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The relationship between nurse contact time and patient outcomes: a retrospective observational study using Real-Time Location data

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Abstract

In this study, we utilize a novel and unique data source to examine the relationship between nurses' contact time and patients' hospital outcomes. While previous research has demonstrated that higher nurse staffing levels lead to better outcomes, the specific contribution of increased direct patient care time to these improvements remains unknown. Using data from a Real-Time Location System (RTLS) that tracks the movement of staff and patients across the hospital wards using Global Positioning System (GPS) sensors, we can estimate the time patients "actually" spend with nursing staff during an inpatient stay. We find that the average patient is in contact with nurses for about 8 h a day, of which 22 min are of direct care at the patient's bedside. We find a statistically significant association between contact time, measured as the total number of minutes in a day the patient is in contact with nursing staff, and in-hospital mortality. A 10-minute increase in contact time is associated in our data with a 0.05% reduction in mortality. By emphasizing the importance of patient-centered care and the role of contact time in shaping patient outcomes, our results suggest the need for healthcare institutions to prioritize strategies that optimize patient-provider interactions.

Keywords Nurses, Nursing, RTLS' real time location system/s, Workforce, Contact time

Introduction and background

Policymakers and regulators have been increasingly focusing on mandated staff-to-patient ratios to ensure safety and quality care for hospital patients. In support of these policies, numerous studies have demonstrated a correlation between staffing levels and patient outcomes [1]. For the United Kingdom (UK), for example, Griffiths et al. show that higher mortality links to more occupied beds per registered nurse/doctor, and hospitals with six or fewer patients per nurse had a 20% lower mortality rate than those with more than 10 patients per nurse [2]. Previous literature also suggests that each additional patient that a nurse cares for increases their probability of death by 7% within 30 days of admission to hospital and a 7% increase in the probability of death after a surgical procedure [3]. More recently, Zaranko et al. establish a statistically significant association between the fill rate of registered nurses and inpatient mortality but found no association when looking at healthcare support and agency workers [4].

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But what aspects of staffing levels contribute to their importance for patient outcomes? A plausible mechanism is that having more staff increases the amount of direct patient care time or contact time. Contact time between patients and healthcare staff is thought to be crucial in optimizing desired health outcomes during an inpatient stay. In theory, it allows staff to target, coordinate, and monitor treatment and contributes to the patient feeling cared for and supported, which may also be an essential factor in determining recovery time [5, 6]. However, empirical evidence on the importance of contact time for patient outcomes is limited, as measuring the time patients spend with staff in hospital is intrinsically challenging.

Current studies that measure contact time have predominantly used time-motion analysis or self-reporting. Both approaches have significant limitations and are difficult to scale. Time-motion analyses require a human observer to record and characterize activities over time [7–9]. This is often costly, time-consuming, and captures only limited time frames and locations. Moreover, having an observer to collect this information may also induce individuals to change their behavior [10]. Self-reported activity logs require staff to record themselves how they spend their time during the day [11, 12]. These methods are subject to recall bias as staff members may overestimate their time with patients [13–15].

We provide in this paper a novel alternative to these methods that use Real Time Location Systems (RTLS) to measure contact time between patients and nursing staff during an inpatient admission. RTLS systems have been increasingly deployed in the healthcare setting, where they are utilized to improve patient and staff flow within hospitals and clinics [16–18]. A key capability of the latest RTLS's is continuous data capture; every movement of a patient or staff movement is recorded and stored in the system's memory [19]. However, few studies have effectively developed and validated quantitative techniques to analyze RTLS data [20].

Using RTLS data from a large NHS Trust, we accurately measure patients' contact time with nursing staff during an inpatient stay. This allows us to empirically estimate the relationship between contact time and patient outcomes as measured by death at discharge. The granularity of this data allows us, moreover, to employ a more sophisticated empirical approach than what could have been implemented using typical data collection strategies in this area.

Methods

Setting

This study was conducted at New Cross Hospital in Wolverhampton, United Kingdom (UK). New Cross is a large District General hospital operating as part of the Royal Wolverhampton NHS Trust (RWT). The Trust is one of the leading healthcare providers in the West Midlands, covering acute, community, and primary care services. At the time of writing, the Trust had more than 10,000 staff. In 2013, the Trust partnered with an American technology company to develop a real-time patient flow and tracking solution [21]. The RTLS application was intended to support staff in delivering care and to enhance efficiency through the process of providing real-time operational information across clinical areas.

