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Mebrahtu, T.F. orcid.org/0000-0003-4821-2304, McInerney, C.D. orcid.org/0000-0001-7620-7110, Benn, J. orcid.org/0000-0001-5919-9905 et al. (7 more authors) (2023) The impact of hospital command centre on patient flow and data quality: findings from the UK National Health Service. International Journal for Quality in Health Care, 35 (4). mzad072. ISSN 1353-4505

https://doi.org/10.1093/intqhc/mzad072

International Journal for Quality in Health Care, 2023, **35(4)**, 1–7
DOI: https://doi.org/10.1093/intqhc/mzad072
Advance Access Publication Date: 26 September 2023
Original Research Article

OXFORD

The impact of hospital command centre on patient flow and data quality: findings from the UK National Health Service

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Handling Editor: Dr Erica Barbazza

Abstract

In the last 6 years, hospitals in developed countries have been trialling the use of command centres for improving organizational efficiency and patient care. However, the impact of these command centres has not been systematically studied in the past. It is a retrospective population-based study. Participants were patients who visited the Bradford Royal Infirmary hospital, Accident and Emergency (A&E) Department, between 1 January 2018 and 31 August 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. 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 min [95% confidence interval (CI): 0.35–1.4], 3 min (95% CI: 2.4–3.5), 9.7 min (95% CI: 8.4–11.0), and 3.1 min (95% CI: 2.7–3.5) 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 the conclusion of consultation showed an increase of 11.5 min (95% CI: 9.2–13.9), 12.3 min (95% CI: 8.7–15.9), 53.4 min (95% CI: 48.1–58.7), and 50.2 min (95% CI: 47.5–52.9) for the respective four post-intervention periods. Furthermore, the length of stay was not significantly impacted; the change was −8.8 h (95% CI: −17.6 to 0.08), −8.9 h (95% CI: −18.6 to 0.65), −1.67 h (95% CI: −10.3 to 6.9), and −0.54 h (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. The findings of the study suggest that a command centre package that includes process change and software technology does not appear to have a 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.

Keywords: command centre; implementation evaluation; patient flow; data quality

Introduction

The introduction of electronic health records has improved the patient care delivery process and quality of care, mainly through the easy access to comprehensive and rich patient data for research as well as minimizing medical errors [1]. However, coordination of activities and sharing of real-time data from each department in hospitals are 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 healthcare services is neither cost-effective nor safe for the delivery of patient care [3, 4]. Such fragmentation can, however, be minimized using health information systems to improve the flow of information between the various departments and services of a hospital to

Received 24 August 2022; Editorial Decision 7 September 2023; Revised 25 May 2023; Accepted 15 September 2023

support more holistic, joined-up management of patient care [5, 6]. A growing number of hospitals in Canada, China, the UK, the USA, and Saudi Arabia have been piloting a digitally enabled 'command centre' approach that draws information from electronic health records and other health information systems and displays consolidated information to a team of physically colocated coordinators. Although not systematic studies, early reports suggest that such technologies have benefits [7–11]. For example, one organization reports that ambulances were dispatched 43 min quicker, and bed allocation was reduced by 3.5 h 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. In 2019, the Bradford Teaching Hospitals NHS Foundation Trust introduced a command centre at the Bradford Royal Infirmary hospital [12]. Through the use of software and display screens (also known as 'tiles'), the command centre provides real-time information on emergency and in-patient 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, centralized 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 of Pakistani origin. The population consists of 25.8% aged <18 years and 74.2% aged ≥18 years (www.ons.gov.uk).

Study population

The study included patients who visited the Bradford Royal Infirmary hospital between 1 January 2018 and 31 August 2021. This was a period in which the command centre was introduced through a number of phases immediately prior to the coronavirus disease (COVID-19) pandemic.

Study design

This is a retrospective population-based cohort study undertaken as part of a mixed-methods evaluation project with a formal evaluation protocol published by the authors in January 2022 [13]. A qualitative study of the command centre programme gave rise to two hypothesized 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 the roll-out of remote access to command centre data across the hospital. See Fig. 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 data were provided by the Connected Bradford data service [14] and uploaded to a trusted research environment on a Google Cloud Platform. Relevant data were then extracted by one of the authors (T.F.M.) from the Google Cloud Platform.

