Designing Technology to Support Nurses' Information Flow

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ABSTRACT
Information flow within medical environments is ubiquitous and is essential for the coordination and collaboration among spatially and temporally distributed multidisciplinary clinicians for achieving work. Thus, nurses working in different shifts must work collaboratively to ensure all the necessary information is communicated so that patient care can be continued properly. The research outlined in this paper comprised of longitudinal field studies to investigate the work practices in use, observe how they are exercised during nurses' information flow, and how they are impacted by new technologies. The results of the studies were combined with past literature to inform the development of a conceptual framework for nurses' information flow. This framework is useful for evaluating the impact of new technologies on information flow and for generating new technology designs. This resulted in the development of a paper and digital integrated charting technology prototype which was then evaluated through a focus group of practicing nurses who indicated promising potential for bridging the nurses' use of paper personal notes and the organizational deployment of digital medical records. The insights gained from this investigation led to the development of a refined set of design guidelines for developing technologies to support nurses' information flow practices.

Keywords
Information flow, nurses, mobile technology, framework, prototype, evaluation, health care.

1. Introduction

Health care, as commonly practiced in hospitals, is a team effort distributed across time and location. One of the important factors for effective patient care is the sharing of information. Medical practitioners need to have access to the right information, at the right time, and ideally in the right location. The round-the-clock nature of hospital work entails the need for clinical handovers which involve the process of passing patient-specific information from one caregiver to another, from a team of caregivers to another team, from one healthcare organization to another, etc.

With increasing specialization in medicine, a patient may require synchronized care from multiple specialties and clinical professionals [7, 9]. Hence paper-based information documents often have to be physically moved between locations where and when they are needed. While paper documents afford valuable benefits in viewing, reviewing, customizing, annotating, carrying, and amending data [11, 13, 14], they often fall short in providing timely, location-independent and simultaneous multiple information access. Therefore, in reality, required information may not be available at the right place and/or at the right time since tedious, sometimes complex, administrative policies, procedures, and coordination often impedes the physical delivery of paper information documents [11]. Thus, medical care is shifting towards the use of technology. Medical records are now largely digital, although most hospitals still maintain a certain amount of paper documents. In general, digital solutions have been increasingly replacing paper documents to provide more consistent, integrated, distributed, and timely sharing of information, which in turn improves work performance [9, 14].

The research presented in this paper focused on the sharing of information during nurses' shift work and across their shift handovers. We chose to study nurses instead of general clinical shift work, as nurses are at the frontline of patient care, spending most of their working hours with patients. The information they obtain during their shift and shift change directly impacts the continuity of care and patient safety. The goal of the research was to investigate how technology may be designed to support nurses' information flow in a hospital setting.

2. Related work

Shift work relies heavily on effective information transfer to ensure patient safety. The information communicated during shift change provides incoming nurses with a "the picture of the ward" [3, 8]; it thereby influences the delivery of care for the entire shift and the overall quality of patient care. Clinical handover, a fundamental practice in medical settings, is used to transfer medical information across shifts and is an essential aspect of health care delivery [6, 15]. Although nurses change in temporally overlapping shifts, they may not occupy the same space in this overlap causing both spatial and temporal separation. This separation can complicate the shift-change process as the separation prevents them from discussing and clarifying the interpretation of information in transit [2, 3, 4].

A literature survey [5] showed that "ineffective handover can lead to wrong treatment, delays in medical diagnosis, life threatening adverse events, patient complaints, increased health care expenditure, increased hospital length of stay and a range of other effects that impact on the health system". Another literature review conducted to assess the effectiveness of improvement interventions in clinical handovers has also confirmed that "clinical handover is a high risk scenario for patient safety with dangers of discontinuity of care, adverse events and legal claims of malpractice" [22]. Communication failure and missing information during shift change have also been found to be contributing factors in many clinical mishaps [6, 15]. Therefore the Joint Commission regards handovers as high risk events to patient safety (2007) after recognizing that almost 70% of all sentinel events are caused by breakdowns in communication. Improving "the effectiveness and coordination of communication among care/service providers…across the continuum" has thus been identified as one of the patient safety goals by Accreditation Canada (2008).