The RTLS at RWT provides real-time tracking of all staff and patients across 564,916 square feet of the New Cross hospital site. Badge transponders communicate with over 2000 location sensors and register when a badge has entered or exited a location [22]. As of April 2022, RWT has issued 7218 staff badges, and most patients are badged on admission for their inpatient stay.

Figure 1 shows an example of how RTLS is set up at New Cross. The system creates a grid of locations identified by a locating node (i.e., multiple boxes on the ceiling covering clinical areas). The locating node detects signals

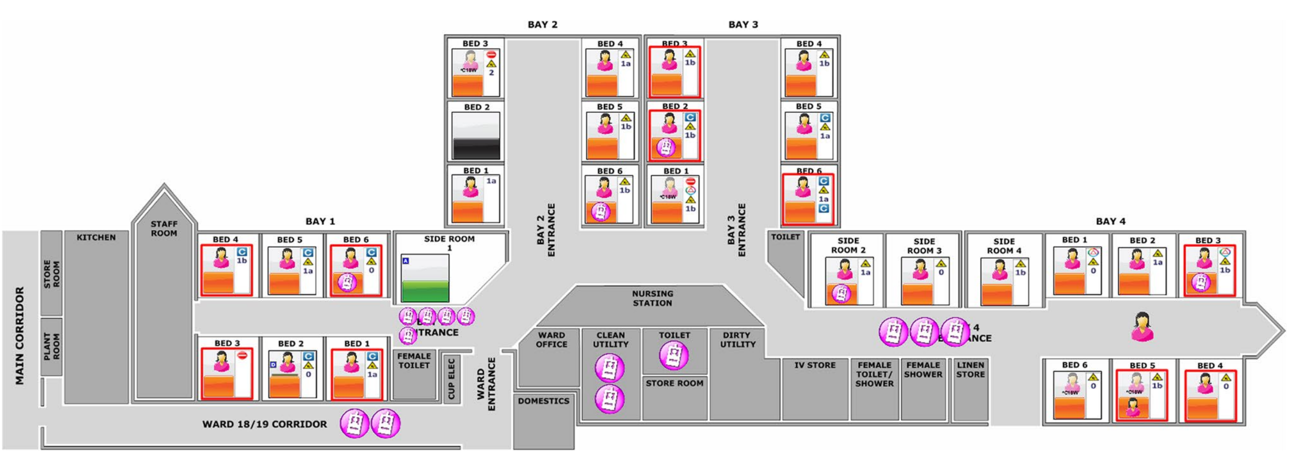

Fig. 1 Example of tracking of RTLS

from the transmitting tags worn by patients and staff to determine the real-time position of the tag. In Fig. 1, the purple dots indicate a staff tag, and we can observe a staff member taking care of a patient in Bed 6 - Bay 1. The timestamp and tag location are then communicated to the location server, which stores this information.

Previous studies have ascertained the reliability and accuracy of the data from the RTLS at New Cross. Cannaby et al. show a high level of agreement between the contact time recorded by an observer for a sample of nurses and the contact time recorded by the system for the same sample. Overall, discrepancies ranged from zero (complete agreement) to 5 min [22].

Ethics approvals were received via the UK competent Authority's application system (IRAS Project ID: 272928), Health Research Authority (HRA) Ethics committee and locally from the Royal Wolverhampton NHS Trusts, Research and Development department and the relevant Trust Governance oversight committees. All necessary approvals were subsequently granted prior to commencement of the study. Informed consent was not obtained from staff participants as the study was deemed exempt. Data was anonymized prior to analysis so that researchers were unable to identify any individual staff members.

Data sources

Data from the RTLS at RWT was extracted from April 2016 to April 2019 to compute daily contact time between patients and nursing staff. These data contained information on the second-by-second location of each patient and staff member at RWT.

The sample of patients included all individuals aged 15 to 95 recorded as having an inpatient admission to RWT. The sample included all New Cross wards[1] except the Maternity ward, which the RTLS does not cover. RTLS data on patients was matched to the hospital's inpatient episode dataset, which contains patient demographic and clinical information, including the discharge method from which hospital deaths are identified.

The staff data was limited to Registered Nurses (RNs) and Health Care Support Workers (HCSW) employed by the hospital between 2016 and 2019. RNs are qualified nurses who coordinate access and deliver prescribed care to patients. HCSWs work under the guidance of a healthcare professional, such as a nurse or a doctor. In a hospital setting, they may assist with the patient's hygiene needs and help mobilize and monitor patients' conditions.

