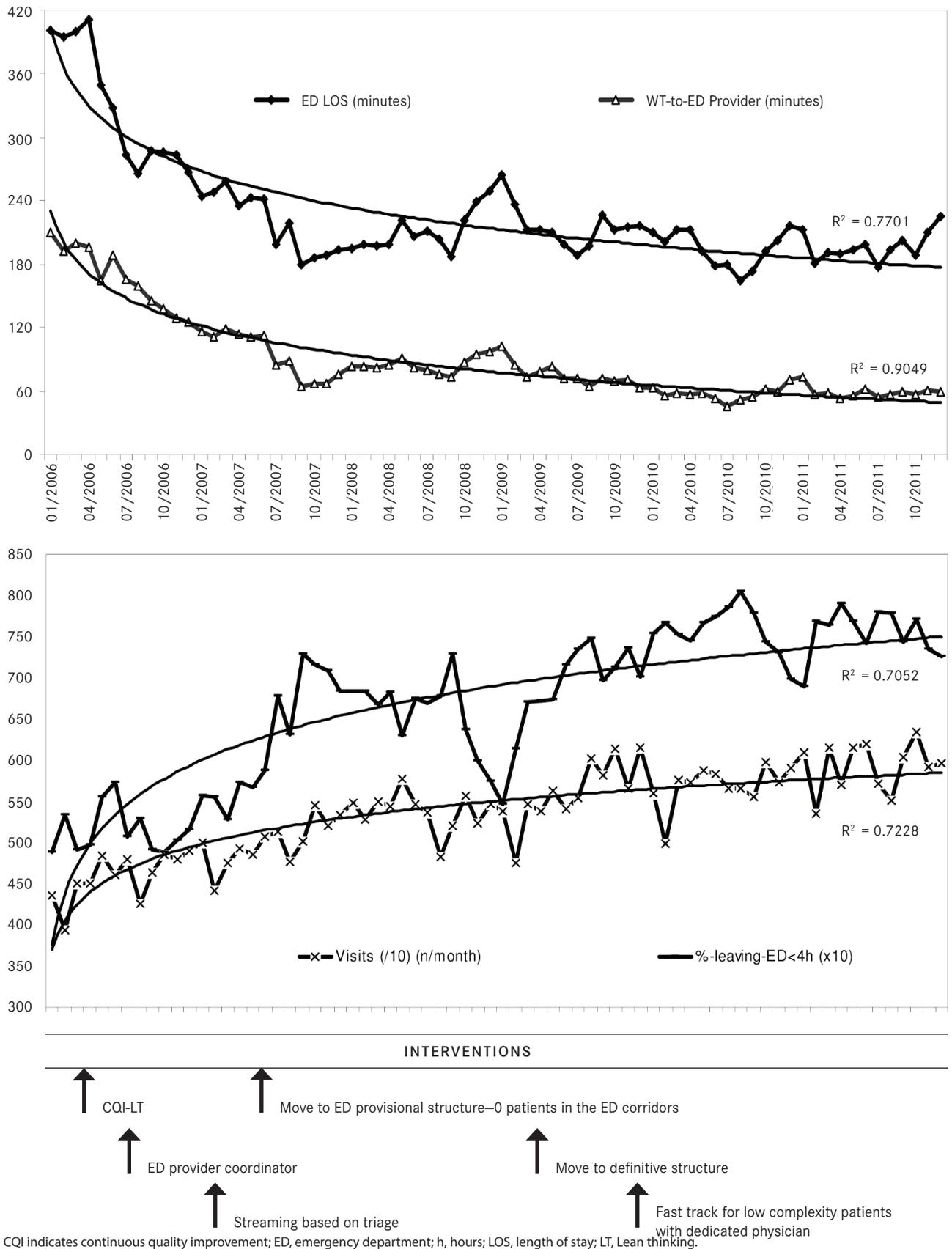
If we look at the progress of the measurements of the different time intervals in the Figure and Table 2, we can see improvements between post intervention measures and the following pre-intervention, ie continuous improvement unrelated to interventions. Thus, another evaluation method was necessary to evaluate the impact of interventions over the study period. Table 3 shows the results of ITS models for ED TIMQIs.

