# A Fit between Clinical Workflow and Health Care Information Systems

## Not Waiting for Godot but Making the Journey

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**A Fit between Clinical Workflow and Health Care Information Systems:**
Not waiting for Godot but making the journey

**Integratie van klinische workflow en informatiesystemen:**
Niet meer wachten op Godot

**Thesis**

to obtain the degree of Doctor from the
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**Zahra Niazkhani**

born in Naghadeh, Iran

ERASMUS UNIVERSITEIT ROTTERDAM

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# Chapter 1

## Introduction

# INTRODUCTION

Health care has long suffered from inefficiencies due to the fragmentation of patient care information and the lack of coordination between health professionals [1]. Health care information systems (HISs) have been lauded as tools to remedy such inefficiencies [2, 3]. The primary idea behind the support of their implementation in health care is that these systems support clinical workflow and thereby decrease medical errors [2]. However, their introduction to health care settings have been accompanied by a transformation of the way their primary users, care providers, carry out clinical tasks and establish or maintain work relationships [4]. Studies have shown that these transformations have not always been productive [5, 6].

Scholars in medical informatics have recently raised the awareness that HISs may introduce certain unintended adverse effects to clinical work [7]. A multi-center study has revealed that among these negative effects, workflow problems were the most frequent [8]. A detailed analysis showed that they included social (e.g., reducing situation awareness), technical (e.g., poor human/computer interaction interface), and organizational issues (e.g., poorly reflecting organizational procedures) [9]. These socio-technical issues cause disruptions in patient care activities, which not only have detrimental effects on patient safety but also make care providers unhappy, resulting in negative attitudes towards HISs. The disruptions and subsequent negative attitudes in turn affect the intention of providers to use, misuse, or bypass these systems in the daily workflow [10].

Wears and Berg noted that the underlying reason for such failures is not because HISs are not developed "right" but because "the right systems" are not developed to *fit* in the socio-technical system of clinical work [11]. Many argued that the model of clinical processes upon which these systems are based does not adequately match the pragmatic workflow of providers [12-14]. Clinical work is fundamentally multitasking, cognitive, distributive, collaborative, interpretative, interruptive, responsive, and reactive [11, 15]. To develop "the right systems", which are in synergy with the nature of clinical work, we need to get "the model of workflow" in these systems right. This is not feasible without an understanding of underlying contexts and processes in clinical workflow and of how a HIS interplays with them in *real* practice [16-18]. This specifically calls for more process-oriented, user-centered HIS studies to be used for the socio-technical design of these systems [4, 16]. Therefore, studying workflow to make a *fit* between HISs and clinical work becomes timely and highly relevant in the implementation of any health care information system [19-21].

This PhD project was inspired by a debate raised in the medical informatics community following a study by Koppel and colleagues published in JAMA in 2005 [10]. Koppel and colleagues studied a computerized physician order entry (CPOE) system in the medication process and explained how and why a system that was intended to improve the efficiency and safety of the medication process was in fact a source of inefficiency for its users and contributed to facilitating medication errors. Regardless of criticism about the methodology of the study and/or about the CPOE system under evaluation, the main point that both critics and supporters agreed upon was that to develop supportive CPOE systems, a comprehensive insight into workflow is required involving these systems in the context of implementation environment and end-users [22-24]. I therefore pursued my research interest to conduct a process-oriented, user-centered evaluation of clinical workflow in the medication process involving a CPOE system.

