The Effect of Removing the Four-Hour Access Standard in the ED:

A Retrospective Observational Study

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ABSTRACT

Background: Time-based targets are used to improve patient flow and quality of care within Emergency Departments (EDs). While previous research often highlighted the benefits of these targets, some studies found negative consequences of their implementation. We study the consequences of removing the four-hour access standard.

Methods: We conducted a before and after, retrospective, observational study using anonymised, routinely collected, patient-level data from a single English NHS Emergency Department between April 2018 and December 2019. The primary outcomes of interest were the proportion of admitted patients, i.e., the admission rate, the length of stay in the ED, and ambulance handover times. We used interrupted time series models to study and estimate the impact of removing the four-hour access standard.

Results: A total of 169,916 attendances were included in the analysis. The interrupted time series models for the average daily admission rate indicate a drop from an estimated 35% to an estimated 31% (95% CI (-4.1 ; -3.9)). This drop is only statistically significant for Majors (Ambulant) patients (from an estimated 38.3% to an estimated 31.4%) and, particularly, for short-stay admissions (from an estimated 18.1% to an estimated 12.8%). The models also show an increase in the average daily length of stay for admitted patients from an estimated 316 minutes to an estimated 387 minutes (95% CI (33.5 ; 108.9)), and an increase in the average daily length of stay for discharged patients from an estimated 222 minutes to an estimated 262 minutes (95% CI (6.9 ; 40.4)).

Conclusion: Lifting the four-hour access standard reporting was associated with a drop in short-stay admissions to the hospital. However, it was also associated with an increase in the average length of stay in the ED. Our study also suggests that the removal of the four-hour standard does not impact all patients equally. While certain patient groups such as those Majors (Ambulant) patients with less severe issues might have benefited from the removal of the four-hour access standard by avoiding short-stay hospital admissions, the average length of stay in the ED seemed to have increased across all groups, particularly for older and admitted patients.

Key Messages

What is already known on this topic:

Previous research has shown that time-based targets lead to a reduction in patients' length of stay in emergency departments (EDs), and ED crowding. However, other studies found an increase in short-stay admissions as a result of introducing time-based targets in the ED. Also, studies found strong evidence of high stress and low morale after the introduction of time-based targets.

What this study adds:

This retrospective, observational before and after study show that removing the reporting of the four-hour access standard led to a reduction in the proportion of patients admitted to the hospital, in particular for short-stay admissions. It also shows an increase in the length of stay in the ED for both admitted and discharged patients.

How this study might affect research, practice or policy:

The four-hour access standard might not affect all patients equally. It would make sense for policymakers to consider such heterogeneity when designing policies.

INTRODUCTION

Delays are common in healthcare. They are the result of a temporary mismatch between the demand for the healthcare service and the capacity available to meet such demand. Long waiting times are associated with an increase in mortality [1] and with adverse patient outcomes [2]. Many countries, including the United Kingdom, Australia, and New Zealand, introduced time-based targets to improve patient flow and the quality of care within Emergency Departments (EDs). In England, the National Health Service (NHS) Constitution for England specifies that at least 95% of patients attending an ED have to be admitted to the hospital, transferred to another hospital, or discharged within four hours of arriving [3].

Previous research highlighted the benefits of system-wide time-based targets. Several studies have shown a link between the introduction of the target and a reduction in patients' overall length of stay and time to assessment [4–9]. For example, Mason *et al.* [10] found that the introduction of the four-hour access standard in England reduced the proportion of patients spending more than four hours, and led to an increase in the proportion of patients departing within twenty minutes of the target. Ngo *et al.* [11] and Higginson *et al.* [12] found a negative relationship between ED crowding and performance against the four-hour access standard.

However, some studies found negative consequences of implementing time-based targets. Tenbencel *et al* [13] and Forero *et al* [14] found an increase in short-stay admissions after the introduction of time-based targets, though other studies found no significant effect on overall admissions after the introduction of the four-hour access standard in NHS England [6]. Further, studies exploring the impact of time-based targets on ED staff found strong evidence of high stress and low morale after the implementation of such targets [15-16].