In the remainder of this paper, we first outline the three field studies that we have conducted and highlight the respective findings. We also present the InfoFlow Framework that we developed from the findings of the first field study and a review of past literature. A paper and digital integrated charting prototype, the design of which was based on the findings of the field studies, will be briefly described. Finally, the results of a focus group study conducted to examine the effectiveness of this technology prototype on facilitating information flow will be outlined.

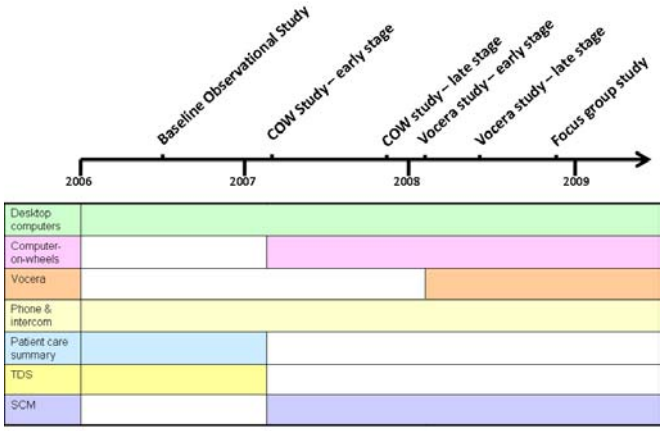

Figure 1: Research timeline indicating the computing technologies available at the time of the studies (Vocera – a mobile voice communication system, Patient care summary – an abbreviated electronic health record in paper, TDS – a legacy electronic health record, and SCM – a new electronic health information system)

We conclude the paper with a summary of the contributions of this research and some future work. Figure 1 shows the timeline of our research agenda.

3. Investigation of information flow

Our research consisted of several in-depth field studies in an acute medical teaching unit in an urban hospital to investigate what and how technologies can be designed to effectively support nurses' information flow. The ward is configured with a star design having a centrally located nursing station and four radiating ward wings of patient

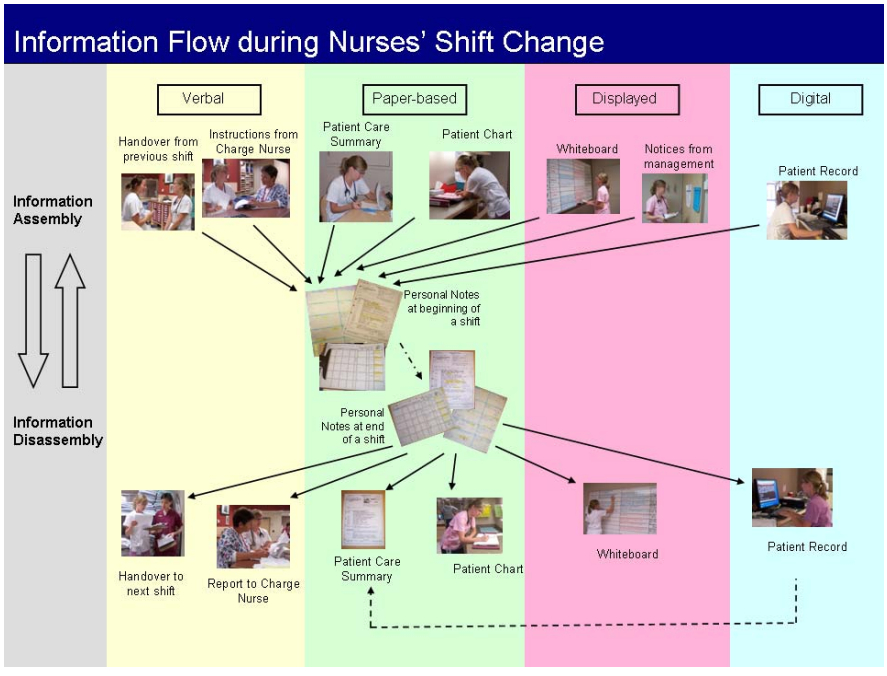

Figure 2: Incoming nurses acquired information from distributed multimedia information sources (top), placed the extracted information in their paper personal notes (centre), added new information to personal notes, and finally charted the new information at a computer (bottom).

