Mediation of adoption and use: a key strategy for mitigating unintended consequences of health IT implementation

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ABSTRACT

Objective Without careful attention to the work of users, implementation of health IT can produce new risks and inefficiencies in care. This paper uses the technology use mediation framework to examine the work of a group of nurses who serve as mediators of the adoption and use of a barcode medication administration (BCMA) system in an inpatient setting.

Materials and methods The study uses ethnographic methods to explore the mediators’ work. Data included field notes from observations, documents, and email communications. This variety of sources enabled triangulation of findings between activities observed, discussed in meetings, and reported in emails.

Results Mediation work integrated the BCMA tool with nursing practice, anticipating and solving implementation problems. Three themes of mediation work include: resolving challenges related to coordination, integrating the physical aspects of BCMA into everyday practice, and advocacy work.

Discussion Previous work suggests the following factors impact mediation effectiveness: proximity to the context of use, understanding of users’ practices and norms, credibility with users, and knowledge of the technology and users’ technical abilities. We describe three additional factors observed in this case: ‘influence on system developers,’ ‘influence on institutional authorities,’ and ‘understanding the network of organizational relationships that shape the users’ work.’

Conclusion Institutionally supported clinicians who facilitate adoption and use of health IT systems can improve the safety and effectiveness of implementation through the management of unintended consequences. Additional research on technology use mediation can advance the science of implementation by providing decision-makers with theoretically durable, empirically grounded evidence for designing implementations.

INTRODUCTION

There is widespread agreement that electronic health records (EHRs) and other clinical informatics applications have significant potential for improving healthcare.1 2 However, the adoption and use of informatics tools vary with the local context, producing results that are unpredictable and dynamic. Estimates suggest that, depending on size, only 5%-26% of physician offices3 and 11.9% of hospitals3 have implemented a basic EHR.4 Additionally, researchers have documented unintended consequences of informatics implementations that create inefficiencies for users and threaten patient safety.5-8 Improving the safety and success of informatics implementations and related user adaptations in work practice is an important area of research and operational focus.9-14

Implementation research in healthcare informatics has produced valuable case studies that present lessons learned,15 analyses producing classifications of unintended consequences,16-18 explorations of best practices,19 20 and conceptual models of work, tools, and behavior.21 22 This study adds to the research on health IT implementation by exploring the mediation of technology adoption and use. Specifically, the results of this qualitative research focus on the activities of mediators who work at the nexus of the institutional setting, the clinical users of information systems, and the IT infrastructure, including developers. The purpose of this paper is to use empirical data on mediation activities (1) to provide practical guidance on mediation as an organizational lever for reducing negative unintended consequences of health information technology (IT) implementation, and (2) to increase awareness of and extend the technology use mediation (TUM) theoretical framework.

Background and significance

Ash and colleagues were the first to explore the roles of ‘special people’ who significantly contributed to the success of IT implementations through their unique knowledge of informatics, understanding of clinical work, and respect for the clinicians who were being asked to learn and use the system.22 Their work articulated the roles of ‘bridgers,’ who are people serving as liaisons between informatics and clinical functions.

Orikowski and colleagues presented research on the roles of mediators, who intervene in the use of technology and impact the trajectory of use patterns.23 TUM is defined as ‘deliberate, ongoing, and organizationally-sanctioned intervention within the context of use that helps to adapt a new communication technology to that context, modifies the context as appropriate to accommodate use of the technology, and facilitates the ongoing effectiveness of the technology over time.’23 The work of mediators is described as changing the organizational context and providing users with mental models and other interpretive resources to draw upon as they learn and use the technology. The researchers attributed the mediators’ effectiveness to several factors: (1) proximity to the context of use, (2) understanding of users’ practices and norms, (3) credibility with users, and (4) knowledge of users’ technical abilities and the technologies at their disposal.23 and stated the need for additional research to further explore the validity of the factors.
The explanation of TUM by Orlikowski and colleagues was in the context of a manufacturing firm, with reference to a communication technology (‘groupware’). Davidson and Chiasson expanded the TUM framework through their study of the use of electronic medical records systems in two healthcare organizations. Responding to speculation that TUM would be most applicable to generalized technologies (eg, communication), the authors were able to demonstrate the utility of the TUM concept with a specialized technology, electronic medical records. Research on implementation of health IT has recently emphasized the ‘human element’ as a key success factor. Similarly, studies of unintended consequences related to health IT implementation have revealed opportunities to adapt elements of design and implementation to improve the fit between workflow and IT tools.