In this study, using patient-level data from the ED unit of a major hospital where the four-hour access standard reporting was stopped as part of an NHS England field study, we are the first to use patient-level data to investigate the effects of the removal of the four-hour access standard on patients' length of stay in the ED, hospital admissions, and ambulance handover times, three key performance and quality indicators used by NHS England [17, 18].

METHODS

Study Design

We conducted a before and after, retrospective, observational study of all adult patients attending a single Emergency Department (ED) in England between April 2018 and December 2019. This particular ED was one of 14 hospital trusts that participated in a field test between May 2019 and December 2019 in which the trusts stopped reporting their performances against the four-hour access standard [19]. The study period did not include the COVID pandemic period because this period was marked with significant and exceptional changes to processes and short-stay wards in the ED.

The primary outcome of interest in our study was the daily proportion of patients admitted to the hospital from the ED, also known as the admission rate. We also analysed the effects of removing the four-hour access standard on the total lengths of stay in the ED and in the hospital, and on ambulance handover times. Due to space constraints in the paper, the main focus of this study will be on adult patients attending the ED. This is also because Paediatric and Resuscitation patients follow different processes and utilise separate resources, making it hard to carry out a valid comparison across all groups. All patients were considered for the ambulance handover time analysis. There was no formal calculation of the number of patients needed in the study.

Adult patients attending the ED can be categorised into three main categories based on their need of urgent care: Minors, Majors (Ambulant), and Majors (Non-Ambulant) [20]. The difference between Majors (Ambulant) and Majors (Non-Ambulant) patients is the need for a bed in the ED. In categorising patients' lengths of stay in the hospital, patients who are discharged on the same day (next day) from when they are admitted to the hospital are referred to as "zero-day" ("one-day") admissions, respectively, whilst patients discharged two or more days after their admission to the hospital are categorised as "two-plus-day" admissions. We considered zero- and one-day admissions patients as one category, representing short-stay admissions.

Data Sources

This study used anonymised patient-level data from a single English NHS ED, as well as anonymised patient-level hospital admissions (from the ED) data between April 2018 and December 2019. This hospital has a complete electronic health record (EPIC) which allows for detailed and complete data collection from ED attendances and hospital admissions. Study also uses hourly occupancy data measured as the proportions of occupied beds in the hospital. Staffing levels remained the same during the pre-intervention and post-intervention periods. For details see Supplementary Data.

Statistical Analysis

To analyse the effect of the removal of the four-hour access standard on the daily proportion of patients admitted to the hospital we used interrupted time series models [21–22]. The model estimates the changes in levels and trends for the proportion of average daily admissions. Using the anonymised patient-level data, we calculated the effect of removing the four-hour access standard on the average daily admission rate, as well as the average daily length of stay, and average daily ambulance handover time. We defined the period between April 2018 and April 2019 as preintervention, and May 2019 through December 2019 as postintervention. The model used was:

$$Y_t = \beta_0 + \beta_1 * time_t + \beta_2 * intervention_t + \beta_3 * time\_post\_intervention_t + \beta_4 * M_{t4} --- \beta_p * M_{tp} + \varepsilon_t \qquad (1)$$

, where *"time"* is the value of time from the start of the preintervention to the end of the postintervention, *"intervention"* is a binary variable indicating whether the observation belongs to the preintervention period, *"time_post_intervention"* is the number of time periods from the start of the preintervention and equals to zero for the preintervention period, and M_{t4} --- M_{tp} are covariates, such as the average age of the patients attending the ED daily, the average daily number of procedures and investigations, and indicator variables for the time and day of admissions.