rooms. Its layout makes it convenient to access information at the central information hub but makes it hard for nurses working in different wings to communicate and to maintain awareness. Our field studies employed an ethnographic approach using mixed methods of minimally-intrusive observations, interviews, examination of formal and informal information documents, and survey. Grounded theory was used for data analysis.

4. Exploratory Study on Information Flow (Study 1)

We conducted the first field study with an exploratory approach to investigate the basic dynamics of nurses' information flow. The study offered insights to the complex information flow process during nurses' shift change with respect to a range of spatial and temporal contexts. Information sharing took place as a pair of parallel processes: information assembly by incoming nurses and information disassembly by outgoing nurses, through four different media: paper, verbal, displayed, and digital media (Figure 2) [16]. In this study, digital information was only accessible through stationary desktop computers. We employed the theoretical framework of common information space to examine the flow of information between various information sources (e.g., paper-based patient chart and Electronic Health Record) and paper-based personal notes prepared by nurses, customized at the beginning of their shifts by extracting important information from various information sources. Their shift work depended on these personal notes as their intermediate notepad and frontline information source. The findings provided important benchmarks for comparison with subsequent field studies in which impacts of technology deployment were examined.

5. InfoFlow Framework

We developed a conceptual framework, the InfoFlow Framework, for nurses' information flow from the findings of Study 1 and a distilment of relevant literature [21]. It consists of six inter-related factors contributing to the information flow process: information, personnel, artifacts, spatiality, temporality, and communication mode (Figure 3). This framework can be used to provide a coherent description of information flow during shift change, has the potential to be useful as a tool to aid assessing current technology use, and to inform the design of new technologies for supporting information flow.

The *information* is typically patient-specific and thus uniquely defined for each patient's illness trajectory. This information is important for planning patient care for individual patients and for coordinating care plans for multiple patients. The *personnel* involved are particularly important when medical diagnosis and care information has not (yet) been fully documented, a common occurrence due to time pressure. Thus, clinicians are required to access different people in order to bring together the intellects and expertise that reside with individual clinicians. The *artifacts*

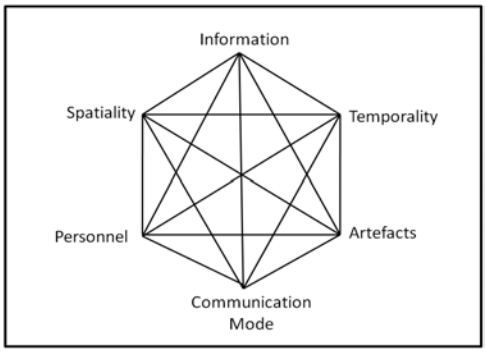

Figure 3: InfoFlow Framework consisting of interrelated factors

are the physical devices that are used to communicate information for delivering nursing care. We study the roles of these artifacts in the information flow and how they hinder or facilitate their intended usage. The *spatiality* considers where communication takes place and how the locations hinder or facilitate information flow such as the mobility needed. We also look into the equipment setup in specific information centers for supporting information flow in similar ways described by Harrison and Dourish (1996). The *temporality* of information flow is the order and timeliness for accessing specific information sources and how this impacts the outcome of information flow, as well as the temporal patterns that may help locate collaborators. Lastly, the *communication mode* is the style and media through which specific kinds of information are communicated. We also study if specific communication modes hinder or facilitate information flow. These six factors are useful in characterizing communication processes, but they are not exhaustive. Other factors like organizational mandate and social structure may also impact the communication process and should be considered. However, the six factors of our framework were particularly instrumental in our study.

