Evaluating the Impact of Technological Change in a Critical Care Unit: Towards a Model to Support Stakeholder Envisionment

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The increased use of health information technology in hospitals brings with it a growing need to appreciate the contexts in which health information technology may be used. Information flow and workflow are directly affected by the implementation of such technology. We present first steps towards a method that will help stakeholders evaluate the impact of technological change on work practice sufficiently early to influence the design and deployment of such technology. By using models of information flow and workflow based on how work actually occurs, analysts may better understand the relationships between the healthcare work and the proposed technological change. Models must be descriptive of healthcare work, must help the analyst evaluate work, and must help the analyst make conjectures about change. In this paper we evaluate whether the model notation is ready for testing with representative analysts, to see if the models help them envision the effects of technologies on work.

INTRODUCTION

Hospitals increasingly use health information technology to support work at the bedside such as chart documentation, and to support communication between departments such as medical order processing. Policy makers hope to realize economic and safety benefits with health information technology (AHMAC, 2008; Reid et al., 2005). However, the consequences of implementing such technology are not always predictable (Karsh et al., 2010; Woods & Dekker, 2000). Changes in technical support can affect both information flow and work practice (Reddy et al., 2005). If analysts do not reason through the consequences of implementing new information systems, clinicians are less likely to use them and their implementation is less likely to be successful (DeLone & McLean, 2003). It could help policymakers and analysts if they had a better understanding of the processes being replaced or changed by health information technology (Baxter & Sommerville, 2011; Leu et al., 2008).

In this research, our goal is to develop a modeling notation that will produce models that help analysts envision, systematically, how changes to current technology may affect information flow and work practice and so evaluate the suitability of different solutions. Such models would go beyond conventional normative business process models (Hoffer et. al., 2007; Madison, 2005). Instead, they would provide a shared representation of the details of current and potential information flow and workflow that could be understood and extended by all analysts (stakeholders) engaged in a procurement or acquisition process. Analysts would include clinicians, health information managers, business analysts, change management specialists, software engineers, and others.

In prior research, Unertl et al. (2009) developed information flow and workflow models to help evaluate the design of health information technology in chronic disease clinics. Hayes et al.'s (2011) narrative networks show variations in work practice, but do not directly support the process of reasoning through the consequences of changes.

We start a little further back and consider what such models should achieve and what properties they should have. To help an analyst evaluate the impact of new technologies, a model should serve three functions:

- The model should *describe* the work practice so it can be understood by the analyst.
- The model should let the analyst *evaluate* the adequacy or inadequacy of the information flow and workflow described.
- The model should let the analyst *conjecture* about the impact of a change (of technology but also of roles) on information flow and workflow.

A model must support understanding before it can support evaluation, and it must support evaluation before it can support conjectures about the impact of technology on work. Therefore each of the above three functions builds on the previous one, somewhat similarly to the way situation awareness level 1 (SA1) (perception) provides a necessary foundation for SA2 (comprehension), and SA2 in turn provides a necessary foundation for SA3 (projection) (Endsley, 1995).

The first step is to develop the models, using interview and walkthrough data, and to assess whether the models will help analysts (1) understand the underlying work, (2) perform evaluations of the work, and (3) use the model to conjecture about the impact of new technology. We report on this first step in this paper. The second step, to be reported elsewhere, is to perform an empirical test of whether people from the healthcare domain can understand the model and use it to evaluate work and make conjectures about the impact of new technology. Empirical testing is needed to establish the validity of the representation and conceptual framework (Moody, 2005).

To illustrate, we model how a non-urgent order is currently made for a blood transfusion for an ICU patient (Torpy et al., 2004). We developed a representation of this process, based on an analysis of interviews conducted with hospital medical and nursing staff, pathology workers and blood bank technicians.

METHODS

Approach

The aim of conducting the interviews was to collect an account from healthcare workers of the information tools used in the work process, the verbal communication that occurred, and how work was coordinated. Two types of interviews were conducted: traditional sit-down *standard* interviews followed by more in-depth *field walkthrough* interviews. For each kind of interview, the following steps were taken.