We found that the interventions of an initial quality improvement step and having an ED medical coordinator had a significant impact on ED LOS, and that the interventions of moving to ED provisional structure and having 0 patients in the ED corridors had a significant impact on the percentage of patients leaving ED in less than 4 hours and on wait time to see the provider.

DISCUSSION

We report on a CQI program over a 6-year study period that included multiple planned managerial, organizational, and architectural interventions. Our study indicates that pre-/post intervention studies offer a short-time evaluation (a 6-week period), whereas ITS analyses offer evaluations of a longer period. ITS analyses were desirable because flow and processes were continuously evaluated and subsequently modified.

Figure. ED Time-Interval Quality Indicators and Number of Visits to ED Over the Study Period



CQI indicates continuous quality improvement; ED, emergency department; h, hours; LOS, length of stay; LT, Lean thinking.

Table 2. Main Results of ANOVA Pre-/Post Interventions Comparisons

	ED Medical Coordinator			Streaming Into 2 Pods as a Function of Triage Nurse		
	Pre Mean ± SD	Post Mean ± SD	P	Pre Mean ± SD	Post Mean ± SD	P
Daily visits (n)	154 ± 11	154 ± 16	1	161 ± 13	160 ± 14	.8
% leaving ED <4 hours	0.57 ± 0.09	0.57 ± 0.08	.9	0.52 ± 0.09	0.51 ± 0.12	.7
ED LOS (min)	343 ± 69	304 ± 56	.001	276 ± 41	269 ± 55	.6
Acuity level 1	687 ± 283	458 ± 260	.0001	315 ± 205	303 ± 136	.8
Acuity level 2	480 ± 142	371 ± 154	.0004	258 ± 65	222 ± 61	.02
Acuity level 3	356 ± 104	368 ± 77	.6	367 ± 66	348 ± 72	.3
Acuity level 4	264 ± 66	254 ± 67	.4	246 ± 49	259 ± 57	.3
Acuity level 5	211 ± 98	210 ± 67	.9	2723 ± 117	260 ± 84	.6
Not admitted	210 ± 35	226 ± 31	.05	241 ± 37	241 ± 53	1
WT to see triage nurse (min)	22.4 ± 7.8	18 ± 7	.02	19 ± 10	16 ± 8	.1
WT to see provider (min)	162 ± 27	146 ± 25	.003	161 ± 13	160 ± 14	.5
Acuity level 1	59 ± 21	42 ± 22	.002	0.52 ± 0.09	0.51 ± 0.12	.2
Acuity level 2	88 ± 14	77 ± 15	.004	276 ± 41	269 ± 55	.6
Acuity level 3	179 ± 35	180 ± 29	.88	315 ± 205	303 ± 136	.6
Acuity level 4	211 ± 33	185 ± 22	.0002	258 ± 65	222 ± 61	.2
Acuity level 5	186 ± 115	175 ± 67	.6	367 ± 66	348 ± 72	.9

ED indicates emergency department; min, minutes; WT, wait time.

In the pre-/post intervention analysis, we measured ED LOS and wait time to see the provider according to acuity level, as well as the wait time to see triage nurse. Analysis of these measurements helped to define the ED sectors or care pathways in which the various interventions might have had a quick impact. Thus, the intervention of having an ED medical coordinator allowed for a significant ED LOS reduction, seemingly explained by the reduction of ED LOS for acuity levels 1 and 2—the most complex patients. In contrast, ED LOS improvement after the move to provisional structure was related to the reduction of ED LOS for acuity levels 4 and 5, showing the importance of the dedicated structure to the care of very low-complexity patients. Similarly, we found significant improvements in wait time to see the provider after the interventions of having an ED medical coordinator and moving to provisional structure. The first is explained by a reduction in the wait time to see the provider for the most complex patients, while the second is related to a more global improvement, but was much higher in patients of low and very low complexity, which indicates the importance of both specific clinical pathways.