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 the selection of indicator outcomes. The lead patient representative (N.S.) has critical input and is a coauthor 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 accident and emergency (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 checkout) 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 → checkout) 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

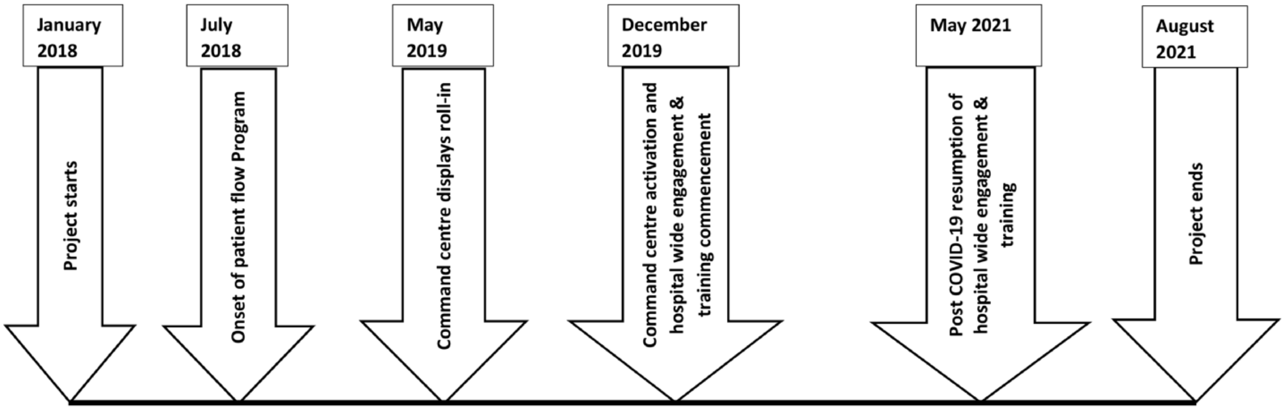

Figure 1 Project timeline and intervention phases.

the onset of the COVID-19 pandemic and subsequent spikes in its 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 and then a value of '0' for the rest of the period. The '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 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 nonstatistically significant. Hence, regression models with autoregressive integrated moving average errors were not sought. The Akaike information criterion [17] and the Bayesian information criterion [18] were used in selecting the best-fitting models for the data.

To estimate the average transition time between different stages of A&E care and to map the destinations of A&E patients, a process-mining technique was 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 model was 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 (CIs) were adopted throughout. Analyses were implemented in R (Version 4.0.2).

Results

Descriptive summary

A total of 203 807 inpatients and 197 084 A&E visits were included in the study.

Patient flow

The overall weekly average length of stay for emergency admission patients remained between 70 and 90 h for much of the period between January 2018 and December 2019. It sharply increased to 105 h during the first week of January 2020 and then dropped to and stayed on ∼80 h 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 appears to be a higher average length of stay during the COVID-19 pandemic than the pre-pandemic period (see Fig. 2 and Supplementary Table 1). The weekly average waiting time (time from arrival until treatment) for A&E visiting patients was between 1.5 and 2.5 h for the periods between January 2018 and November 2019 but increased to ∼3 h in the second week of December 2019. It then showed a steady drop until March 2020 to 0.5 h and then increased steadily until the end of the study. Although there was a significant variation of patterns between the pre- and post-pandemic periods, the average waiting time remained below the 4-h mark [20] in both periods.

The weekly average 'clinician seen time' (time from arrival until assessed by a clinician) stayed <1 h throughout the study period (see Fig. 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 in the 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 clinician seen dates and treatment dates was 23.4% (range = 20.8–28.5%) and 42.7% (range = 14.7–53.5%), respectively. The weekly proportion of missing clinician seen dates ranged between 12% and 34% during the follow-up period. Although it