In summary, β_0 is the baseline level of the outcome in April 2018, β_1 is the slope during the preintervention period, β_2 is the change in the mean of the outcome at the start of the intervention, β_3 is the difference in slopes between the post and preintervention periods, We used time-related covariates, such as the month of attendance and hour of arrival, to control for seasonality. We used robust standard errors for all models. For models where the outcome variable is constrained between 0 and 1, such as the admissions rate, we used beta regressions [23]. For all other models we used OLS.

We run the interrupted time series model for different patient categories and age groups to compare the pilot's impact across those categories and groups. Using β_3, the coefficient that explains the intervention's impact on the dependent variable, we compare how the pilot study impacted different age groups in terms of, for example, length of stay in the ED. The following *z*-test compares whether two regression coefficients are different:

$$Z = \frac{\beta_{3,1} - \beta_{3,2}}{\sqrt{SE(\beta_{3,1})^2 + SE(\beta_{3,2})^2}} \quad (2)$$

where $\beta_{3,1}$ is the coefficient for group 1 (e.g., Majors (Ambulant) patients), and $\beta_{3,2}$ is the coefficient for group 2 (e.g., Minors patients) [24].

To express the results of the segmented regression models, we will also compare preintervention with postintervention estimated outcomes using November 15th as the date for comparison. The difference between the estimates is the intervention effect.

Results are similar when using October and December as the months for comparison. November was chosen over October due to being later into the study, while December has behavioural aspects related to the Christmas holidays that might make it harder to correctly identify the pilot's impact.

Research Ethics (Board) approval was not required following the algorithm on the NHS HRA website [25].

RESULTS

Table 1 shows a summary and demographic breakdown of attendances to the ED and hospital admissions.

Table 1: Demographic characteristics of patients attending the ED

	ED	
Patient Category	**Preintervention April 2018 – April 2019**	**Postintervention May 2019 – December 2019**
Number of Adult Patients Attendances	102,227	67,689
Admitted Adult Patients	36,700 35.9%	22,350 33%
Number of Majors (Ambulant) Patients	41,669	28,750
Admitted Majors (Ambulant)	16,948 40.7%	10,185 35.4%
Number of Majors (Non-Ambulant) Patients	22,925	14,341
Admitted Majors (Non-Ambulant) Patients	17,020 74.3%	10,521 73.4%
Number of Minors Patients	37,633	24,598
Admitted Minors Patients	2,732 7.3%	1,644 6.7%
Patients Admitted or Discharged Before Four Hours	78%	57.5%
	ED - LoS (minutes)	
	Preintervention Median	**Postintervention Median**

	April 2018 – April 2019	May 2019 – December 2019
Admitted Patients	237	314
Discharged Patients	168	184
	Hospital	
	Preintervention	**Postintervention**
Patient Category	**April 2018 – April 2019**	**May 2019 – December 2019**
All Admitted Patients	50,708	24,822
Zero/One Day Patients	21,291	10,408
Two+ Days Patients	29,417	14,414
	Ambulance	
	Preintervention	**Postintervention**
	April 2018 – April 2019	**May 2019 – December 2019**
Number of Arrivals	44,175	22,970
Percentage of Total Attendances	35.5%	33.9%
Mean Handover Time	15.7	16.4
Median Handover Time	14	14

We estimated the ED's patient volume [26], standardised by staffing levels, using the number of arrivals from the hour prior to the arrival of each patient. Based on the ED's patient volume faced by individual patients, we calculate the hourly average ED's patient volume, and then calculate the average daily ED's patient volume to use as a control for crowding. Similarly, to control for a possible effect of the hospital's occupancy level on ED-to-hospital admissions (e.g., exit-block) [27], using the hourly occupancy data, we calculated the average daily hospital occupancy level and used its one-day lagged average to avoid using data that is not available at the point of the estimation.