1. A broad sampling strategy was used, with interviews completed in the Intensive Care Unit (ICU), Emergency Department (ED), Pathology, Cardiovascular Unit, Post-Anesthetic Recovery Unit, and High Dependency Units (HDU).
2. Prior to conducting the interviews, the main contexts of work and main work activities were identified (using the research nurses' expertise and pilot observations in the ICU).
3. The main contexts of work and work activities served as interview topics and were incorporated into printed protocols for the interviewer's use. The protocols standardized the introductory and debriefing statements, wording and timing of questions, and ensured the participant could add further information before the interview finished.
4. Video recordings were made of each interview so that members of the research team could conduct a full review as needed. Whenever possible, two researchers were present at each interview.

The interviewing team included 1 academic (PS), 1 PhD student (CS), and 2 registered nurses (CBO and LJ) who worked in the ICU at a tertiary hospital that was also the research site. The hospital and university Human Research Ethics Committees granted ethics approval.

Data collection

Standard interviews took place in an office within the hospital, isolated from the participant's work area. To facilitate discussion of information flow in different work contexts (e.g., bedside work, shift handovers), drawings were presented of workspace physical layout, artifacts from the workplace, and a basic representation of information flow. One camcorder captured the participant's face and upper body; the other captured the table surface and the hands of participant and researcher.

Field walkthrough interviews took place in the participant's work environment. The researcher(s) and participant spent time in multiple work locations, walking through activities and interactions with electronic, physical and human information sources. One miniature video camera captured a view from the researcher's head or shoulder and a second camera was positioned on the researcher's clipboard to capture close detail of objects and digital interfaces. For safety reasons, field walkthrough interviews did not take place while the participant was providing direct patient care.

Ten of the 41 interviews contributed to the analysis of blood transfusion (Table 1). The 10 interviews were conducted in different hospital units and across different professions, and they included six standard interviews and four field walkthrough interviews. All 10 participants had at least two years experience in their unit. Data collected included the videotaped recordings, sample printed material from the patient chart and commonly used information systems, and de-identified artifacts. Average interview duration was 90 minutes.

Table 1. Profile of the ten interviews included in the analysis of the blood transfusion workflow. The parenthesized letters (s) and (f) stand for *Standard* and *Field walkthrough* interviews respectively.

Hospital Unit	Participant's Role	Number (Kind) of Interviews	Duration (minutes)
Intensive Care Unit	Nursing Staff	2(s), 1(f)	90, 75, 80
	Medical Staff	1(s)	150
	IT Manager	1(f)	120
Blood Bank	Technician	2(s), 1(f)	90, 85, 70
Pathology-Hematology	Technician	1(s), 1(f)	50, 90

Data analysis

Each interview produced descriptions of the information tools and technologies used by units, reports of workflow from nursing, medical and laboratory entities, and a report/ demonstration of technology in use. Content analysis for each interview began with full video review by the main researcher/interviewer (CS), who divided the audio-video tracks into time-stamped data cells containing content summaries, including initial codes for categorizing aspects of information flow and workflow. Review by research nurses (CBO, LJ) on specific parts of each interview clarified clinical detail. Researcher comments were kept in data tables using Microsoft Word™ or the OpenSHAPA™ video analysis software. The research team reviewed key points in the interviews, and then developed a framework for the model of blood transfusion of an ICU patient.

Model Development

The first step in model development was to divide the work context into main steps or functional areas. Five broad areas of work activity are shown as steps in the shaded process boxes in Figure 1. Second, a whiteboard was used to sketch connections between information sources found in the data. Next, the whiteboard drawing was transferred into a MS Visio™ drawing, where the model was refined. A set of symbols was developed to describe how information is stored, transferred and transformed in the work process (see legend in Figure 1).

The model structures the sequence of the work, identifies work locations and information systems, and identifies workers who use the systems. Additional symbols indicate where there is variability in practice (see ViP circles) or special conditions for performing the work (see clouds). For example, ViP in Step 3b refers to different ways that Blood Bank technicians retrieve a patient's history, depending on system availability, which hospital unit orders the test, and preference.

To make sure that all modalities and process steps were included in the diagram, we examined the model for complete presentation of the information sources, stores, and sinks (Barker et al., 2007).