6. New Mobile Information Technology (Study 2)

The second field study investigated the impacts of a mobile information device, computer-on-wheels (COW). This study was conducted at two months and at eleven months after the deployment of the new technology. The goal was to assess how the technology impacted nurses' information flow practices and dynamics, and in particular, whether the technology was able to be used as a ubiquitous information device to replace the use of personal paper artefacts for achieving work [18]. Our observations indicated problems in technical, engineering, organizational, and social aspects. For example, Figure 4 revealed the form-factor issue of the technology in impeding the mobility of patients and hospital staff. More importantly, we found that the informal paper notes are personally created and play special roles in the nurses' actual work practices. The nurses rely on their personal paper artifacts to:

Figure 4: A crowded hallway parked with COWs making it difficult for patients to go through or janitors to do their work

- hold the work plan for delivering patient care,
- provide a bedside information source,
- be an opportune notepad, for recording information, and
- be an information source for reporting and handover

Table 1 shows how these vital roles are realized with paper based artifacts (left-hand column) and with the COW (right hand column). Note the sharp difference between the flexibility and mobility provided by paper in contrast to how the COW has failed to live up to its intended use as a mobile and ubiquitous information artifact in nursing care. The mismatch between the mobile technology and the nurses' work practices thus led us to propose to design technology to bridge the paper and digital media to support the shift work.

Table 1. A comparison of paper personal notes and computer on wheels

Paper personal notes	Computer On wheels
Foldable and portable in pockets, so low cost	Wheeled cart for mobility, difficult in crowded space
Customizable as work plan, overview visualization	Information scattered in different screens
Manual construction help build mental map	Memory overload of information
Convenient, low-cost (efficient) bedside information source	High cost of information access
Flexible, low-cost (convenient) immediate notepad	High cost of information entry
Centralized, overview information basis for reporting and handover	Information scattered in EHR or memory overload

7. New Mobile Voice Communication Device (Study 3)

The final field study investigated the impacts of a mobile voice communication system, Vocera (Figure 5). This study was conducted in the first week and in the fifth month after the deployment. The goal was to evaluate the role of the

Figure 5 (left) A Vocera badge - http://www.vocera.com (right) Pressing the Vocera button to place a call

technology in nurses' communication [19]. The InfoFlow Framework was used to guide the data collection and analysis. We identified many communication strategies, which resonate with some aspects of the framework. We found the six framework factors all associated with a primary strategy used for coordinating the communication on the ward as follows:

- Choosing appropriate *artifacts* for information flow;
- Choosing an appropriate *communication mode*;
- Identifying and locating *personnel* to communicate;
- Off-loading *information* to the intended recipient;
- Minimizing *spatial* movements;
- *Prioritizing* and *scheduling* activities.

We also found that the technology was adopted with varied responses, from loving it to hating it. The negative responses were mainly due to their disappointment with the connection experience whereas the positive adoption was attributed to the convenience of connecting with other coworkers without having to spatially move to locate them. The findings helped inform the (re)design of similar technology to better support information flow in the dynamic and time-critical hospital settings, and served as a guide for Vocera deployment in other hospital wards. Specifically, this study revealed the importance of supporting easy connection of the mobile device because frequent communication among clinicians is often required for work accomplishment. Designing for heterogeneous adopters of the system should also be considered to meet their varying needs and job nature while providing contextual information would reduce unnecessary or inappropriate interruptions to peer colleagues and patients.

8. Paper and Digital Integrated Charting Prototype

With valuable insights gained from the field studies and the InfoFlow Framework, we designed and developed a technology prototype that integrated paper and digital charting for supporting nurses' information flow. The technology design is schematized in Figure 6. The prototype makes use of Anoto™ digital pen and paper technology (Figure 6, left) and is designed to support informal use of paper personal artefacts as an integral part

