Clinical Information Flow and Variability in Practice in Healthcare

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WISH 2010, April 11, 2010, Atlanta, Georgia, USA.
ACM 978-1-60558-930-5/10/04.

Abstract
We summarise ongoing research directed to the problem of prospectively evaluating the impact of eHealth technologies on work in the critical care context. We outline our approach and present a simplified model of clinical information pathways in a large Australian intensive care unit some months after the implementation of an Electronic Health Record (EHR). Observations and discussion with stakeholders make it clear that there is considerable variability across patients and caregivers in how the EHR is configured and used by caregivers, and therefore what the information pathways might be. Such "variability in practice" creates a challenge for prospectively evaluating the impact of further technical changes.

Keywords
eHealth, evaluation, information pathways, critical care

ACM Classification Keywords
H.5.1. Information interfaces and presentation: Multimedia Information Systems---Evaluation/Methodology.

Introduction
Now that many health delivery organisations are starting to use eHealth systems, researchers have uncovered unintended negative consequences of such systems for work practice [1]. Stakeholders could

benefit from methods to predict at least some of the consequences of implementing a new eHealth system. Changes needed in system design, work practices, or implementation plans could then be identified and negotiated well in advance of implementation.

Most evaluations of eHealth applications are *retrospective*, focusing on existing implementations that have been partially successful or unsuccessful [2]. As part of a broad program of research, we are developing methods and tools that support *prospective* evaluations of information and communication technology (ICT). One part of our research focuses on the introduction of electronic health records (EHR) to the intensive care unit (ICU). Much prior research in this area has taken work practices as a primary focus and information and communication technology (ICT) as a secondary consideration. In contrast, we take information flow as a primary focus, while noting that it reflects the work practices of users.

In this paper we present a simplified model of clinical information pathways in an ICU some months after the implementation of an EHR. We show information flow as a patient moves from the cardiac operating theatre (OT) to the ICU. Such modeling provides a basis for determining some of the changes in information flow that will occur with new ICT. However such modelling also reveals factors that challenge attempts to prospectively evaluate the impact of new information systems such as EHRs.

Methodology

Setting

The setting was the cardiac post-operative recovery area of a large Australian ICU.

Data collection

Traditionally, data flow diagrams depict information movement and state changes in an existing system [3]. Recent field studies of healthcare environments model system-wide workflow [4] and emphasize the fundamental interrelation between the technical and social features of a system [5]. We combined both approaches and collected data on information flow via occupational shadowing of ICU nurses, document analysis and semi-structured interviews with key ICT and nursing staff. We inventoried the contents of information artifacts, electronic and otherwise, and analysed how their contents were generated, preserved, and transmitted during a normal work shift.

Model preparation

Figure 1 shows a highly simplified version of some of our modelling. It shows the information sources, forms of transmission, and destinations in three areas of patient stay: a pre-operative area, the OT itself, and the cardiac post-operative part of the ICU. Computer screen icons represent various information systems that are working independently, in conjunction with biomedical devices, or with other information systems. Arrows with labels are information pathways indicating how and where information is passed between locations and/or devices, and what information becomes part of the paper-based record. Note that some objects persist across the three areas of Figure 1.

The model has three types of pathways, each associated with a work process. (1) A → D refers to analogue to digital conversion of physiological signals, (2) **(e)** refers to the exchange or transmission of electronic information, and (3) printout refers to printed artifacts such as lab results and progress notes.

Findings

The model plus fieldwork reveal a complex picture. First, separate pathways support the flow of medical, physiological, and administrative information, yet there are points at which they converge. Second, communication and coordination is required between physicians, nurses and staff to successfully execute patient care. Third, all the ICT requires some human interaction. Fourth, a large paper-based patient chart persists, despite the ICT present. Fifth, there is *variability in practice* across nurses and patients in how the EHR is used: work gets done in different ways, reflecting adaptive behavior in the face of change, uncertainty, or different knowledge levels.