## 1. CPOE AND WORKFLOW IN THE MEDICATION PROCESS

In Chapter 1, I broadly define clinical workflow as the flow of care-related tasks as seen in the management of a patient trajectory: the allocation of multiple tasks of a provider or of co-working providers in the processes of care and the way they collaborate [25]. CPOE is defined as the process by which care providers (but not intermediaries) directly enter care-related orders into a computer application [8, 20]. Almost any clinical actions, such as evaluating necessary lab values, administering medications, or stopping them, need an order. CPOE systems therefore target the very heart of clinical workflow: the management of clinical orders. Among these, medication orders are the largest group. The process in which medications are managed, the medication process, is shared among different professional groups who manage it in collaboration. It is also extremely information- and time-intensive. In addition, this process transverses the divisional boundary of a ward and a department, involving other departments in a hospital. Furthermore, because of the interplay between different factors – including a patient's clinical condition, the variety of medication orders in different clinical wards and the constraints to supply them, and so on – the medication process is one of the most complex clinical processes in a hospital, with a constant trade-off between multiple goals and incentives [26]. Therefore I chose to study how a *fit* can be made between a computerized medication order entry system and the nature of the medication process. This can provide insights into the essence of the interaction between clinical workflow and HISs in general.

## 2. THE RESEARCH QUESTIONS

The aim of the study in this thesis is to understand the re-configuration of clinical workflow with CPOE in practice. I specifically aimed to comprehend what attributes of clinical workflow affect or are affected by the implementation of a CPOE system. The study addresses the following sub-questions:

1. Which aspects of clinical workflow are most impacted by CPOE implementation?
2. What are the benefits and/or drawbacks of a CPOE system compared to paper-based systems?
3. How does a CPOE system affect the inter-professional medication work?
4. Which elements of a clinical context play a prominent role in the deployment of a CPOE system and how do they affect workflow efficiency?
5. What are the difficulties or breakdowns in the medication use process and their possible root causes in the context of CPOE? How are these issues addressed?

## 3. METHODOLOGY

To answer the above-mentioned questions, I used mixed methods to conduct a case study of a computerized physician medication order entry system (Medicatie/EVS®, iSOFT, Leiden, the Netherlands) at Erasmus Medical Center (MC), a 1237-bed academic hospital in Rotterdam, The Netherlands. The central role of people, organizational, and social issues has been highlighted in understanding the impact of medical informatics applications [27]. Kaplan and Shaw have pointed out the potential of the "multi-method approach" to allow for "complex contextual issues" to be addressed [27]. They have recommended that the evaluations should be conducted "throughout the life of a project, with studies conducted in actual clinical settings".

This PhD study includes multiple methods of data collection and multiple forms of analysis. The focus of the analysis is on the medication process and how the system and the users relate to this process. Empirical data encompassed both quantitative and qualitative data. The quantitative data was collected by two ques-

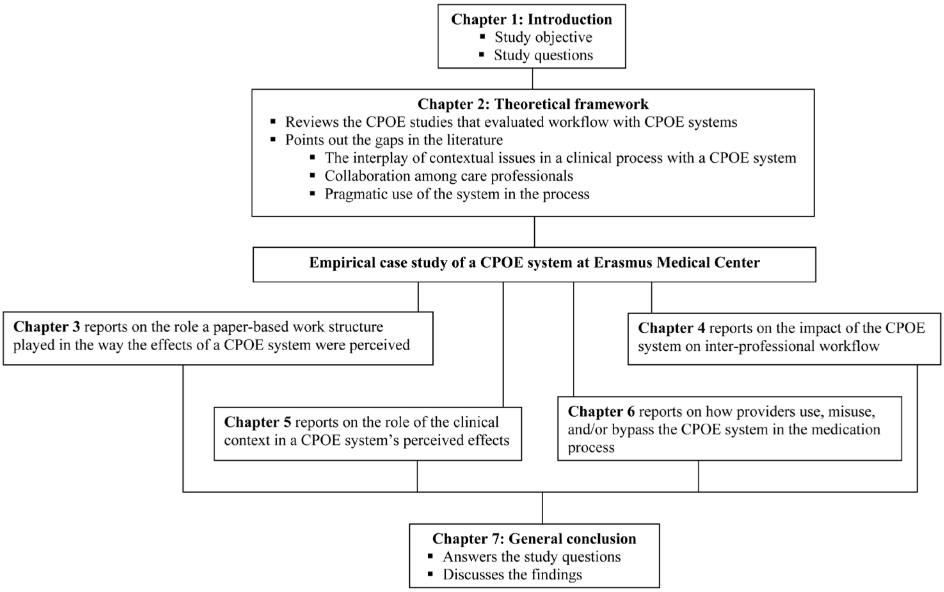


Figure 1.1 Thesis structure

tionnaire surveys conducted pre- and post-implementation of the CPOE system. The qualitative approach used interviews and observation. This approach was also supplemented with an analysis of documents, including the handwritten records and system printouts used daily in the medication process and the educational materials for teaching the end-users. More detailed explanations of the methodologies are provided in each chapter.