The ED and the hospital data sets do not have a common patient identifier. However, we were able to match 50,841 (80.9%) admitted patients from the ED dataset with the hospital admissions dataset using the patients' age and gender information, and a six-hour time window between departure from the ED and admission to the hospital, assuming no patients arrive to the ED after they were admitted to the hospital. The matched dataset was only used for regressions where the outcome variable were short-stay and long-stay admissions.

Observations with missing data points were removed since they represented only 0.6% of all the observations. All models were run for all adult patients, and for each category of patients separately. This allowed us to study the impact of removing the four-hour access standard on the ED as a whole and on each category of patients separately.

Figure 1: Emergency Department Trends

Emergency Department trends for the admission rate for Majors (Ambulant) patients (I), and for the daily average length of stay for all adult admitted (II) and discharged (III) patients. The light-grey lines indicate the daily average data, the dark-grey lines indicate the 7-day moving average, and the grey lines indicate the trend before and during the intervention. The dashed vertical line indicates the start of the intervention period in May 2019.

Admission Rate

When analysing the regression results for the daily admission rate for all adult patients attending the ED, we see that there was a drop in the admissions rate during the pilot study (Table 2 – Time Post Intervention – 95% CI (-0.0326 ; -0.012). This represents a 4.05 percentage points estimated drop in the daily adult patients' admission rate, from 35.1% to 31%.

We further investigated whether and to what extent different patient categories saw a decrease in their admission rate. We observed that only Majors (Ambulant) patients saw a reduction in the daily admission rate (Supplementary Table B – Time Post Intervention – 95% CI (-0.0019 ; -0.0009)), and only for short-stay admissions (Supplementary Table C – Time Post Intervention – 95% CI (-0.003 ; -0.001)). These represent an estimated drop from 38.4% to 31.4% in the daily admission rate, and an estimated drop from 18.3% to 12.4% for short-stay admissions.

The models for Minors and Majors (Non-Ambulant) patients did not show a statistically significant change in their admission rate post-intervention (see Supplementary Data – Tables D & E). In addition, while Resuscitation and Paediatric patients are outside the scope of our paper, we nevertheless checked their daily admission rates post-intervention and found no statistically significant changes for them.

While older patients, i.e. patients over 70 years, attending the ED are more likely to get admitted to the hospital (60% admission rate compared to 25%), during the pilot test both groups of patients saw a statistically similar proportional drop in their admission rate (p-value = 0.4, Supplementary Tables F & G for regression tables).

Table 2: Admission Rate Regression Results for all Adult patients

	Daily Admission Rate		
	(1)		
Predictors	**Estimates**	**CI**	**p**

(Intercept)	-2.12422	-2.60927 – -1.63917	**<0.001**
Time	0.00012	-0.00007 – 0.00030	0.211
Intervention	-0.01191	-0.08652 – 0.06270	0.754
Time Post Intervention	-0.00085	-0.00116 – -0.00054	**<0.001**
Procedures	0.01436	-0.03795 – 0.06668	0.591
Investigations	0.12208	0.09285 – 0.15131	**<0.001**
Ambulance Proportion	0.51744	0.15176 – 0.88311	**0.006**
Patient Volume	-0.19385	-0.39566 – 0.00796	**0.06**
Lag Occupancy	-0.00481	-0.00836 – -0.00125	**0.008**
Age	0.02133	0.01446 – 0.02820	**<0.001**
Observations		**639**	
R2		**0.532**	

The estimated coefficient of Time (β_1 in Section 2.3) is 0.00012. The estimated coefficient of Intervention (β_2 in Section 2.3) is -0. 01191. The main coefficient of interest, Time Post Pilot (β_3 in Section 2.3) shows the intervention's impact on the dependent variable. A negative coefficient represents a drop in the daily admission rate associated with the pilot (intervention). Time-related controls, such as month of attendance and day of the week were also included. See Supplementary Table A for complete regression table.

