The Impact of Hospital Command Centre on Patient Flow and Data Quality: findings from the UK NHS

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Abstract:

Background: In the last six years, hospitals in developed countries have been trialling the use of command centres for improving organisational efficiency and patient care. However, the impact of these Command Centres has not been systematically studied in the past.

Methods: It is a retrospective population based study. Participants were patients who visited Bradford Royal Infirmary Hospital, accident and emergency (A&E) department, between Jan 01, 2018 and August 31, 2021. Outcomes were patient flow (measured as A&E waiting time, length of stay and clinician seen time)and data quality (measured by the proportion of missing treatment and assessment dates and valid transition between A&E care stages).Interrupted time-series segmented regression and process mining were used for analysis.

Results: A&E transition time from patient arrival to assessment by a clinician marginally improved during the intervention period; there was a decrease of 0.9 minutes (95% CI: 0.35 to 1.4), 3 minutes (95% CI: 2.4 to 3.5), 9.7 minutes (95% CI: 8.4 to 11.0) and 3.1 minutes (95% CI: 2.7 to 3.5) during 'patient flow program', 'command centre display roll-in', 'command centre activation' and 'hospital wide training program', respectively. However, the transition time from patient treatment until conclusion of consultation showed an increase of 11.5 minutes (95% CI: 9.2 to 13.9), 12.3 minutes (95% CI: 8.7 to 15.9), 53.4 minutes (95% CI: 48.1 to 58.7) and 50.2 minutes (95% CI: 47.5 to 52.9) for the respective four post-intervention periods. Further, length of stay was not significantly impacted; the change was -8.8hrs (95% CI: -17.6 to 0.08), -8.9hrs (95% CI: -18.6 to 0.65), -1.67hrs (95% CI: -10.3 to 6.9) and -0.54hrs (95% CI: -13.9 to 12.8) during the four respective post intervention periods. It was a similar pattern for the waiting and clinician seen times. Data quality as measured by the proportion of missing dates of records was generally poor (treatment date=42.7% and clinician seen date=23.4%) and did not significantly improve during the intervention periods.

Conclusion: The findings of the study suggest that a command centre package that includes process change and software technology does not appear to have consistent positive impact on patient safety and data quality based on the indicators and data we used. Therefore, hospitals considering introducing a Command Centre should not assume there will be benefits in patient flow and data quality.

Key words: command centre; implementation evaluation, patient flow; data quality

INTRODUCTION

The introduction of Electronic Health Records (EHR) has improved patient care delivery process and quality of care, mainly through the easy access to comprehensive and rich patient data for research as well as minimising medical errors [1]. However, coordination of activities and sharing of real-time data from each department in hospitals is often missing [2]. In fact, in most UK National Health Service (NHS) hospitals, health service delivery is still fragmented across multiple departments and services with major implications for patient safety, efficiency and good patient care.

The fragmentation of the healthcare services is neither cost-effective nor safe for the delivery of patient care [3, 4]. Such fragmentation can, however, be minimised using health information systems to improve the flow of information between the various departments and services of a hospital to support more holistic, joined-up management of patient care. [5, 6] A growing number of hospitals in Canada, China, the UK, US and Saudi Arabia have been piloting a digitally enabled 'command centre' approach that draws information from Electronic Health Records (EHRs) and other health information systems and displays consolidated information to a team of physically co-located co-ordinators. Although not systematic studies, early reports suggest that such technologies have benefits [7-11]. For example, one organisation reports that ambulances were dispatched 43 minutes quicker, and bed allocation was reduced by 3.5 hours for emergency department admitted patients [8].

In the UK, command centres are currently being trialled in four NHS hospital trusts, including Bradford Teaching Hospitals NHS Foundation Trust (BTHFT). In 2019, the BTHFT introduced a command centre at the Bradford Royal Infirmary (BRI) hospital [12]. Through the use of software and display screens (also known as 'tiles'), the command centre provides real-time information on emergency and inpatient hospital services: overall hospital capacity, emergency department status, patient transfers, discharge tasks, care progression, and patient deterioration. The Bradford Command Centre project aimed to provide faster and safer care with the potential to improve future patient flow and information (or data) quality. In this study we examined whether these benefits were achieved and tested the hypothesis that the implementation and integration of a real-time, centralised hospital command centre improves patient flow and data quality.