Measures

Contact time between nurses and patients

The starting point for computing contact time using an RTLS system is to combine patient and staff data to detect meaningful clinical interactions. An interaction is detected when the staff member and the patient are in a location of interest. Only clinical interactions that occurred at the patient bed or in the patient's room/bay were used to capture clinically meaningful interactions. The RTLS records comprise more than 20 million of these described interactions for our sample period. A contact-time duration in minutes was computed for each interaction.

Contact time was defined as the daily number of minutes the patient/s spent with nursing staff in clinically meaningful locations (i.e., the sum of the interactions' duration in a day). This was measured separately for interactions at the patient's bedside and in the patient's room/bay. Bed-side contact time captures significant face-to-face interactions between the patient and the staff member. These may include interactions where the nurse will be near the patient, providing personal care like taking vital signs or administering medications. Room-level contact time instead captures periods when the nursing staff is in the patient's room/bay but not directly at the patient's bedside although they could still be observing and communicating with the patient. The total contact time is our variable of interest. Our final data comprises 175,475 patient-day combinations from April 2016 to April 2019.

Outcome of interest

The patient's outcome measure used was inpatient mortality at discharge. This necessarily misses some important patient outcomes that are affected by nursing outcomes; these include patient morbidity and patient satisfaction, both of which are likely affected by additional contact. However, our data does not allow us to credibly measure either outcome. Mortality was selected because it is salient to patients and providers, is unambiguous, and has been used in previous research on staff levels. A binary variable was coded as one indicating the patient's death at discharge and zero otherwise.

Statistical method

This is a retrospective observational longitudinal study using data from the RTLS system and inpatient records for the New Cross Hospital at RWT from April 2016 to April 2019. Three linear regression models of patient mortality were estimated to assess the relationship between patient outcomes and contact time. In the first statistical specification, we control for a rich set of observable patients' characteristics that may bias our results if omitted from the model. These include

[1] The list of the hospital wards at the New Cross hospital can be found here: https://www.royalwolverhampton.nhs.uk/our-services/wards-by-hospital.html.

Table 1 Patient sample summary statistics

	Mean	SD	Min	Max
Female (share)	0.5	0.5	0	1
White (share)	0.8	0.7	0	1
Age	67.1	18.5	15	95
Admitted via Emergency (share)	0.2	0.4	0	1
Charlson Comorbidity Index (CCI)	2.3	2.4	0	15
Length of Stay (days)	12.1	16.3	1	583
In Hospital-Deaths (share)	0.08	0.27	0	1
Room-level contact (Hours)	7.9	4.7	1	22.1
Bed-side contact (Minutes)	22	15.3	5	372
Observations	52,419			

Unit of analysis is the patient/day level. Non-white patients include those whose ethnicity was recorded as unknown. Room-level CT is identified as lapses of time where a nurse was present where the patient bed is located (room or bay). Bed-side CT is identified as lapses of time where a nurse is at the patient bedside

Table 2 OLS regression estimates, dependent variable in-hospital mortality

	Model (1)	Model (2)	Model (3)
Contact Time	-0. 027 (0. 007)	-0. 034 (0. 007)	-0.046 (0.009)
Patient Characteristics	Yes	Yes	Yes
Year-Month Fixed Effects	No	Yes	Yes
Ward Fixed Effects	No	No	Yes
N	101,377	101,377	101,377

The unit of analysis is the patient admission. Coefficient from linear regression model with dependent variable binary indicator of death at discharge. Standard errors are in parenthesis and clustered at the ward level. Patient characteristics are age, age squared, indicator for ethnically white, indicator for female and primary diagnosis dummies. Coefficients and standard errors have been multiplied by 1000

confounders such as patient age, sex, and ethnicity, as well as the first three digits of their primary diagnosis code and eleven comorbidity variables. In the second specification, the same model was estimated but including year-month fixed effects that capture differences in the odds of death over time that may be constant across wards. Lastly, the statistical model was enriched with ward-fixed effects that capture time-invariant differences in the odds of death by ward across the sample period. In this last form, the study design links mortality to contact time within narrowly defined groups of patients that are observationally similar (i.e., have the same demographic and clinical characteristics) and have received care in the same ward and period. In all models, standard errors were clustered at the ward level in anticipation of sampling error being is correlated within hospital wards.