Length of Stay in the ED

Daily average length of stay in the ED increased for admitted patients (Table 3 – Column 1 – Time Post Intervention – 95% CI (0.2 ; 0.5)) and for discharged patients (Table 3 – Column 2 – Time Post Intervention – 95% CI (0.1 ; 0.2)). This represents an estimated 71 minutes increase for admitted patients, and an estimated 23 minutes increase for discharged patients (Supplementary Table W).

Table 3: Interrupted Time Series Models for the Daily Average Length of Stay (LoS)

	Daily Average LoS - Admitted Patients (1)		
Predictors	**Estimates**	**CI**	**p**
(Intercept)	-284.478	-444.719 – -124.237	**0.001**
Time	0.052	-0.016 – 0.120	0.134
Intervention	3.744	-25.325 – 32.813	0.8
Time Post Intervention	0.339	0.218 – 0.460	**<0.001**
Procedures	12.526	-2.238 – 27.289	0.096

Investigations	2.505	-6.082 – 11.092	0.567
Ambulance Proportion	0.299	-0.463 – 1.060	0.441
Patient Volume	2.209	1.484 – 2.933	**<0.001**
Lag Occupancy	4.132	2.750 – 5.515	**<0.001**
Age	**0.174**	**-1.566 – 1.914**	**0.844**
R2 / R2 adjusted		**0.556 / 0.537**	

	Daily Average LoS - Discharged Patients (2)		
Predictors	**Estimates**	**CI**	**p**
(Intercept)	-98.23	-170.105 – -26.354	**0.007**
Time	0.018	-0.013 – 0.050	0.253
Intervention	0.965	-11.980 – 13.910	0.884
Time Post Intervention	0.114	0.061 – 0.168	**<0.001**
Procedures	3.643	-4.746 – 12.032	0.394
Investigations	20.261	15.792 – 24.730	**<0.001**
Ambulance Proportion	0.541	-0.037 – 1.118	0.066
Patient Volume	1.466	1.134 – 1.797	**<0.001**
Lag Occupancy	1.251	0.636 – 1.865	**<0.001**
Age	-0.134	-1.098 – 0.830	0.785
Observations		**639**	
R2 / R2 adjusted		**0.522 / 0.502**	

Time-related controls, such as month of attendance and day of the week were also included. See Supplementary Table H & I for complete regression tables.

Using Equation 2 and the *Time Post Pilot* regression coefficients for admitted and discharged patients (Table 3 Columns (1) & (2)), we see that the daily average length of stay in the ED increased in a higher proportion for admitted patients than for discharged patients (p-value < 0.001).

It is important to investigate whether the pilot had a larger impact on older patients. When comparing the daily average length of stay in the ED for admitted patients, older patients saw an estimated 84 minute increase, while younger patients saw an estimated 60 minute increase (Supplementary Table W, Supplementary Tables P & R for regressions). Similarly, when comparing between discharged patients, older patients saw an estimated 33 minute increase, whereas younger patients saw an estimated 21 minute increase (Supplementary Tables Q & S). It is worth mentioning that for admitted and discharged patients, older and younger patients saw a statistically similar proportional increase in their average length of stay in the ED.

On the other hand, if we compare the pilot's impact across patient categories, we see that Majors (Ambulant) and Majors (Non-Ambulant) saw a proportionally higher increase in their length of stay in the ED than Minors (p-value = 0.04 and p-value = 0.002), while Majors (Ambulant) and Majors (Non-Ambulant) saw a similar proportional increase (p-value = 0.12) (see Supplementary Tables J – O for regressions). It is also important to note that, on average, Majors (Non-Ambulant) patients' length of stay in the ED is higher than Majors (Ambulant) patients (Supplementary Table W).

Patient-Based Implications

Besides admission rate and overall length of stay in the ED, ambulance handover times provide useful insight into the extent of crowding in the ED [28]. The results are not clinically significant for the daily average handover time during the postintervention period (Supplementary Table T).