METHODS

Study setting

Bradford is the seventh largest metropolitan district in England and Wales with a population of over half a million. It is ethnically diverse, with 56.7% identifying as of White British origin, and 25.5% identifying as Pakistani-origin. The population consists of 25.8% under 18 years and 74.2% 18 and over (www.ons.gov.uk).

Study population

The study included patients who visited Bradford Royal Infirmary (BRI) hospital between January 01, 2018 and August 31, 2021. This was a period in which the Command Centre was introduced through a number of phases immediately prior to the COVID-19 pandemic.

Study design

This is a retrospective population based cohort study undertaken as part of a mixed method evaluation project with a formal evaluation protocol published by the authors in Jan 2022 [13]. Qualitative study of the Command centre programme gave rise to two hypothesised intervention timelines, one focusing on the implementation and activation of the technological components of the command centre and the other a 'complex' intervention model that sought to account for the broader patient flow and operational redesign programme in which the command centre technology was a part. For the technology model, a three-phase, interrupted time-series model was used to reflect incremental implementation of the visual displays in the command centre, consisting of a pre-intervention (Baseline), first intervention component ('Command centre displays roll-in') and second intervention component ('Command centre activation'). For the complex intervention model, a five-phase, interrupted time-series model was used that consisted of pre-intervention (Baseline), first intervention component ('Onset of patient flow program'), second intervention component ('Command centre displays roll-in'), third intervention component ('Command centre activation') and fourth intervention component ('hospital wide engagement and training'), the latter referring to roll-out of remote access to command centre data across the hospital. See ***Figure 1*** for the details of the time interrupts. Note that the COVID-19 pandemic caused serious stress on the hospital, and global health systems, commencing February 2021.

Data Source

Data from the hospital's Secondary Use Services (SUS) data was provided by the Connected Bradford data service [14] and uploaded to a trusted research environment on a Google Cloud Platform (GCP). Relevant data were then extracted by one of the authors (TFM) from the GCP.

Patient and public involvement and engagement

Public and patient representatives were consulted throughout the study period through workshops at the command centre. Representatives contributed to the development of the research protocol [13] and selection of indicator outcomes. The lead patient representative (NS) has critical input and is a co-author of this publication.

Outcome variables

A range of patient flow and data quality outcome indicators were identified in the study protocol [13] and are listed below.

Patient flow

In-patient length of stay in emergency admissions (defined as the duration between date and time of admission and discharge), 'clinician seen time' (the duration between A&E time of arrival and the time seen by a clinician) and A&E waiting time (the duration between A&E time of arrival and time of treatment) were used as indicators for weekly patient flow metrics throughout the study period. In addition, average times taken between A&E transitions (arrival, assessment, treatment, visit conclusion and check out) were used as indicators for patient flow metrics during the same period.

Data Quality

The proportion of missing dates of treatment and clinician's assessment for A&E patients were used as indicators for weekly data quality metrics throughout the study period. In addition, the proportions of records showing valid transition of patients in A&E care (arrival →assessment →treatment →visit conclusion →check out) were also used.

Variables for analysis

Dummy variables were created for each of the intervention components – 'Onset of patient flow program', 'command centre displays roll-in', 'command centre activation' and 'hospital wide engagement and training'. We also identified the onset of the COVID-19 pandemic and subsequent spikes in pandemic impact [15]. The components of the intervention were given a value of "1" starting from the date of its introduction until the introduction of the next component or phase, then a value of "0" for the rest of the period. "COVID-19 pandemic" was given a value of "0" through February 2020 and a value of "1", thereafter. A spike dummy variable was also added by setting "1" for the COVID-19 spike periods based on the UK data [15] and "0" throughout.

A continuous incremental time variable was coded from the start of the time series (e.g. 1,2,3,4). The intervention phases were also modelled using five continuous time variables with "0" in the pre-intervention period, "1,2,3,4…." from the onset of the intervention phase until the end of the phase then level-off for the rest of the study. In addition, seasonality was modelled by including dummy variables for the number of weeks in a year.