We used organizational routines theory to explore the impact of technology on work practices during the implementation of a barcode medication administration (BCMA) system. Conceptualizing structured ‘intersections’ of major healthcare routines such as medication administration and pharmacy verification and scheduling. We explored the problem-solving role of mediators at these intersections, finding that mediation activities provided a corrective to misalignment in the intersections created by new technology use practices.

This study extends the original TUM framework by examining specific mediation practices in healthcare IT implementation. Using data from the BCMA study described above, we provide practical guidance for using TUM in implementation and demonstrate that, in the healthcare setting, additional factors can contribute to mediation effectiveness.

The BCMA system relied upon a new pharmacy information system that produced patient-specific barcoded labels for medications. At the time of medication administration, the BCMA workflow required the nurse to scan the patient for identification, then scan the medication barcodes, then scan the patient again. Once all of the medications were given to and/or taken by the patient, the nurse clicked the ‘Confirm’ icon. This confirmation resulted in the administration(s) being automatically charted in the new electronic medication administration record (eMAR). This fundamental workflow is common among BCMA systems being implemented in the USA. Research on BCMA implementations has produced a mixed picture. Some studies have shown clear benefits of the technology in reducing medication errors.

Other research has focused on the impact of BCMA on work practices, with evidence of minimal impact on nurses’ time with patients but also documenting numerous types of workarounds that compromise the safety features of the technology and other system-based errors.

Setting
The study site for this research was a multi-hospital, tertiary medical center during implementation of a BCMA system. The hospitals involved in the rollout of BCMA had a total of 1058 beds. For over a decade, the organization had invested in informatics as part of the core strategy for improving care. Clinical applications already installed included computerized provider order entry (CPOE), a nursing documentation system, and an EHR, and all of the major departmental systems (ie, pharmacy, respiratory therapy, etc).

Mediators: the informatics support team
The informatics support team (IST) was a group of approximately 20 registered nurses responsible for the rollout of informatics-based systems in the hospitals. Many of the members of the IST had additional training in IT. The team had successfully implemented CPOE and a nursing documentation application in the hospitals. The IST had a number of responsibilities, including:

- Representing the needs of users to in-house developers for customizing vendor products and designing application solutions for specific needs
- Working with project managers, vendors, informatics staff, hospital management, and clinical staff to design implementations, including detailed equipment considerations and rollout scheduling
- Training new staff on clinical systems and training all users on new systems
- Go-live support, including 24/7 coverage in the early weeks for each unit
- Initiating and participating in problem resolution for new systems being rolled out, including interface issues with other systems
- Ongoing support of implemented systems.

The implementation plan involved rolling out one nursing unit at a time, with 2 weeks for each unit to settle in before the IST moved on to the next one. Prior to go-live, the IST trained all of the BCMA users for a given unit. The team provided 2 weeks of 24 h go-live support to each nursing unit bringing the system online. This support included one-on-one coaching, troubleshooting hardware and software problems, and identifying issues that required policy and process changes.

METHODS
Institutional Review Board approval was obtained prior to initiating the study, which employed a case study methodology. Data collection methods included over 50 h of observation of medication administration activities and IST support work, including meetings, training classes, and go-live support during the rollout of BCMA. Data included field notes from observations, documents such as meeting minutes and reports, and email communications. This variety of sources enabled triangulation of findings between activities observed, discussed in meetings, and reported in 170 emailed IST shift reports. A comprehensive discussion of the methods can be found in our previous publication from the study.