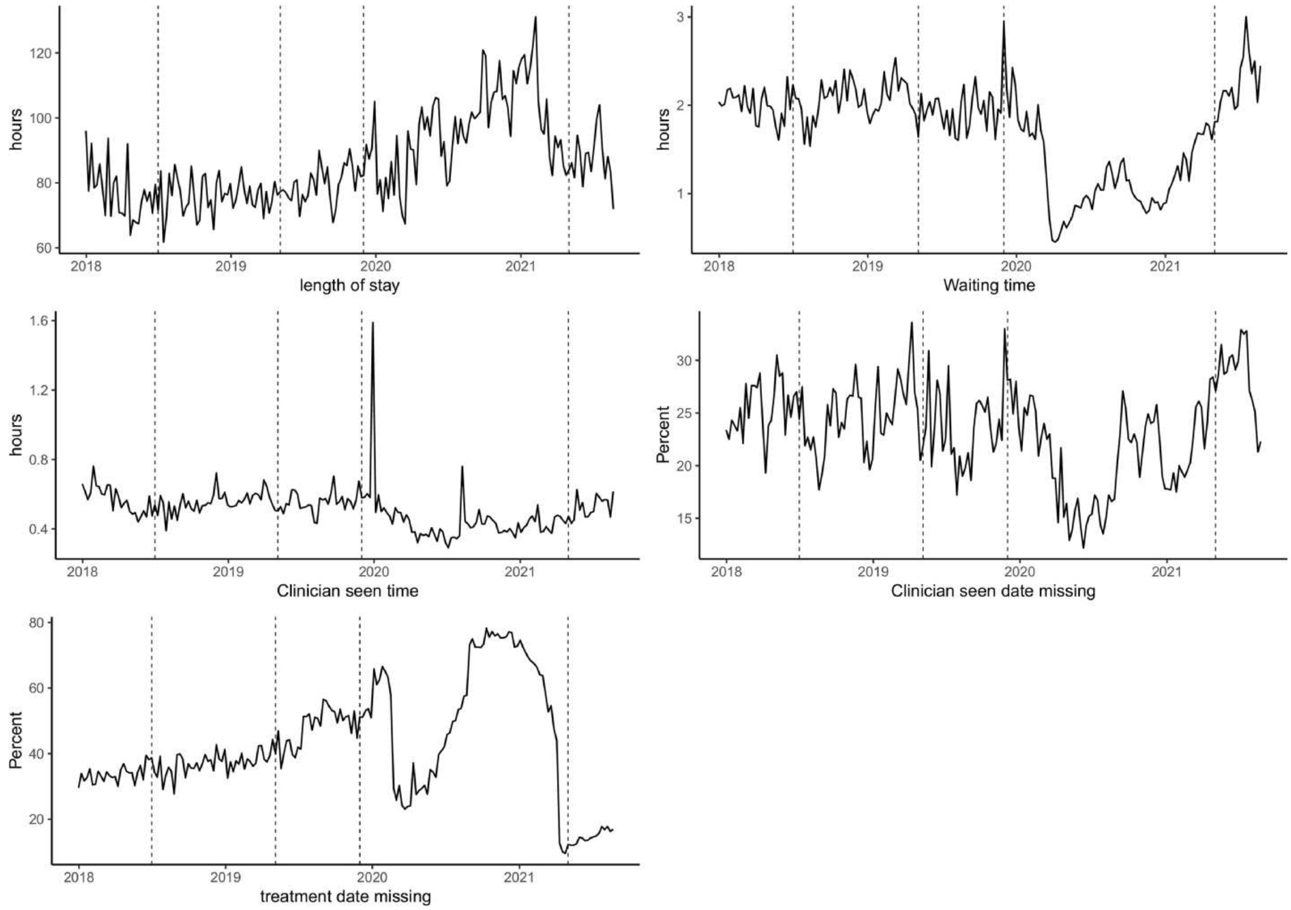

Figure 2 A weekly pattern of patient flow and data quality indicators during the study period (vertical dashed lines are the interrupts).

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 missing treatment dates showed a steady increase from January 2018 (30%) until February 2020 (67%), which then sharply decreased to ∼25% in March 2020 before a sharp increase to >75% in August–December 2020 (see Fig. 2 and Supplementary Table 1).

The proportions of A&E visits progressing to the next 'valid' stage of care remained similar among the pre-intervention and post-intervention periods. Visits with records of consultation conclusion time were most likely (>92%) to have their checkout 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 period. The A&E waiting times (time from arrival until patient received treatment) showed an increase of 62 min (95% CI: 40–85 min) 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 min (95% CI: 4–16 min) and 9 min (95% CI: 2–15 min) 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 min (95% CI: 0.35–1.4), 3 min (95% CI: 2.4–3.5), 9.7 min (95% CI: 8.4–11.0), and 3.1 min (95% CI: 2.7–3.5) 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 the conclusion of consultation showed an increase of 11.5 min (95% CI: 9.2 –13.9), 12.3 min (95% CI: 8.7–15.9), 53.4 min (95% CI: 48.1–58.7), and 50.2 min (95% CI: 47.5–52.9) 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 that the weekly proportion of missing clinician seen dates significantly worsened during the 'hospital wide engagement resumption' period when compared with the pre-intervention period (change = 17%; 95% CI: 10.4–32.5%). Likewise, there was a significant increase in the weekly proportion of missing treatment dates during the 'command centre activation' period when compared with the pre-intervention period (see Table 1).