Statistical analysis and software

Interrupted times-series linear regression analysis, [16] was used to assess the impact of the command centre on the patient flow and data quality measures. First, linear time-series models were fit to the data. Tests for serial autocorrelation test of residuals were conducted and all tests were non-statistically significant. Hence, regressions models with ARIMA errors were not sought. Akaike information criterion [17] and Bayesian information criterion [18] were used in selecting the best fitting models to the data.

To estimate the average transition time between different stages of accident and emergency care, and to map the destinations of accident and emergency patients, a process mining technique were used [19].

A five-phase interrupted time-series was used for the main analyses. To explore if the technology alone had an impact on outcomes, a three-phase interrupted time-series models were used as sensitivity analysis. The 'Broad patient flow program' and 'Hospital wide engagement and training' were assumed as independent events of the Command Centre and adjusted as independent dummy variables in sensitivity analysis models. Five percent significance level and 95% confidence intervals were adopted throughout. Analyses were implemented in R (Version 4.0.2).

RESULTS

Descriptive summary

A total of 203,807 inpatients and 197,084 accident and emergency visits were included in the study.

Patient flow

The overall weekly average length of stay for emergency admission patients remained between 70 hours and 90 hours for much of the period between January 2018 and December 2019. It sharply increased to 105 hours during the first week of January 2020 to then drop to and stay on around 80 hours until the end of February 2020. It then steadily increased starting from March 2020 until January 2021 and then showed a steady decrease until the end of the study period. Overall, there appear to be a higher average length of stay during the COVID-19 pandemic than the pre-pandemic period (see ***Figure 2*** and ***Supplementary Table 1***). The weekly average waiting time (time from arrival until treatment) for accident and emergency visiting patients was between 1.5 hours and 2.5 hours for the periods between January 2018 and November 2019, but increased to around 3 hours in the second week of December 2019. It then showed a steady drop until March 2020 to 0.5 hours, and then increased steadily until the end of the study. Although there was a significant variation of patterns between the pre and post-pandemic period, the average waiting time remained below the four hours mark,[20] in both periods.

The weekly average 'clinician seen time' (time from arrival until assessed by a clinician) stayed below one hour throughout the study period (See ***Figure 2*** and ***Supplementary Table 1***).

The average transition time between A&E care stages was largely similar in the pre-intervention and post-intervention periods except that there was a significant increase of transition time from treatment to conclusion of the visit during the 'command centre going live' and 'hospital wide engagement and training' periods (see ***Supplementary Table 2***).

Data Quality

Overall, the weekly proportion of missing in clinician seen dates and treatment dates was 23.4% (range=20.8% to 28.5%) and 42.7% (range=14.7% to 53.5%), respectively. The weekly proportion of clinician seen dates missing ranged between 12% and 34% during the follow-up- period. Although it remained between 20% and 30% for the majority of the study period, there was a moderate decrease between March and May 2020. On the other hand, the weekly proportion of treatment dates missing showed a steady increase from January 2018 (30%) until February 2020 (67%) which then sharply deceased to around 25% in March 2020 before a sharp increase to over 75% in August-December 2020. See **Figure 2** and ***Supplementary Table 1***.

The proportions of A&E visits progressing to the next 'valid' stage of care remained similar amongst the pre-intervention and post-intervention periods. Visits with records of consultation conclusion time were highly likely (>92%) to have their check-out time recorded in all intervention periods. Visits with assessment time recorded were least likely (28-70%) to have their treatment time recorded for the same period, see ***Supplementary Table 3*** for details.

The effect of intervention

Main analyses (five phase interrupted time series):

Patient flow

There was no significant difference in the weekly average length of stay of admitted patients between the pre-intervention period and the post-intervention periods. The A&E waiting times (time from arrival until patient received treatment) showed an increase of 62 minutes (95% CI: 40 minutes to 85 minutes) during the fourth ('Hospital wide engagement resumption') intervention period when compared with the pre-intervention period. The first and second intervention periods also showed a decrease of 10 minutes (95% CI: 4 minutes to 16 minutes) and 9 minutes (95% CI: 2 minutes to 15 minutes) in the average A&E clinician seen time when compared with the pre-intervention period (See ***Table 1***).