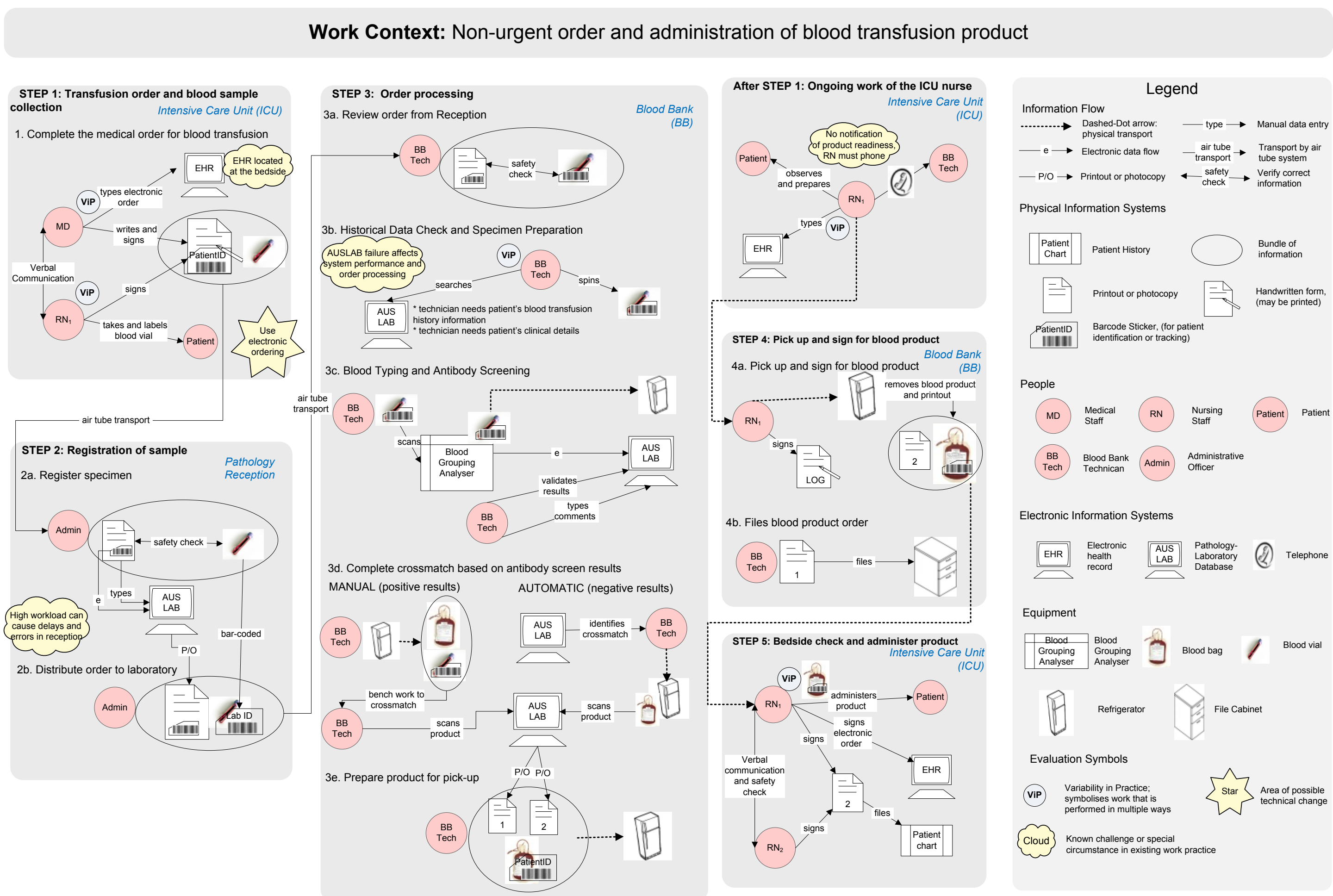

Figure 1. Model of information flow, technologies, and work practices between ICU, pathology reception and blood bank, in the context of processing a non-urgent order for blood transfusion. (Models such as this will evolve as empirical tests are performed of their fitness for purpose.)

RESULTS

The interviews and work artifacts yielded data from which we built an account of the process of making a non-urgent order for blood products and administering a blood transfusion. Below we consider factors that suggested that the model is ready to test empirically with representative analysts from the healthcare domain.