Data analysis
Files containing field notes and email content were imported into QSR NVivo (Versions 7 and 8), a qualitative data analysis software program. In NVivo, each file becomes a ‘source’ document. Sources are then opened and text units (usually paragraphs) are coded (assigned one or more labels, or nodes). The principal investigator performed all of the coding of the data. TUM was selected as a potential explanatory theoretical framework because of its relevance to the work of the IST, its prior utility in health IT research, and its strong foundation in well-established social theory. In iterative analyses nodes were grouped where relevant, and analytical categories related to the TUM were applied. We sought reliability through triangulation of findings from observation of rollout support, discussions observed in meetings, and email reports from IST members. The coauthors discussed the data over the course of the study, resulting in further data collection and analysis, trial of other frameworks, and selection of the themes reported here. The TUM framework did not explain all of the activities in the data, and the authors were able to extend the framework with three
new factors related to mediation effectiveness, described in the Discussion section.

**FINDINGS**
Many of the IST members were practicing nurses in the organization prior to joining the IST. This clinical and organizational experience provided contextual knowledge that the IST members used to help nurses integrate BCMA into practice. The IST was intimately involved in many aspects of the nurses’ transitions from pre- to post-BCMA. In addition to getting to know each nurse in training classes, IST members spent time on each unit several weeks in advance of go-live to gain a detailed understanding of the work on that unit. The challenges encountered on each unit varied primarily with the patient population served by the unit.

In this paper we report on three of the themes that emerged in the analysis of the work of the IST: (1) resolving challenges related to coordination, (2) integrating the physical aspects of BCMA into everyday practice, and (3) advocacy work. These themes were selected because they describe areas of activity not yet explored in the literature on mediation or support activities, and provide evidence to support recommendations for the training, experience, and goals of similar teams in other organizations. A further description for each theme follows. The sub-themes are summarized in table 1.

**Theme 1: resolving challenges related to coordination**

**Coordination with hospital units not using BCMA or eMAR**
One of the first units to go live was the Cardiac Care Unit (CCU), which frequently transferred patients back and forth from the Cardiac Catheterization Laboratory (CCL). The CCL was not using BCMA or the eMAR. A nurse who specialized in transferring patients between the CCU and CCL expressed concern about the implementation of BCMA and the potential errors that could result with the two units using two different systems for documenting medications. In the ‘pre-BCMA’ world, the paper chart (including the paper MAR) physically went with the patient to procedural areas, was used for documentation, and came back with the patient to the unit. When BCMA was implemented, the IST helped the nurses develop a procedure for checking the information coming from the CCL with the patient and updating the eMAR with the relevant medication data. Intravenous fluids were of particular concern. The CCL often hung or ‘started’ an intravenous bag before the patient was taken back to the CCU. This created more tasks for nurses in the CCU, who were responsible for ensuring that the documentation of each intravenous bag was entered into the BCMA system, which was designed to accommodate the hanging of barcoded, patient-specific, pre-numbered intravenous bags in numerical order. The IST members developed a procedure for the nurses on the CCU to document the start of an intravenous bag from another unit in the eMAR. The IST was able to understand these detailed problems and develop solutions as a result of the investment in time on the unit prior to go-live. The procedure mitigated potentially widespread negative consequences of BCMA implementation: inaccurate documentation of intravenous lines started in non-BCMA units, and inaccurate or incomplete transfer of documentation from paper into BCMA.

**Coordination with the nurse on the subsequent shift**
Prior to BCMA, medications were ordered in the CPOE system and were subsequently represented on a pre-printed MAR that organized each ordered dose temporally across the page. The paper MAR was used as both a document of patient care and as a communication tool. Given the variety of contingencies experienced by nurses during a shift (such as unplanned or off-schedule procedures, new patients being admitted, or clinical emergencies), it was common for doses to be given late or early in order to accommodate the complex itinerary of the patient and the activities of the unit. If there were instructions or a message for the nurse on the next shift related to a specific medication, nurses sometimes wrote the instructions on the MAR, adjacent to the relevant dose. The notes included information about ‘staggering’ doses over time to get the patient onto the standard hospital schedule, missed doses, and instructions specific to a particular dose of a medication, for example, the need to draw blood for measurement of peak and trough levels of a drug in the patient’s blood.

As the IST became aware of the need to communicate across shifts with instructions or advice about specific doses, and the inability to place a ‘note’ adjacent to a specific dose in the eMAR (as had been done with the paper MAR), they worked with the system developers to devise a solution that involved a special type of order in the CPOE system to enable a nurse to create a ‘medication instruction’ order for the nurse taking care of a specific patient on the next shift.