The transition time from arrival to assessment consistently improved during the intervention period; there was a decrease of 0.9 minutes (95% CI: 0.35 to 1.4), 3 minutes (95% CI: 2.4 to 3.5), 9.7 minutes (95% CI: 8.4 to 11.0) and 3.1 minutes (95% CI: 2.7 to 3.5) during 'patient flow program', 'command centre display roll-in', 'command centre activation' and 'hospital wide training program', respectively. However, the transition time from assessment, treatment and visit conclusion to the next respective A&E stage of care had worsened significantly during the intervention periods. For example: the transition time from patient treatment until conclusion of consultation showed an increase of 11.5 minutes (95% CI: 9.2 to 13.9), 12.3 minutes (95% CI: 8.7 to 15.9), 53.4 minutes (95% CI: 48.1 to 58.7) and 50.2 minutes (95% CI: 47.5 to 52.9) during 'patient flow program', 'command centre display roll-in', 'command centre activation' and 'hospital wide training program', respectively(***Table 2***).

Data quality

The data quality did not change significantly during the study period, except, the weekly proportion of missing clinician seen dates significantly worsened during 'Hospital wide engagement resumption' period when compared with the pre-intervention period (change=17%; 95% CI: 10.4% to 32.5%). Likewise, there was a significant increase in the weekly proportion of treatment dates missing during 'Command centre activation' period when compared with the pre-intervention period (See ***Table 1***).

The proportion of arrivals and patients with their consultation closed (or recorded as 'concluded visits') that progressed to the next 'valid' stage of A&E care (i.e. assessment and check-out, respectively) had largely improved during the intervention period. For example: there was an increase in the proportion of patients who arrived in the A&E and assesses by a clinician improved by 2.4%, 3.0% and 3.7% during the 'patient flow', 'command display roll-in' and 'Hospital wide engagement resumption' periods, respectively (see ***Table 3)***. However, the proportion of those who were assessed or treated that progressed to the next 'valid' stage of A&E care (i.e. treatment and concluded visits, respectively) were consistently lower than the pre-intervention period (see **Table *3***).

Sensitivity analysis (three phase interrupted time-series):

When only the technology was assumed as part of the intervention, there was no meaningful difference between the pre- and post-intervention periods in the patient flow indicators (length of stay, waiting time and clinician seen time). For example, the change in the length of stay during the 'Command centre display roll-in' and 'Command centre activation' intervention periods were -4.39 hours (95% CI: -16.1 to 7.3) and 3.2 hours (95% CI: -7.6 to 14.0), respectively; see **Supplementary Table *4*** . However, the average transition time between A&E care stages significantly improved during the same period, see **Supplementary Table *5***. The data quality had largely worsened during the intervention period. For example, proportion of treatment date missing increased by 10.7% (95% CI: -4.0 to 25.5) and 22.5% (95% CI: 8.8 to 36.2)

(see **Supplementary Table *4* & Supplementary Table *6***).

DISCUSSION

Statement of principal findings

In this pre- and post-intervention comparative study using time series data from the hospital's information systems, the findings indicate that introduction of the Command Centre, including software technology and process changes, or the software technology-alone had no significant and consistent measurable impact on patient flow and data quality. Based on patient flow indicators: the length of stay showed a non-significant decrease of 8.8 hours (Standard error (SE): 4.5), 8.9 hours (SE: 4.9), 1.7hours (SE: 4.4) and 0.55 hours (SE: 6.8). The waiting time (time taken until patient treatment), clinician seen time (time until patient is seen by a clinician) and A&E transition time (time taken to progress from one stage of A&E care to the next stage of A&E care) also did not significantly improve during the study period.