Table 1. Summary results for five-phase models.

Outcome	Intervention phase	Change (95% CI)[a]
Length of stay (h)[b]	Pre-intervention	Reference
	Patient flow programme	−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 (h)[c]	Pre-intervention	Reference
	Patient flow programme	−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 (h)[c]	Pre-intervention	Reference
	Patient flow programme	−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	0.0 1 (−0.14 to 0.15)
Clinician seen date missing (%)[c]	Pre-intervention	Reference
	Patient flow programme	−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 (%)[c]	Pre-intervention	Reference
	Patient flow programme	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)

[a]Models were adjusted for trends, the COVID-19 pandemic (pre- and post-pandemic), and COVID-19 spikes.
[b]Inpatient emergency admissions.
[c]A&E visits.

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 checkout, 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) was 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 changes in the length of stay during the 'command centre display roll-in' and 'command centre activation' intervention periods were −4.39 h (95% CI: −16.1 to 7.3) and 3.2 h (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, the proportion of missing treatment dates was increased by 10.7% (95% CI: −4.0 to 25.5) and 22.5% (95% CI: 8.8–36.2) (see Supplementary Tables 4 and 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 the 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 h [standard error (SE): 4.5], 8.9 h (SE: 4.9), 1.7 h (SE: 4.4), and 0.55 h (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 treatment dates and clinician seen dates was 42.7% and 23.4%, respectively. In comparison to the pre-intervention period, the proportion of A&E visitor's missing treatment dates 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' programmes 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 a reduction of intensive care unit lengths of stay by 10% in emergency admissions [7]. The intensive care unit length of stay reported by Alharbi *et al.* [7] disagrees with the findings of this study. In fact, the average ICU lengths of stay (as calculated separately) for the pre- and post-intervention periods are 91 and 108 h, respectively, which is an increase of 18.7% after the 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 were from the first wave of the COVID-19 pandemic, whereas the Bradford

Table 2. A summary of changes in the average A&E transition time.

Intervention phase	Average transition time (min) [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)

CC, command centre; HW, hospital wide.

Table 3. A summary of changes in the proportion of A&E visits following 'rules'.

Intervention phase	Changes in the 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)

CC, command centre; HW, hospital wide.

Command Centre was used only in the Bradford Royal Infirmary hospital and we have used >3 years' worth of data in our analyses.

The Johns Hopkins Hospital in Baltimore, USA also reported reduction in time for ambulance 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 an impact on the population of patients and capacity management in the hospital. Cancellation and postponement of surgical operations were common due to the 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 organizational in addition to technological elements. There were suggestions that the colocation 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 a significant time lag between the activation of components and any impact on patient flow outcomes. Given the complexity of 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 could not explore all outcomes identified for analysis in our study protocol.

Nonetheless, the strengths of the study are 3-fold. First, we have used a large sample size for the analyses (203 807 in-patient visits and 197 084 A&E visits). Second, the use of electronic health records data minimizes 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 the positive impact of these novel technologies on patient flow and data quality outcomes. Therefore, further research using data from other hospital organizations that use the technologies is warranted.

Conclusions

The findings of the study suggest that a command centre package that includes the change of process and software technology does not appear to have a 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 a 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.

Acknowledgements

We thank the Patient and public involvement and engagement (PPIE) representatives for their contribution to the conception, development, ongoing implementation, and future communication of this project.

Supplementary data

Supplementary data are available at *INTQHC* online

Funding

This project is funded by the National Institute for Health Research Health Service and Delivery Research Programme (NIHR129483) and the National Institute for Health Research (NIHR) Yorkshire and Humber Patient Safety Translational Research Centre. The views expressed in this article are those of the authors and not necessarily those of the NHS, the NIHR, or the Department of Health and Social Care.

Data availability

Data pertaining to analysis results are fully available in the main text of the manuscript and the supplementary material file.

Author contributions

J.B., C.M., C.D.M., and O.J. conceptualized the study. T.F.M., J.B., C.M., C.D.M., J.G., N.S., and O.J. contributed to the study design. T.F.M. conducted data extraction, management, analysis, and preparation of the first draft of the manuscript. J.B., C.M., C.D.M., J.G., N.S., I.H., T.L., R.R., and O.J. reviewed the manuscript for important intellectual content. All authors have been involved in revising the work and have approved the final versions for publication.

Ethics Approval

The study was approved by the University of Leeds Engineering and Physical Sciences Research Ethics Committee (#MEEC 20-016) and the NHS Health Research Authority (IRAS No.: 285933).

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