Additionally, we found that the percentage of patients leaving the ED in under 4 hours was improved later, while ED LOS enhancement occurred earlier. These data suggest that both quality and performance indicators probably evaluate different processes in ED organization, and that both should be measured after

any intervention. We did not find a significant reduction in wait time to see triage nurse after any intervention, except for having an ED medical coordinator; nevertheless, we saw a steady improvement in this measure between interventions. We consider that, while wait time to see the ED provider is dependent on the dynamics of medical teams, the wait time to see the triage nurse depends on the nurse's team.

Our new policy of having 0 patients in the ED corridors, which occurred with the move to the provisional structure, had significant impacts on different time intervals despite the smaller space. Certain features can explain the measurements associated with this intervention. First, the provisional ED structure had a medical bay in the triage area, which did not exist in the older premises. This bay was used to manage very low-complexity (acuity level 5) patients, serving as a fast track for these patients. The impact of this intervention, therefore, appears to be linked to the acceleration in treatment of very low-complexity patients with an overall impact on ED main TIMQIs. Contemporary with the move, the ED staff was working on correcting patient neglect in the ED as defined by the French Health Authority.²³ We found that this occurred frequently, with patients in the corridors being one of its main indications. Organizational improvements must be instituted to eliminate patient neglect in the ED. We considered combatting patient neglect in the ED and having the goal of there being 0 patients in the ED corridor as complementary

Move to ED Provisional Structure— 0 Patients in the Corridors			Move to Definitive Structure			Dedicated Physician for Low-Complexity Patients		
Pre Mean ± SD	Post Mean ± SD	P	Pre Mean ± SD	Post Mean ± SD	P	Pre Mean ± SD	Post Mean ± SD	P
156 ± 16	167 ± 19	.006	182 ± 18	179 ± 24	.5	185 ± 21	178 ± 18	.1
0.57 ± 0.1	0.64 ± 0.1	.005	0.71 ± 0.07	0.74 ± 0.08	.1	0.7 ± 0.1	0.75 ± 0.06	.008
242 ± 40	219 ± 50	.04	191 ± 27	183 ± 38	.3	203 ± 40	210 ± 33	.4
258 ± 101	244 ± 138	.6	101 ± 114	164 ± 164	.08	155 ± 183	255 ± 265	.09
184 ± 40	198 ± 77	.4	145 ± 59	138 ± 46	.6	198 ± 94	246 ± 107	.06
326 ± 54	310 ± 73	.3	289 ± 49	279 ± 96	.6	344 ± 125	366 ± 90	.4
240 ± 46	212 ± 49	.02	197 ± 42	177 ± 39	.05	182 ± 30	171 ± 32	.2
244 ± 74	201 ± 79	.03	162 ± 38	156 ± 46	.6	124 ± 37	125 ± 36	.9
215 ± 40	183 ± 41	.002	165 ± 26	156 ± 30	.2	155 ± 23	145 ± 25	.08
17 ± 6	18 ± 7	.9	12 ± 5	12 ± 5	.4	13 ± 4	12 ± 4	.4
113 ± 30	95 ± 24	.006	75 ± 16	73 ± 22	.6	62 ± 13	59 ± 12	.3
30 ± 17	18 ± 10	.0003	12 ± 14	17 ± 14	.2	15 ± 14	15 ± 18	.9
44 ± 11	39 ± 10	.07	28 ± 9	32 ± 9	.1	30 ± 8	31 ± 8	.9
81 ± 27	69 ± 22	.05	56 ± 13	61 ± 22	.6	58 ± 16	53 ± 14	.2
146 ± 40	125 ± 38	.02	84 ± 24	72 ± 24	.04	65 ± 15	58 ± 14	.05
203 ± 75	151 ± 55	.002	98 ± 30	99 ± 38	1	79 ± 25	79 ± 25	1

and a reachable strategy and objective. The ED team stuck to this objective, which also valorized their function and was inspired by patient-centered care.²⁴ It has been suggested that an increase in the percentage of patients leaving the ED in less than 4 hours leads to there being 0 patients in the corridors of some British EDs.^{5,25} In our study, the 0 patients in the ED corridor objective led to an increase in the percentage of patients leaving the ED in under 4 hours, and a reduction in the waiting time before seeing a medical provider.