The data quality also was worse when the command centre was introduced. On average, the proportion of missing in treatment dates and clinician seen dates was 42.7% and 23.4%, respectively. In comparison to the pre-intervention period, the proportion of missing in A&E visitor's treatment date was higher by 3% (SE: 45.8), 10.2% (SE: 6.3), 21.5% (SE: 5.6) and 2.3% (SE: 8.7) when a "patient flow program", "Command centre display roll-in", "Command centre activation" and "Hospital wide engagement resumption" programs were implemented, respectively.

Interpretation within the context of the wider literature

There is a paucity of studies that investigate the impact of multidepartment hospital-based command centres on patient flow and data quality. A recent study in Saudi Arabia reported that the use of a 'smart centre' led to reduction of Intensive Care Unit (ICU) lengths of stay by 10% in emergency admissions [7]. The ICU length of stay reported by Alharbi *et al.*, [7] disagrees with the findings of this study. In fact, the average ICU length of stays (as calculated separately) for pre-intervention and post-intervention periods are 91 and 108 hours, respectively, which is an increase of 18.7% after implementation of the command centre. One notable difference between our study and Alharbi *et al.* [7] is that the Saudi Arabian Command Centre was a national hub and the data used was of the first wave of COVID-19 pandemic whereas the Bradford Command Centre was used only in the BRI hospital and we have used more than three years' worth of data in our analyses.

The Johns Hopkins Hospital in Baltimore, USA also reported reduction in time for ambulances dispatches and bed allocation for emergency department admitted patients [8, 9]. However, we do not have data in our study to support or refute this claim.

Strengths and limitations

Our study has certain limitations. First, health service delivery was significantly affected by the COVID-19 pandemic resulting in rapid system-wide effects which may have impacted on the population of patients and capacity management in the hospital. Cancellation and postponement of surgical operations was common due to reallocation of resources during the peaks of the pandemic. Although we attempted to control for the effects of the pandemic in our time series models, the proximity of the activation of the command centre with the onset of the pandemic surge makes it difficult to isolate the effect of the intervention.

Another potential limitation of the study concerns the focus of this quantitative evaluation on a small number of outcome indicators for what was a system-wide initiative designed to impact many areas. Although informing our intervention models using qualitative research at the study site was a strength in our design, qualitative investigation additionally revealed the complexity of this type of intervention and the challenges of implementation within a pressured acute care environment. This may have influenced the study outcome in a number of ways. Staff recall of the historical implementation timeline was variable, especially for the piloting and roll-in of intervention components, including organisational in addition to technological elements. There were suggestions that the co-location of staff in the command centre room that preceded the roll-in and activation phase for command centre displays may have already been established and coordinating functions sooner than the intervention timeline suggests, leading to under specification of our model. When considering the challenges observed in implementing the technological aspects of the intervention, including data quality, there may have been significant time lag between activation of components and any impact upon patient flow outcomes. Given the complexity in our intervention model we did not seek to control for lagged effects of intervention implementation (the time it takes for an intervention to start to influence detectable outcomes). Rather, we presumed that the effects of the intervention components were instantaneous. Finally, due to data access limitations we couldn't explore all outcomes identified for analysis in our study protocol.

Nonetheless, the strengths of the study are threefold. First, we have used a large sample size for the analyses (203,807 inpatient visits and 197,084 A&E visits). Second, the use of electronic health records data minimises the inherent biases and errors in other types of observational data. Third, we employed a robust quasi-experimental design using repeated time series measurement.

Implications for policy, practice and research

Currently, data on the impact of command centres on patient flow and data quality are scarce although the use of these technologies has widely been adopted in the developed world. Our study also has not found strong evidence of positive impact of these novel technologies on patient flow and data quality outcomes. Therefore, further research using data from other hospital organisations that use the technologies is warranted.

Conclusions

The findings of the study suggest that a command centre package that includes change of process and software technology does not appear to have consistent positive impact on patient flow and data quality based on the indicators and data we used. Moreover, when only the software technology was assumed as component of the intervention, no consistent and significant positive impact on patient flow and data quality was observed. Therefore, hospitals considering introducing a Command Centre should not assume there will automatically be benefits in patient flow and data quality.