## 4. THESIS OUTLINE

The thesis consists of two parts: the first provides a theoretical background for the study (Chapter 2) and the second reports on the empirical field studies of the CPOE system at Erasmus MC (Chapters 3 to 6). Figure 1.1 shows an overview of studies reported in each of the following chapters.

Chapter 2 is a literature review and provides a theoretical model for understanding and evaluating clinical workflow involving CPOE systems. To develop this model, I carried out an integrative review [28] of insights from the social sciences, cognitive sciences, workflow systems, the field of Computer Supported

Cooperative Work, and medical informatics with regard to the interplay between Information Technology and medical work. The review provides a framework for the most important aspects of clinical workflow that may interplay with a CPOE system and affect its outcome. This framework was used to analyze the findings of the CPOE literature that evaluated workflow with CPOE systems. The literature review identified gaps and indicated which studies are most likely to cover them. I then examined several of the gaps in the following chapters.

Chapter 3 presents outcomes of the transition from two different paper-based systems to the same computerized medication order entry system. In a quantitative study conducted before and after the CPOE implementation, I compared how nurses who were working in two different paper-based systems perceived the impact of the system on their medication-related activities. While the structure of the nursing medication work after the implementation was similar to one of the paper-based systems, it was completely different from another. The "Adaptive Structuration Theory" was used to interpret the outcomes.

Chapter 4 assesses the effects of the CPOE system on *inter-professional* workflow in the medication process. The study used qualitative research design to study division of tasks, flow of information, and task coordination among the three main professional groups involved in the medication process: physicians, nurses, and pharmacists.

Chapter 5 compares and reports the effects of the CPOE system in two different clinical contexts of nonsurgical and surgical specialties, when the system was assumed to be adopted and fully integrated to existing work practice. Although the structure of the post-implementation medication process was similar in both types of specialties, the attitudes of clinicians and their perceptions of the CPOE system's effects were different. The study showed how a medication process having the same structure supported the needs of different specialties in a dissimilar manner.

Chapter 6 evaluates and reports on how and with what consequences a CPOE system can be operational in real practice. The study focuses in particular on "workarounds" devised to bypass workflow difficulties.

The thesis ends with a general conclusion that answers the study questions and discusses the findings.

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# Chapter 2

## The Impact of Computerized Provider Order Entry (CPOE) Systems on Inpatient Clinical Workflow: A Literature Review

**Zahra Niazkhani, Habibollah Pirnejad, Marc Berg, Jos Aarts**

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## ABSTRACT

Previous studies have shown the importance of workflow issues in the implementation of CPOE systems and patient safety practices. To understand the impact of CPOE on clinical workflow, we developed a conceptual framework and conducted a literature search for CPOE evaluations between 1990 and June 2007. Fifty-one publications were identified that disclosed mixed effects of CPOE systems. Among the frequently reported workflow advantages were the legible orders, remote accessibility of the systems, and the shorter order turnaround times. Among the frequently reported disadvantages were the time-consuming and problematic user-system interactions, and the enforcement of a pre-defined relationship between clinical tasks and between providers. Regarding the diversity of findings in the literature, we conclude that more multi-method research is needed to explore CPOE's multidimensional and collective impact on especially collaborative workflow.


**Keywords:** computerized provider order entry system; CPOE; medical order entry systems; clinical workflow; review literatures

# 1. INTRODUCTION

Computerized provider order entry (CPOE) systems have been recognized as highly valuable tools to increase the efficiency and effectiveness of medical work [1]. However, their potential to change workflow and its consequence for patient safety has brought the concept of workflow to the forefront of CPOE implementation [2, 3]. As a result, the integration of CPOE systems into clinical workflow has been identified as one of the most important implementation considerations [4]. Nevertheless, studies have shown that this integration may not be easy [5].