Variability in practice also affects the flow of information. For example, the integration of bedside technologies with the EHR varied with operator knowledge and with the availability of basic resources such as adaptors and cables. Moreover, printouts were sometimes filed in the patient chart but sometimes just discarded. Finally, constraints imposed by the EHR on

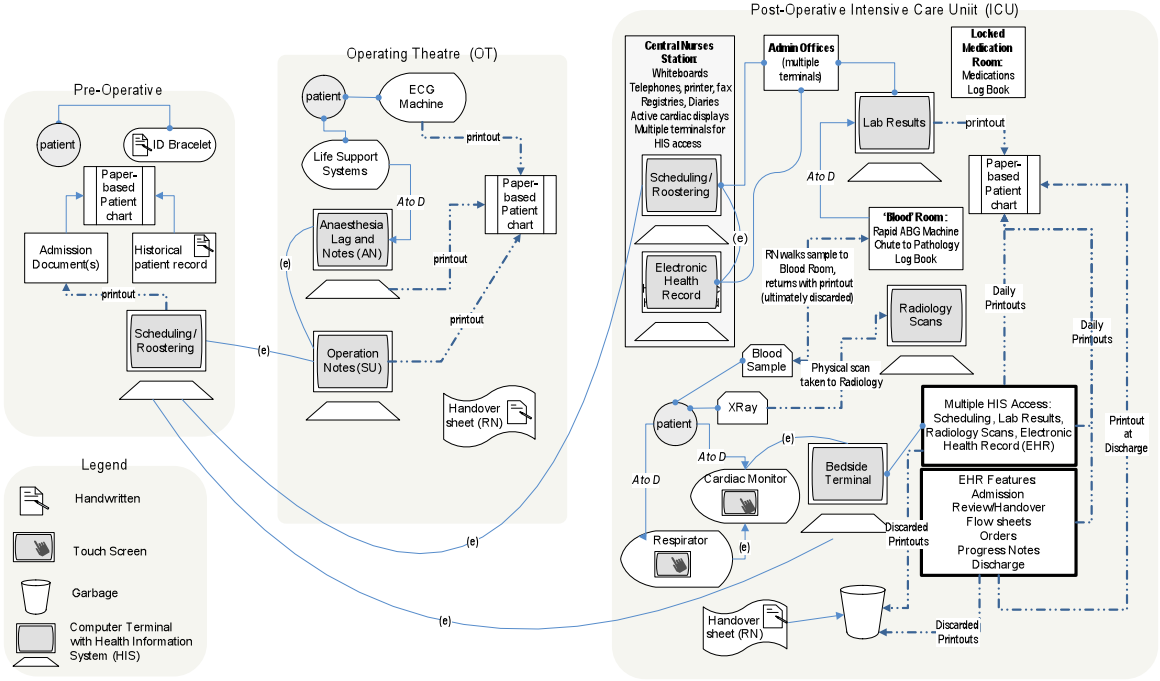

Figure 1. Highly simplified and partial model of ICU information pathways, showing various existing health and clinical information systems alongside the paper-based patient chart (square with vertical lines) and an EHR (lower right). Note persistence of some physical objects such as patient chart and patient (circle) which move across units.

work practices led to a variety of workarounds that became the means of keeping the record accurate (e.g. back-dating orders, writing in progress notes, and relying upon verbal handover).

Variability in practice presents a modelling challenge to prospective evaluation. Because different practitioners in different situations arrange their information environment in different ways, new technologies may enhance such arrangements, disrupt them, or leave them unaffected. Therefore, analysts attempting to evaluate ICT prospectively must infer forms of change from several versions of current practice. They must also determine if new technology will pose challenges that motivate new forms of variability in practice.

Implications and Future Work

Our approach of focusing primarily on information flow and secondarily on work practices gives us a solid basis for determining the impact of new ICT. Models such as Figure 1 let us view the exact technical changes that will occur, and also to see where further opportunities for interoperability may lie. An understanding of work practices and how they vary then lets us analyze the different ways that the impact of a technical change may be realised.

Our approach is useful for health informaticians, students of workplace practices, and healthcare professionals, all of whom in our experience appear to recognise its usefulness. Feedback about the model and process from stakeholders in the ICU has been very positive. In addition, information specialists managing ICT procurement within our healthcare system recognise that the model and process will add value to forthcoming eHealth initiatives, and they have expressed strong interest in using the approach.

In future work we will extend and formalise the prospective evaluation process, supplementing other work in progress with the highly specific visual tools that the present approach provides. We will then apply our approach to several local eHealth initiatives.

Acknowledgements

The authors acknowledge ARC DP0880920 and National ICT Australia. NICTA is funded through the Australian Government's Backing Australia's Ability initiative in part through the Australian Research Council. The authors also thank staff at Princess Alexandra Hospital (Brisbane, Queensland) for participation and feedback.

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