Description. First, wherever possible the model uses semi-pictorial representations to aid analysts' understanding. Second, the model is built from the point of view of multiple interviewees from different professional groups working in different locations, which should offer robustness. Third, the two interview techniques probed knowledge differently from each other, possibly expanding the range of information provided beyond what would be provided from either interview technique alone. Participants in standard interviews described the main steps and systems used in their role, and were asked to recall examples from recent shifts. Participants in field walkthrough interviews took researchers to specific work locations and gave details of using information systems in specific circumstances in the workplace. We are now performing empirical investigations to test the descriptive adequacy of the model.

Evaluation. Because at face value the model appears to provide an adequate description, we can consider whether it helps analysts evaluate information flow and workflow. To support evaluation, the model must let analysts immerse themselves in the *operational structure* of work. An analyst who is generally familiar with the healthcare system within which the work modeled is embedded should then be able to judge the adequacy or inadequacy of the information flow and workflow provided in the description.

The operational structure of work is best captured by integrating multiple perspectives on information flow and workflow. Data from workers who interacted with the same information at different times (e.g., request form and specimen) have given the researchers some detail about the modalities in which information arrives, and the conditions under which required information may or may not be available, accessible, or transmittable. For example, the main electronic system used (AUSLAB) can run slowly or shut down unexpectedly, creating delays in providing blood products and blood test results. Including detail about system performance may help analysis make further inferences about what is or is not working well. We are now performing empirical investigations to test whether the model helps analysts make evaluations.

Conjecture. Because at face value the model appears to support evaluation, we can consider whether it may help analysts make conjectures about the impact of new technology. The model must help the analyst make inferences about the effects that technical changes have on existing information flow and workflow throughout the process, not just at the immediate point of implementation. We have provided a 'star' symbol to identify a point of the process where technical change is possible. This is a starting point from which analysts can envision how a technical change may affect the work. We are now performing empirical investigations to test whether the model helps analysts make such conjectures.

DISCUSSION

A method of using interviews with healthcare professionals, and modeling of information flow and workflow has been developed to help analysts and stakeholders consider the consequences of technological change on work. Using a clinical example of blood transfusion, we have discussed findings in terms of three kinds of activity the model must support: describing information flow and workflow so that analysts understand it; helping analysts evaluate aspects of the current work practice; and helping analysts make conjectures about the impact of technical change.

Our method has apparent similarities with aspects of other modeling approaches, but we suggest that in its entirety it is different. For example, our approach differs from that of Hayes et al. (2011), Unertl et al. (2009), Leu et al (2008) and others in one or more of the following ways. First, the models are intended to be inspected by clinicians and, where appropriate, used by clinicians to engage in discussions about the impact of technology, as well as by analysts. Therefore the models use semi-pictorial elements. Second, the models represent aspects of work that are vulnerable to change, such as modalities of information and artifacts, and the means through which communication occurs. Third, the models can show tight temporal relations where logically entailed, but also loose temporal relations where there is variability. Fourth, the models show details of actual work rather than idealized views. Fifth, a key concern has been the notational adequacy of the modeling symbology for prospective evaluation – an adequacy that is still under test.

There are limitations to the work presented here. First, the model notation was developed on the basis of interviews at a single site, so the notation may not successfully represent all critical care settings. Second, the model itself is based on the accounts of work from 10 participants only, which may reduce the accuracy of the model. Third, no observations were made while participants were working or providing direct patient care, so the model rests on reports or field walkthroughs of work rather than on observations of actual work. Fourth, because each model is valid only until there is a change in work artifacts, protocols, tools, staffing or policy, each model will need continual updating if it is to continue to support evaluation and conjecture. However, we wish to create models that analysts can easily update as work changes and systems updated. Finally, as noted, the models need to be tested empirically at the three levels identified in the results. This phase of research is currently in progress (Stitzlein et al., in press).

The model is based on actual accounts of work and is therefore useful not only in estimating the impact of new technologies but also in exposing the need for a technological change to overcome shortcomings with current information flow and workflow. However, as the socio-technical systems are complex (Woods & Dekker, 2000) there may be other considerations regarding the uptake of new systems which are unrelated to existing information flow and workflow, such as deficiencies in the process of organizational change or in system development (Baxter & Sommerville, 2011).

Decisions associated with the design, procurement, configuration and implementation of clinical information products are complicated. Stakeholders may benefit from the ability to step through processes with graphical models that show current information systems and workflow. With a representation in a physical form, analysts can immerse themselves in the clinical context, step through reasoning about technical changes, and record conjectures about the impact.

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