It has been argued that interruptions in workflow after the implementation of health care information systems (HISs) have mainly arisen due to a narrow and simplistic workflow model that underlies these systems [6]. When this simplistic model is put into practice, it often fails to address the highly cognitive, collective, collaborative, and *ad hoc* nature of clinical workflow [7]. For example, the model of workflow in these systems tends to conceptualize order creation and communication in a pre-defined, linear, and stepwise fashion, whereby only physicians' computerized orders give the permission to carry them out [6]. Yet, medical work is far from being such a straightforward process. Rather, it is fundamentally a multitasking, cognitive, distributive, collaborative, interpretative, interruptive, responsive, and reactive procedure [8, 9]. These characteristics need to be understood and considered in CPOE design.

The aim of this chapter was to gain an insight into the impact of CPOE systems on clinical workflow. We addressed specifically the following questions: "What are the benefits and/or difficulties that CPOE systems bring to clinical workflow?" and "Which aspects of clinical workflow are most impacted by CPOE implementation?" An understanding of the pragmatic workflow involving CPOE can help to improve the model of workflow that underlies these systems.

# 2. BACKGROUND

As the concept of clinical workflow has different connotations, defining a conceptual model was deemed necessary. For this purpose, we first drew upon principles of the modeling of work processes in the workflow literature [10, 11]. This literature deals with the modeling of work processes to design information systems that not only do the work, but also manage the workflow: "the process is managed by a computer program that assigns the work, passes it on, and tracks its progress" [10]. These information systems contain organizational knowledge of where work flows in default cases. They are defined as systems that "help organizations to specify, execute, monitor, and coordinate the flow of work cases within a distributed office environment" [11].

Guided by this description of workflow, we next did an *integrative* review (page 32) [12] of the social and cognitive sciences, and the field of Computer Supported Cooperative Work (CSCW). The sociology of medical work has studied how division of labor and articulation work enable different professional groups to carry out tasks when managing care trajectories [13, 14]. The cognitive science deals with the analysis and modeling of complex human performance such as decision-making [15, 16]. The field of CSCW examines the computer-assisted collaborative activities such as communication carried out by a group of collaborating individuals. It has been noted that medical informatics can benefit from the insights gained in this field to design and deploy successful HISs [17]. By summarizing broad themes in these fields pertaining to the concept of clinical workflow, we developed a conceptual model. The resulting model enabled us to examine the interplay between the social context of health care work and CPOE systems.

Health care is a complex activity system of specialized and non-specialized workers, their tools, and their environment [9]. Health care work involves continuous interaction among different elements and trade-offs between multiple goals, preferences, values, incentives, and motivations in the course of care processes [18]. Physical (e.g., paper records) and psychological artifacts (e.g., individual experiences) mediate the work and foster collaboration [19, 20]. Despite being spatially distributed, the work of different actors in health care is highly interconnected because they are dependent upon each other in terms of skill, knowledge, expertise, and physical assistance [21].

### 2.1. A model for clinical workflow

In the workflow literature, a workflow process is defined as "a predefined set of work steps, and partial ordering of these steps" [11]. Workflow processes are carried out by participants that can "fulfill roles to execute, to be responsible for, or to be associated in some ways with activities and processes". Inspired by this literature, we define clinical workflow as the flow of care-related tasks as seen in the management of a patient trajectory: the allocation of multiple tasks of a provider or of co-working providers in the processes of care and the way they collaborate. The aspects of clinical workflow therefore can be categorized into four elements:

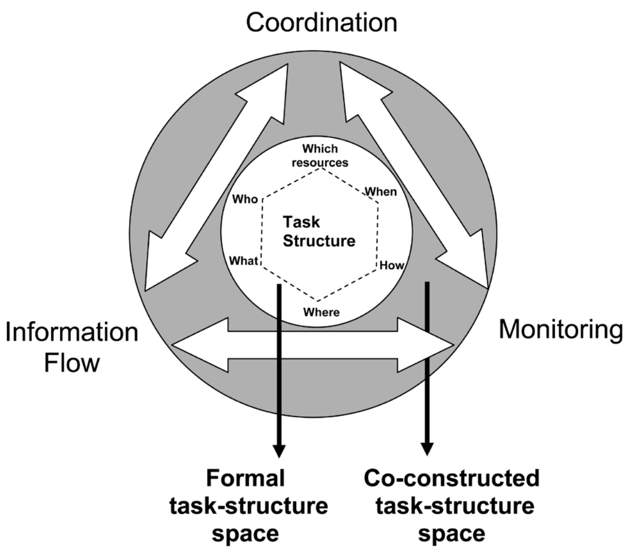


Figure 2.1. A conceptual model for clinical workflow, showing its different aspects and their relationship

1) structuring of clinical tasks, 2) coordinating of task performance, 3) enabling of the flow of information to support task performance, and 4) its monitoring [10, 11]. These aspects are often closely connected to and dependent upon each other, as any intervention in one aspect can affect the others. Figure 2.1 shows a visual model of these aspects and their relationship. We will touch upon them in the following sections.

### *2.1.1. Structuring of tasks*

To avoid possible conflicts among tasks and providers, a work structure is required on the basis of which actions as well as interactions can be constructed. This is mainly the subject of "division of labor", which deals with "*dividing up* work, workers, and the relationships both between and within these divisions" [13]. It is referred to as "formal task-structure space" in Figure 2.1. The formal version of task structure is mainly drawn on the integration of organizational knowledge and domain knowledge in health care. Organizational knowledge is based on local cultures, norms, values, and available capacities or accessible resources while medical domain knowledge gets inputs from evidence-based findings. The resulting work structure particularly specifies "who" does "what", "when", "where", and "how" by employing "which resources", and in "what relation" to other tasks and providers (i.e., sequentially, simultaneously, or in any other order).

Medical work is comprised of tasks of individual providers as well as the tasks which connect collaborating providers. Researchers who studied cognition in medical work have described the cognitive models of an individual clinician's task performance and defined the demand characteristics of particular tasks such as information management strategies [22]. But also they have started to characterize cognition as a process that is distributed across groups, cultures, and artifacts [23, 24]. This indicates that even seemingly discrete individual activities take place while dynamically interacting with other complex factors such as social and organizational [16, 25].

### *2.1.2. Coordination of work*

To perform tasks, co-workers are required not only to coordinate with each other but also to coordinate their temporal and spatial dimensions. To coordinate tasks, actors *passively* follow the scripted roles and relationships among the tasks coded in written rules, plans, or tacitly assumed traditions and norms [26]. For temporal coordination between tasks, three levels of activities have been defined: synchronization of interrelated tasks, scheduling, and temporal allocation [27]. Moreover, care is provided by different professionals in different specialties using different resources in the hospital. To gain access to them, providers and patients should move within and between these specialties [28]. Therefore, the spatial dimension of tasks also needs to be coordinated.

### *2.1.3. Information processing and flow*

Medical work is information-intensive. Hence, the collection, documentation, communication, and retrieval of patient information are among the critical activities of providers (page 251) [29]. The source of information may be patients, colleagues, or other informed individuals, but it may also be medical records. These disparate pieces of information should then be integrated, completed, verified, interpreted, or negotiated. This is necessary because of the contextual nature of information, which implies that data acquired from different sources are not self-explanatory [30]. As a next step, information should be communicated in order to enable the collaboration of multiple providers involved.

### *2.1.4. Monitoring*

To cooperate, actors must *actively* adjust the actions in hand with the actions of co-workings [26]. For this purpose, they need to *monitor* for changes in task requirements. Monitoring provides an overview of ongoing activities and enables providers to supervise and control the intended execution of tasks.