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List of Tables

Table 1: Summary results for five phase models

Outcome	Intervention phase	Change (95% CI)*
Length of stay (hours)†	Pre-intervention	Reference
	Patient flow program	-8.8(-17.6 to 0.08)
	Command centre display roll-in	-8.9(-18.6 to 0.65)
	Command centre activation	-1.67(-10.3 to 6.9)
	Engagement resumption	-0.54(-13.9 to 12.8)
Waiting time (hours)‡	Pre-intervention	Reference
	Patient flow program	-0.14(-0.39 to 0.11)
	Command centre display roll-in	-0.21(-0.48 to 0.06)
	Command centre activation	-0.19(-0.43 to 0.06)
	Engagement resumption	1.04(0.67 to 1.42)
Clinician seen time (hours)‡	Pre-intervention	Reference
	Patient flow program	-0.16(-0.26 to -0.06)
	Command centre display roll-in	-0.14(-0.25 to -0.04)
	Command centre activation	-0.06(-0.16 to 0.03)
	Engagement resumption	0.01(-0.14 to 0.15)
Clinician seen date missing (%)‡	Pre-intervention	Reference
	Patient flow program	-1.5(-4.75 to 1.76)
	Command centre display roll-in	-0.85(-4.38 to 2.69)
	Command centre activation	0.44(-2.72 to 3.60)
	Engagement resumption	17.2(12.26 to 22.10)
Treatment date missing (%)‡	Pre-intervention	Reference
	Patient flow program	3.0(-8.37 to 14.38)
	Command centre display roll-in	10.2(-2.16 to 22.54)
	Command centre activation	21.5(10.4 to 32.5)
	Engagement resumption	2.3(-14.8 to 19.5)

Note: *; models were adjusted for trends, covid-19 pandemic (pre- and post-pandemic) and covid-19 spikes; †, inpatient emergency admissions; ‡, accident and emergency visits.

Table 2: Summary of change in average A&E transition time

Intervention phase	Average transition time in minutes (Mean (95% CI))			
	Arrived →assessed	**Assessed →treated**	**Treated →concluded**	**Concluded→ checked out**
Pre-intervention	Reference	Reference	Reference	Reference
Patient flow	-0.9 (-1.4 to -0.35)	5.9 (3.9 to 7.9)	11.5 (9.2 to 13.9)	14.0 (-33.1 to 5.2)
CC display roll-in	-3.0 (-.3.5 to -2.4)	4.7 (2.3 to 7.1)	12.3 (8.7 to 15.9)	4.1 (2.8 to 5.4)
CC activation	-9.7 (-11.0 to -8.4)	-21.0 (-23.1 to -18.9)	53.4 (48.1 to 58.7)	0.9 (-1.2 to 3.0)
HW training	-3.1 (-3.5 to -2.7)	10.2 (8.1 to 12.3)	50.2 (47.5 to 52.9)	-0.4 (-2..4 to 1.6)

Note: CC, command centre; CI, confidence intervals; HW, hospital wide

Table 3: Summary of change in proportion of A&E visits following 'rules'

Intervention phase	Change in proportion of A&E activities following 'rules' (95% CI)			
	Arrived →assessed	**Assessed →treated**	**Treated →concluded**	**Concluded →checked out**
Pre-intervention	Reference	Reference	Reference	Reference
Patient flow	2.4 (1.7 to 3.2)	-3.7 (-4.8 to -2.6)	-1.5 (-2.4 to -0.7)	1.5 (0.9 to 2.1)
CC display roll-in	3.0 (2.3 to 3.8)	-18.1 (-19.3 to -16.9)	-8.0 (-9.1 to -6.9)	3.2 (2.7 to 3.8)
CC activation	-0.0 (-0.0 to 0.0)	-32.6 (-33.5 to -31.7)	-25.7 (-26.5 to 25.0)	-0.5 (-0.9 to -0.0)
HW training	3.7 (3.1 to 4.3)	9.3 (8.4 to 10.2)	-11.4 (-12.0 to -10.7)	3.7 (3.2 to 4.1)

Note: CC, command centre; CI, confidence intervals; HW, hospital wide