Results

Estimated daily bedside and room-level contact time

Table 1 documents the characteristics of the patients in our sample. 50% percent of patients are females, 80% percent are ethnically white, and the average patient is 64 years old and has a length of stay of 12 days. Furthermore, 20% of patients have been admitted via the emergency department, and the average Charlson Comorbidity Index (CCI) is 2.5. We estimate that the average patient in our sample receives 8 h of daily room-level contact time (i.e., when the nurse is in the patient's room/bay) of which 22 min are of bedside contact time from nursing staff (i.e., direct care at the patient/s bed).

Relationship between contact time and in-hospital mortality

Table 2 documents the relationship between contact time and in-hospital mortality estimated using a linear regression model. We estimate the following relationship:

$$Mortality_{iwt} = \beta Avg\ Contact\ Time_{iw} + \delta X_{iwt} + \epsilon_{iwt}$$

The dependent variable $Mortality_{iwt}$ is a dummy variable equal to 1 if patient *i*, admitted to ward *w*, at time *t* did not survive the hospital stay. The regressor of interest is $Avg\ Contact\ Time_{iw}$ that is the average daily contact time (the sum of room and bed-side contact time) received during the hospital stay. For a patient that has spent two days in hospital and received 5 h of contact time during her first day and 3 during her second day, this would average to 4. X_{iwt} contains patient characteristics and other control variables of relevance, and ϵ_{iwt} is an idiosyncratic component.

Model 1 shows the estimated relationship when X_{iwt} includes only patient level confounders including diagnosis, age, and comorbidities.[2] In this case, the estimated regression coefficient is negative and statistically significant indicating that an increase in average daily contact time is associated with a reduction in the probability of in hospital death.

Model 2 and Model 3 show the estimated relationship when X_{iwt} also includes year-month and ward fixed effects. The coefficient on contact time is still negative and statistically significant, confirming that a higher level of contact time is associated with lower in hospital mortality. Moreover, adding the fixed effects increases the precision of our estimates and the absolute magnitude of the coefficient. In the case of Model 3 the coefficient change suggests that some wards that have high levels of contact time have low mortality rates leading to an attenuation bias when comparison is done across rather than within wards. Model 3, whose results arise from within ward and year-month comparison of similar patients, is our preferred specification. This suggests that a ten minute increase in contact time is associated with a 0.5%

[2] These include Myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, rheumatologic disease, peptic ulcer disease, liver disease mild and moderate/severe, diabetes, hemiplegia or paraplegia, renal disease, malignancy, leukemia, lymphoma, AIDS.

reduction in mortality given a baseline in-hospital mortality of 0.08 [1].

Discussion

Using RTLS data, this study provides two critical insights. Firstly, it demonstrates an estimate of contact time between patients and nurses during an inpatient hospital stay. While prior research has explored the reliability and validity of RTLS systems for such estimations [22], this study is a first effort at quantifying contact time utilizing RTLS data. The average patient in our samples receives about 8 h of contact time with nurses of which 22 min are of direct care at the patient bedside. Unlike the previous literature which has focused on quantifying the proportion of time nurses allocate to patient care, this study takes a patient-centric perspective and shifts the focus from the provider's actions to the patient's experience, aligning with patient-centered care principles.

Secondly, this study examines how estimated contact time correlates with hospital mortality. Our findings suggest a noteworthy association: for every additional 10 min of contact time, there is a corresponding decrease of 0.05% in mortality rates. To the best of our knowledge, this study marks the first attempt to quantify this relationship between contact time and in-hospital mortality. While it cannot be said to be causal, the statistical estimators used include a rich array of time, patient, and ward controls. This sheds light on a fundamental mechanism underlying patient care in hospitals. Beyond the adequacy of staff levels, the amount of time spent by healthcare providers with patients is associated with significant reductions in mortality. It underscores the critical role of patient-provider interactions in influencing patient outcomes, even when staffing levels are deemed sufficient.