The work of the IST helped bring attention to the communication practices related to medication instructions, including

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<td>Theme 1: Resolving coordination challenges. Raising awareness among users and developing workaround for dose-specific communication across shifts.</td>
<td>‘Stolen doses’ resulting in inaccurate downstream documentation in eMAR. Lack of information about specific doses (timing, patient-specific details, etc) that could impact safety or efficiency.</td>
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<td>Theme 3: Advocacy. Advocacy for policy changes.</td>
<td>Workarounds and hindered adoption due to nurses’ inability to achieve extant policy objectives.</td>
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*New factors identified in this study are in bold print.*
Theme 2: integrating the physical aspects of BCMA into everyday practice

Managing barcodes and wristbands

IST members had credibility with bedside nurses because they were registered nurses with clinical experience. This provided them with clinical background knowledge to advise nurses not only on technical issues, but on clinical and practical ones as well. The excerpt in box 1 from an IST support shift report email demonstrates how intimately the IST members engaged in the transformation of the material aspects of practice (in this case a problem with the new barcoded armbands), including communicating with the patient’s family.

This type of engagement demonstrated to the nurses that the IST members had experience with nursing practice and were willing to get involved in specific patient cases to make sure the system was working well. IST activities gave the nurses a vocabulary or script that could be used with patients and families to help explain the system and related paraphernalia such as armbands and barcodes, and also an awareness of the armband, which had become an essential part of medication management. These actions may have smoothed relations with patients and families, who were the unwitting participants in a health IT implementation.

Inappropriate dependency on medication barcodes

Scanning the barcode on the medication while logged into the patient’s record provided a safety check for drug and dose. The design of the BCMA implementation included a visual confirmation of the drug by the nurse, in case the wrong barcode had been placed on the drug package somewhere in the supply chain. This reasoning was momentarily lost on one nurse, busy with a complicated patient, a student nurse, and the learning curve of BCMA. Attempting to confirm the dosage on the back of the blister pack (printed in a micro-sized font) she commented, ‘Is this 4 mg? I guess I could just scan it and see.’ In this case the IST support person examined the blister pack and confirmed the dose. The visual check of the medication represented a new rule to deal with a new risk—that the barcode could be wrong. This risk was dramatically portrayed by another nurse, who found an erroneous barcode that displayed the medication as half of the actual dose. She complained that if she had not looked at the medication with her ‘two eyes,’ she would have given the patient double the proper dose. The IST reinforced this new logic to the nurses in training and in coaching, potentially reducing the serious negative consequence of a wrong dose error based on an erroneously coded barcode.

Theme 3: advocacy work

We refer to the work in this theme as ‘advocacy’ because it describes how the IST voiced the concerns of the front-line nurses to hospital management. The IST implemented a nursing documentation system in the years prior to the BCMA implementation. The director of the IST had been in the organization for many years, and was involved in all of the general purpose clinical system implementations, including the CPOE system, the electronic chart, and the nursing documentation system. Therefore, the IST leaders were well known to the nursing unit managers, as well as to the nursing and informatics executives. The BCMA project had strong backing from nursing leadership, evidenced by regular meetings between the IST and the vice-president of nursing, and the active participation of a nursing executive as the project’s champion. One product of this relationship was the alteration of the policy that defined ‘late’ and ‘early’ medications prior to the introduction of BCMA. The IST and project manager estimated that BCMA would add to the time and complexity of medication administration. The existing policy defined administrations as ‘early’ if the dose was administered more than 0.5 h before the ordered time, and ‘late’ if administered more than 0.5 h after the ordered time. The new policy expanded the window of on-time administrations to 1 h before and 1 h after the ordered time.