In fact, the reality of patients being in the corridors at several points during their stay in the ED indicated small defects in the organization of care. We were able to fix some with specific processes, such as direct patient's installation in beds or cubicles. In other cases, though, no processes were specified, yet it appears that providers took on the goal of having 0 patients in the ED corridor and figured out ways to avoid that scenario. From our experience, it was the ability to share the value we placed on having 0 patients in the ED corridor that permitted the reorganization of the patient processes. This was achieved by the ED team without a specified intervention of the CQI team. We believe this is close to models of "learning organization" or "knowledge management,"²⁶ and a culture of improvement,^{27,28} that have been initiated early in the CQI program.

Permanent ED structures have more spacious premises and a total number of beds/cubicles. The absence of significant im-

pact of the intervention (to move to a permanent ED structure) is concordant with previously published studies which have reported^{29,30} that the number of beds in an ED has no significant impact on ED LOS. We believe that organizational and process management features are more important than the number of beds.

The ITS analyses allowed us to evaluate the complex relationships among the different interventions and, thus, define their impact and sustainability. In the present study, we identified "permanent gradual" as the best impact type: the increase or decrease due to the intervention is gradual, and the final permanent impact becomes evident only after some time. By analyzing the trend line for the time period after an intervention, we noticed a significant difference on the trend line for the time period leading up to the intervention. Furthermore, the ITS analysis offers a new approach to evaluate the cumulative effect of specific interventions and to evaluate the strength of each one in an overall CQI program.

In our model, significant values for the 2 parameters (delta and omega) indicates a gradual and permanent evolution of the studied parameter. ED LOS model found significant values following interventions: initial quality improvement step, having an ED medical coordinator. The percentage of patients leaving ED in less than 4 hours and wait time to see medical provider models show that only ED move to the provisional structure of having 0

Table 3. Interrupted Time Series Analysis

	Mean Change (mean ± SD)	95% CI	Parameter (omega & delta) ^a	Asymptotic Parameter ^b	SD	95% CI	P	
ARIMA model for ED length of stay								
Initial quality improvement step	-33 ± 11	-55 to -12	ω δ	-10.88 0.88	3.23 0.04	-17.32 to -4.44 0.8-0.97	.001 <.0000001	
ED medical coordinator	-93 ± 12	-118 to -69	ω δ	24.37 0.60	12.44 0.18	-0.43 to 49.18 0.25-0.96	.05 .001	
Streaming into 2 pods as a function of nurse triage	-34 ± 11	-56 to -12	ω δ	4.4 0.87	3.89 0.08	-3.37 to 12.17 0.71-1.02	.3 <.0000001	
ED move to provisional structure—0 patients in the ED corridors	-36 ± 8	-53 to -18	ω δ	-27.4 0.45	18.35 0.5	-63.99 to 9.2 -0.55 to 1.45	.1 .4	
ED move to definite structure	-0.4 ± 8	-17 to 16	ω δ	0.001 1.32	0.02 0.76	-0.03 to 0.04 -0.2 to 2.83	.9 .09	
Dedicated physician for low-complexity patients	-14 ± 8	-31 to 2	ω δ	-5.15 -0.97	10.08 0.29	-25.27 to 14.97 -1.56 to -0.39	.6 .001	
ARIMA model for percentage leaving ED <4 hours								
Initial quality improvement step	4.9 ± 1.9	1.1-8.6	ω δ	-1.67 -0.96	1.6 0.06	-4.87 -1.09	1.52 -0.83	.3 <.0000001
ED medical coordinator	-2.4 ± 2.2	-6.7 to 1.9	ω δ	-0.06 0.63	0.6 1.4	-1.25 -2.16	1.14 3.43	.9 .7
Streaming into 2 pods as a function of nurse triage	5.6 ± 1.9	1.7-9.4	ω δ	1.33 -0.86	2.53 0.48	-3.72 -1.83	6.38 0.1	.6 .08
ED move to provisional structure—0 patients in the ED corridors	10.3 ± 1.5	7.3-13.4	ω δ	6.92 -0.62	3.37 0.16	0.19 -0.95	13.65 -0.29	.04 .0003
ED move to definite structure	6.2 ± 1.4	3.3-9.0	ω δ	-0.04 -1.15	0.21 0.22	-0.46 -1.58	0.37 -0.72	.8 .000001
Dedicated physician for low-complexity patients	3.2 ± 1.4	0.2-5.9	ω δ	1.24 -0.04	1.62 1.25	-1.99 -2.53	4.48 2.46	.4 .9
ARIMA model for WT to see ED provider								
Initial quality improvement step	-26 ± 5.9	-38 to -14	ω δ	-1.35 0.71	1.33 0.29	-4.01 0.14	1.30 1.28	.3 .01
ED medical coordinator	-43.4 ± 6.7	-57 to -30	ω δ	7.73 -0.47	5.74 0.57	-3.72 -1.61	19.18 0.66	.2 .4
Streaming into 2 pods as a function of nurse triage	-29.8 ± 6	-42 to -18	ω δ	-1.42 0.39	2.48 0.81	-6.37 -1.23	3.53 2	.6 .6
ED move to provisional structure—0 patients in the ED corridors	-32.5 ± 4.7	-42 to -23	ω δ	9.91 0.66	4.35 0.22	1.23 0.23	18.59 1.1	.03 .003
ED move to definite structure	-13.5 ± 4.5	-22 to -5	ω δ	-0.83 -0.92	3.05 0.41	-6.91 -1.73	5.26 -0.11	.8 .03
Dedicated physician for low-complexity patients	-10 ± 4.5	-19 to -1.1	ω δ	1.86 -0.49	2.89 0.95	-3.91 -2.39	-3.91 -2.39	.5 .6