While we are cautious about ascribing a causal mechanism to our results, the most obvious mechanism is that nurse observation and care prevents deterioration. If this is the case, our study has implications for nursing staff organization. Our results suggest that more nursing contact time can reduce patient mortality and, where this is a goal, improving contact should be a key goal of nursing care. The avenue through which to improve contact is ensuring that, within a fixed number of nurses, more nursing time is devoted to care as opposed to other clinical tasks like administrative tasks. Other results suggest that a significant proportion of nursing time is devoted to reviewing EHR and charting for patients [7] and that 10% is devoted to non-nursing activities. Time motion studies also suggest that only about a third of a nurses time is devoted to direct patient care as opposed to other tasks [23]. A key question is whether some of this time can be better devoted to patient care and which tasks like reviewing patient information in the EMR are critical to perform nursing tasks.

Alternately, these results speak to increasing the number of nurses so that a nurse's time is less divided between patients. Our paper fits into a larger literature on nurse to staff ratios that shows that more staffing burden leads to higher patient mortality [4], nursing burn-out and job dissatisfaction [3]. Higher staff ratios are also associated with reduced mortality in surgical outcomes [24] and cross-country studies of neonatal and perinatal mortality [25]. While our study does not directly implicate nurse to staff ratios as a cause of increasing mortality, it does provide evidence on a mechanism as to why higher ratios may reduce mortality.

Limitations

This study focuses exclusively on room-level and bed-side contact time between patients and our sample of nursing staff. It is not designed to explore contact time outside the inpatient ward and other locations and staff members. Likewise, this study does not intend to address the perceived quality of care between staff and patients or the reason for its assignment. Additional contact time likely results in better patient satisfaction and so our focus on mortality as a main outcome ignores the improved morbidity and patient happiness that accompanies nursing contact [26]. Furthermore, it is important to acknowledge the sensitivity of our results to the level of compliance among nursing staff with the Real-Time Location System (RTLS). Our ability to measure contact time hinges upon nursing staff consistently wearing the RTLS badge and ensuring its functionality throughout their shifts. Failure to adhere to these protocols, including regular battery changes as mandated, may lead to underestimation of the actual contact time patients receive [22]. In addition, despite the comprehensive nature of our statistical model, which incorporates a wide array of patient characteristics as well as time and ward fixed effects, caution must be exercised in interpreting the estimates. It is crucial to recognize that our findings do not imply a causal relationship, as there may exist omitted variables that could influence the outcomes under scrutiny. Finally, these data are only current to 2019; this was intentional to avoid any pandemic related shocks to RWT. However, nursing shortages have become even more acute after the pandemic. If nursing care and contact time is in even shorter supply, the association between mortality and contact time may change [19].

Conclusion

This study provides valuable insights into the dynamics of patient-nurse interactions within the inpatient setting, utilizing Real-Time Location Systems (RTLS) data to examine contact time between patients and nursing staff. By focusing on room-level and bed-side interactions, it contributes to a better understanding of care delivery at the micro-level, highlighting the significance of contact time in influencing patient outcomes. Despite the limitations, these findings offer valuable implications for healthcare practice and research. By emphasizing the importance of patient-centered care and the role of contact time in shaping patient outcomes, our study underscores the need for healthcare institutions to prioritize strategies that optimize patient-provider interactions.

Abbreviations

RTLS	Real-Time Location Systems
GPS	Global Positioning System
UK	United Kingdom
RWT	Royal Wolverhampton NHS Trust
NHS	National Health Service
IRAS	Integrated Research Application System

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Authors' contributions
Elena Ashtari Tafti wrote the main manuscript and text. Elena Ashtari Tafti has performed the statistical analysis with aid from Stephenson Strobel. Stephenson Strobel, Vanda Carter, and Ann-Marie Cannaby have provided the discussion of the hospital. All authors have contributed to the data collection.

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Data availability
The research data supporting the findings of this manuscript are confidential and cannot be publicly accessed due to legal restrictions. However, replication files and further details may be made available upon reasonable request to the corresponding author.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethics approval was obtained from the Health Research Authority (HRA) Research Ethics Committee (IRAS Project ID: 272928), and locally from the Royal Wolverhampton NHS Trust's Research and Development department and relevant governance committees.
Informed consent to participate was not obtained from staff participants, as the study was deemed exempt from this requirement by the approving committees due to the use of anonymized secondary data. Patient data used in the study were also fully anonymized prior to analysis, and the requirement for informed consent was waived by the same ethics committees in accordance with UK regulations governing secondary use of anonymized health data.

Consent for publication
All necessary local approvals were obtained prior to commencement of the study as outlined in the approved protocol (Version 10.0, April 3rd, 2020).

Competing interests
The authors declare no competing interests.

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