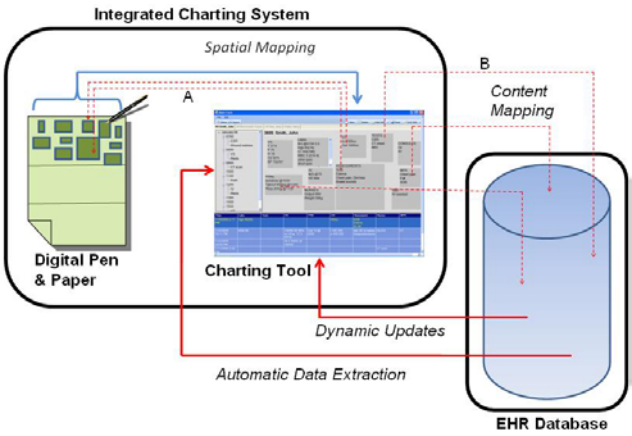

Figure 6: Design scheme of the paper and digital integrated charting prototype.

of the official digital documentation process. A digital pen contains a digital camera that captures all the markings, including locations, made on digital paper. This information can be downloaded to a computer immediately via Bluetooth technology, or at any point in time using the pen docking station (Figure 7, right). Our design allows nurses to retain their familiar and efficient practice of personalized information recording (e.g., spatial organization) on paper artefacts for facilitating information retrieval and dissemination (Figure 7) while integrating their paper inscriptions and direct input into the digital hospital information system [17, 20]. The digital Charting Tool (Figure 6, middle), which mirrors the spatial layout of paper personal notes, interfaces the informal paper artefacts with the digital medical records. It provides easy transfer of information from digital paper notes to the electronic health records to provide timely, low-cost, and continuous information flow. Additionally, it offers a quick reference to archived medical information without having to navigate the hierarchical medical records and a timeline for nurses to visually plan their nursing work.

We conducted a focus group study with practising nurses around our prototype as a preliminary step to evaluate its effectiveness in facilitating nurses' information flow. We received valuable feedback on the benefits they perceived

Fig. 7: (left) Personal notes template printed in digital paper with customized layout of bounding boxes and static information, (right) A digital pen docking station.

and well-articulated suggestions for improving the system. In particular they perceived great benefits in retaining the use of the familiar pen and paper, as described by a participant, *"because our entire day works on that piece of paper, everything we do, when we need reports, we wouldn't go to the computer. It's all on that [the personal notes]."* They were also excited about the automatic conversion of their handwriting to digital text although *"there're glitches that are not working as well as we'd like. But we're moving towards the right direction"*. Together, they helped refine the set of design guidelines, summarized as follows, that other researchers and designers may find useful in their specific settings.

- Support flexibility and personalization
- Facilitate information entry and retrieval
- Provide an overview
- Support 'personal' information use
- Safeguard the accuracy of information
- Support system dispersal

9. Conclusion and Future Work

Through a series of careful observational field studies, this research expanded the understanding of the work practices used during nurses' information flow. These findings were then integrated with relevant literature to create the information flow framework. This framework has been used to describe current work practices, to assess the potential benefits and problems of newly deployed technology, and to inform the design of new technologies. The approach to research, starting from an in-depth understanding and moving towards the design of technologies, is intended to provide a more seamless and less obtrusive fit of technology within the working environment. This research thus contributed:

- The identification of the basic information flow dynamics and practices during nurses' shift change
- The identification of the impacts of a new mobile information technology on information flow and the unique affordances of paper artefacts for use as work plan, bedside information source, opportune notepad, and information basis for reporting for supporting nurses' shift work.
- The development of a conceptual framework, the InfoFlow Framework, for providing a coherent description of nurses' information flow, using as a tool for assessing technology use, and informing the design of new technologies.
- The design and prototyping of a paper and digital integrated charting concept, designed to support informal use of paper personal artefacts as an integral part of the official documentation process.
- The study and analysis of focus group feedback from nurses to evaluate the effectiveness of this integrated

charting approach, which led to a detailed set of design guidelines for future technology development.

This research also revealed several directions that warrant further study. These directions include further prototyping and evaluation of technology designs for supporting various aspects of nurses' information flow, further exploration of information flow practices in other contexts and settings such as physicians' handover, and investigating whether the InfoFlow Framework is applicable to other settings including other hospital settings and other high-reliability domains.

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