Finally, patient self-discharged rates increased during the pilot by an estimated 0.39 percentage points (Supplementary Table W, Supplementary Table U for regression). However, there were no changes to the 72-hour revisit rates (Supplementary Table V). Additionally, we also investigated the effects of the intervention on other measures of quality of care such as reported incidents and mortality. We did not find statistically significant changes for reported incidents or for 30-day mortality rates for patients admitted to the hospital, although the mortality data is a limited sample. We did not find statistically significant changes to the daily average ED occupancy levels (defined as the ratio between number of patients in the ED and number of doctors and nurses) during the pilot.

Sensitivity Analysis

We run the regressions using the data from May 2018 until December 2018 and May 2019 until December 2019 and the results are similar. The results for the length of stay and ambulance handover times regressions are similar when using individual, patient-level data.

DISCUSSION

This study investigated the effects of the removal of the four-hour access standard reporting in the ED by using data from a single major NHS trust which was part of a field study by NHS England. During the post-intervention period when the ED stopped reporting the four-hour access standard, we observed a drop in the daily proportion of patients admitted to the hospital from the ED, in particular for short-stay admissions of Majors (Ambulant) patients. This suggests that the hospital might benefit from a reduction in short-stay admissions when the pressure to adhere to the four-hour access standard in the ED is lifted. However, our analysis also reveals an increase in the daily proportion of patients spending twelve hours or more in the ED, and an increase in the daily average length of stay in the ED, post-intervention. More importantly, admitted patients saw a proportionally higher increase in their length of stay in the ED compared to discharged patients, even when controlling for patients' age group and category. Self-discharged rates increased during the intervention, however there were no changes to patient 72-hour revisit rates.

Our study is the first systematic investigation that uses detailed patient-level data to analyse the effects of lifting the four-hour access standard reporting in the ED, and it presents a set of interesting results and potential trade-offs. Our findings suggest that the removal of the four-hour standard in the emergency department does not impact all patients equally. While certain patient groups such as those Majors (Ambulant) patients with less severe issues might have benefited from the removal of the four-hour access standard by avoiding short-stay hospital admissions, the average length of stay in the ED seemed to have increased across all groups, particularly for older and admitted patients.

Our study offers several important policy implications. First, although various performance measures and targets have been considered, implemented, and ceased in the NHS over the years, such as the four-hour access standard, these critical policy changes do not always have a rigorous evidence-driven basis. Moreover, there are often only limited investigations of their implications within hospitals. By deep diving into one ED with large-scale data, our study illuminates a previously unrecognised trade-off between short-stay hospital admissions and ED lengths of stay associated with the four-hour access standard reporting. Second, our findings point to a possible behavioural mechanism whereby ED staff might have responded to the original four-hour access standard by speeding up ED operations. While this helped patients by reducing the length of stay in the ED, it might have resulted in greater short-stay admissions in the hospital, which are costly. While access to timely care is important, a short length of stay in the ED can lead to negative clinical outcomes for patients with the highest level of priority [29-30]. As such, in devising policy and performance targets, it is essential to consider behavioural implications for ED staff, which may be the main driver behind the policy outcomes.

The study has several limitations. Firstly, it only used data from one NHS trust, so the results may not generalise. Also, the daily number of patients attending this particular ED has considerably increased, while the number of resources has remained the same. Secondly, the study did not use a control ED or hospital, thus, causality cannot be established. Thirdly, since the data did not allow for differentiation between treatment time in the ED and waiting time, the study cannot conclude that the increase in the average observed length of stay and the reduction in short-stay admissions are due to patients receiving extra care in the ED. Lastly, the study covers a pre-COVID pandemic period. Patient composition and processes in the ED might have changed since then, which calls for caution in interpreting our results.

It appears that lifting the four-hour access standard might have had the unintended consequence of benefiting the less urgent patients the most and the more urgent and older patients the least. It would make sense for policymakers to recognise such heterogeneity, and to consider, more explicitly, how different patient groups may be affected differently by such interventions.

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