ARIMA indicates autoregressive integrated moving average; ED, emergency department; WT, wait time.

^aOmega and delta indicate the increase or decrease due to the intervention and its sustainability. Omega indicates an average estimate of the difference in the proportion of time intervals before and after the intervention, and delta estimates whether the effect is constant. In this model, when evaluating a fitted model, both parameters should be statistically significant.

^bAsymptotic change indicates the shift in the overall mean.

patient in the ED corridors, as omega and delta have significant values. Even if some interventions were not associated with significant level and slope changes, we think that our study indicates the importance of the cumulative value of successive interventions within the framework of continuous quality improvement policy, rather than the individual results of every intervention.

Our results suggest that the progressive establishment of specific care pathways, often called fast tracks, for low- (acuity level 4) and very low- (acuity level 5) complexity patients, was a determining factor in the overall strategy of quality and performance improvement, which confirms previous publications.^{13,31} This establishment began with the triage nurse who streams the patients into 2 different sectors; the availability of a bay in the triage area; the move to our permanent ED structure that included streaming the patients into 3 pods; and finally with the assignment of a dedicated physician for fast-tracking low-complexity patients.¹

Limitations

This study has several limitations. Firstly, even though we analyzed some successive interventions and described a number of these, other factors probably exist that can influence ED quality indicators. Secondly, because there is no single consensus on ED quality indicators, we measured ED time intervals, which are currently the most recommended performance measurement.³² Thirdly, we did not include parameters that could affect the performance of an ED, such as ED or hospital census variables. Finally, the ability to replicate the interventions in other EDs is unknown.

CONCLUSIONS

Our study demonstrates that ED performance and quality, evaluated by using time-interval measurements, may be improved by a CQI program based on Lean thinking. Our results confirm the importance of CQI and Lean thinking as methods of analyzing processes, management, and redesign of EDs. The study indicates the importance of complex and successive interventions including managerial, organizational, and architectural features. Early and progressive changes in the process and organization may have driven subsequent improvements. The establishment of a fast track for low- and very low-complexity patients, as well as a culture of change and improvement among the ED staff, appear to us to be very significant. Furthermore, we showed that before-and-after comparison studies are insufficient to evaluate the effect of multiple complex interventions over long time periods, and that ITS analysis is a relevant approach method.

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