The introduction of BCMA brought a suite of new management reports for nursing leadership. One report, the ‘Overdue Medications Report,’ flagged doses that were overdue. The report listed the patient, medication, and ordered time, and could be run for medications that were 1–8 h overdue or 10–48 h overdue. The nurses perceived this as a measurement of their performance. A result of this perception was the nurses’ frequent documentation of medications as ‘Not Given,’ which took the medication off the list of active orders and thus off the Overdue Medications Report. This documentation was used, for example, when a patient was off the unit for a procedure and the nurse knew the medication would be late. However, in the BCMA system, the ‘Not Given’ documentation actually meant ‘will never be given,’ and if the nurse later administered the dose, she would be required to ‘steal’ the next dose in the eMAR, which sometimes caused a cascade of inappropriately documented doses stretching out across several shifts. The IST members, as nurses, understood the nurses’ desire to avoid the stigma of ‘Overdue’ medications and facilitated a name change to ‘Outstanding Medications Report.’ The IST conducted an educational campaign to help nurses understand that the system was not ‘judging’ them for having a late medication (note: our data did not reveal definitively whether or how the nurses were being judged with respect to on-time medications), and remind the nurses that there were many valid reasons for a medication being late. In this way, the IST members used their clinical and social experience as nurses to understand the goal the nurses were working toward (minimizing Overdue Medications), transform the BCMA structure (the title of the report), and realign the nurses’ clinical priorities, thus minimizing the potential for negative consequences related to the problem of...
stolen doses. More generally, the advocacy work of the IST helped bring awareness of specific challenges faced by the nurses to the senior management, enabling reallocation of resources or policy changes.

**DISCUSSION**

**TUM to mitigate negative unintended consequences**

The IST and their approach to problem-solving had a potentially significant impact on patient safety during the rollout phase of BCMA. Their experience as nurses, particularly previous experience in the same organization, contributed to their creativity in problem-solving. Having been in direct patient care, they could empathize with the problems the nurses encountered and achieve a rapid understanding of the nurses’ experience. Their collaborative approach to problem solving using emails and face-to-face meetings resulted in solutions and new procedures that were tailored to the unit experiencing the problem yet exportable to other units. While it is impossible to know the extent and importance of the impact of the IST on patient safety, several areas of practice were addressed by the group in ways that potentially reduced negative consequences, including (1) patient transfers, particularly among units on different medication documentation systems, (2) shift handoffs, (3) documentation and the new potential for ‘stolen’ doses, and (4) helping nurses to understand new potential risks created by the system (such as the risk of an inaccurately coded barcode and the need for visual inspection of the dose).

The value of the connection between the IST and senior leadership cannot be underestimated. The vice-president of nursing and the IST director had a long-standing relationship that was the result of their shared experience implementing a major nursing documentation system. The closeness of the team and senior leadership was demonstrated by their socializing outside of the work environment. They gathered to celebrate the impending birth of a baby and at a party at the home of a team member to celebrate the team’s success. All levels of the organization were represented at both events. These strong relationships likely enabled the IST to advocate more effectively for the nurses using the system.

**Extending the TUM framework**

The IST comprised a particular set of talents and approaches to problems that proved useful in the implementation of BCMA in this setting. Linking their actions to contextual aspects of the implementation through a theoretical framework like TUM produces insights that could be widely applied. An aim of the paper is to examine the work of the IST with respect to the factors related to mediators’ effectiveness described by Orlikowski and colleagues, which include (1) **proximity to the context of use**, (2) **understanding of users’ practices and norms**, (3) **credibility with users**, and (4) **knowledge of users’ technical abilities and the technologies at their disposal**. Table 1 summarizes this analysis, describing the unintended consequences addressed and three new factors that we will explore in more depth.

**Factors related to mediation effectiveness**

In this case, mediation of technology adoption and use involved substantial work in problem identification and resolution. The work of the IST involved facilitating changes to the electronic systems, work practices, and institutional policy. We found that the IST members’ influence on leaders’ opinions and informatics development priorities featured prominently in their ability to solve problems and positively impact adoption and appropriate use of the BCMA and eMAR tools. Another aspect of problem-solving was the commitment of the IST to understanding all dimensions of the nurses’ work, even if that meant spending time in another unit to understand how the patient transfers needed to occur. Therefore, we observed three additional factors related to mediation effectiveness in this case: (1) ‘influence on system developers,’ (2) ‘influence on institutional authorities,’ and (3) ‘understanding the network of organizational relationships that shape the users’ work.’

**Influence on system developers**

Berg has argued that health IT can bring value to healthcare when tool and practice are brought into alignment and tasks are redistributed among them appropriately. This does not occur automatically and users, engaged in their own work, have little time to present their information needs to the informatics department and follow-up on the design and implementation of changes. In this case, the IST worked with system developers and with the vendor to make changes to the system to support the nurses’ goals, including the development of a CPOE-based workaround to enable nurses to communicate with colleagues on future shifts. The IST served as an important link for the developers and the vendor to the events unfolding on the nursing units implementing the system. The IST met regularly with system developers, project managers, and pharmacy informatics staff to solve problems, and these exploratory discussions helped the IST members understand the way the system was designed, including details of the interaction between pharmacy, BCMA, and order data. Armed with information about the fundamental system design, the IST members were better equipped to set expectations with the nurses regarding potential solutions to problems.

**Influence on institutional authorities**

The access to institutional leaders by the IST was a result of strong organizational commitment to the BCMA project and to relationships among leaders in nursing, informatics, and the IST. The IST provided thoughtful analyses of unintended consequences and workarounds that arose, including assessments of how the system was impacting nurses’ goals. The nursing executives conveyed a sense of trust in the IST leaders through their endorsement of proposed changes. In the case of the impact of the late medications report on nurses’ documentation practices, the IST was empowered to speak for nursing leadership, educating the nurses about the clinical validity of a late medication in some cases.

**Understanding the network of relationships that shape users’ work**

We found that the mediators, deployed before and during the BCMA rollout, were able to anticipate some potential problems with the system, such as coordination of medication administration information between the ‘live’ BCMA units and those that were not using the system. Early in the implementation, the IST members were prepared to coach and teach the nurses on this issue. Other unintended consequences, such as the unorthodox use of the paper MAR as a communication tool and the challenges presented by the new wristband for some patients, came as a surprise, but were caught and managed very early in the implementation. In TUM theory, a critical factor in this achievement was ‘proximity to the context of use.’ We extend this dimension by noting that while knowledge of the users’ (eg, nurses in the CCU) work was essential, the IST members enhanced the effectiveness of their mediation activities through knowledge of the work of others with whom the users interacted (eg, nurses in the CCL). We refer to this factor as
‘understanding the network of relationships that shape the users’ work.’

Limitations
Methodological limitations of this work must be considered. First, data collection and initial analysis were conducted by one ethnographer. However, all of the authors collaborated on developing insights relevant to the TUM framework, both theoretical and practical. No formal interviews were conducted. The workload for nurses during the rollout was very high, as they were learning the new tool while still accomplishing all of their other tasks. The principal investigator opted to use a more informal approach, getting brief interviews with nurses when an opportunity presented itself on the unit. The informal interviews had the advantage of being situated in the work environment, rather than being physically removed from the unit activities. This could have contributed to less filtered comments from the nurses.

CONCLUSION
Regardless of how the work or workload of the nurse has changed, medications must still be administered. In the case of BCMA, the adaptation of work practices and technology occurs ‘on the job,’ with real patients. The TUM framework proved useful in explicating the work of the IST, a team that mediated the adaptation of practices and technology with situated, thoughtful observation of nursing work before and during the implementation of BCMA. The credibility and influence the IST held with users, system developers, and institutional authorities were essential elements of their effectiveness in solving problems, mitigating unintended consequences, and positively impacting the safe adoption and use of BCMA. This research suggests that employing clinically experienced, IT-trained staff, dedicated to the purpose of mediating changes in work that result from health informatics implementations can help mitigate negative unintended consequences. Deploying sufficient mediators to provide 2 weeks of 24 h coverage for departments or units going live with the technology enabled continuous surveillance of emerging issues. Issues identified were quickly resolved, partially due to the effective communication channels established between the mediators and senior management.

This case demonstrates that the TUM framework has utility in health IT implementation research and practice, and suggests that with additional empirical research, the framework may be further specified for use in healthcare IT and other technological implementations.

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Contributors
LLN: conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article and revising it critically for important intellectual content, final approval of the version to be submitted. SA: analysis and interpretation of data, revising the article critically for important intellectual content, final approval of the version to be submitted. CGS: conception and design of the study, analysis and interpretation of data, revising the article critically for important intellectual content, final approval of the version to be submitted.

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