### 2.2. Co-constructed workflow

As discussed earlier, the task structure using organizational- and domain- knowledge serves the core in constructing workflow. Yet, medical work is inherently *ad hoc* and contingent. To avoid any halt or to recover from that, providers restructure their work constantly [14]. For instance, a continuing deterioration in a patient's condition or unavailability of certain resources may necessitate rearranging the patient's care plan by canceling the previous orders, by reordering task priorities, or by involving new providers and procedures.

Moreover, the familiar pattern of health care work is what Strauss termed "*negotiated order*" (page 267) [29]. In a patient trajectory, multiple representatives of different professional groups interact constantly. In order to trade off and reach a formal or informal agreement in any organizational action (such as decision-making), negotiation is necessary. In fact, in the light of information flow and the conditions of coordinative and cooperative work, clinicians often negotiate and re-construct their work. For this *co-constructed* workflow, actors first focus on co-construction of a shared object and then turn to *re-conceptualize* their workflow on the basis of this shared object [27].

## 3. METHODS

### 3.1. Search strategy and inclusion criteria

A literature review was conducted in the PubMed and Cochrane library for journal articles, conference proceedings, and summaries. We used MeSH terms and keywords to identify CPOE evaluations published in the English language between January 1990 and June 2007. To detect relevant articles in the social, computer and cognitive sciences that may have evaluated CPOE systems, we also searched two other databases: the IEEE Computer Society and the Sciences Citation Index. Figure 2.2 shows a complete list of our search terms and search strategy and flow.

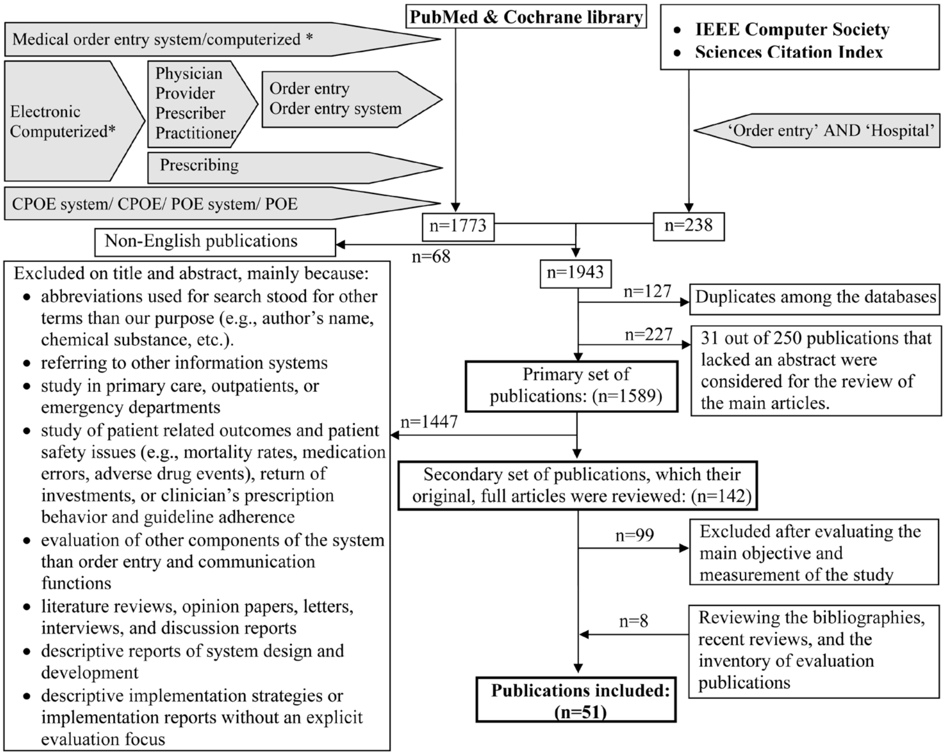


**Figure 2.2.** The search terms and search flow; *MeSH term

After duplicate literature, non-English publications, and those without abstracts[1] were removed, the search resulted in 1589 publications. Among them, we searched for studies that 1) evaluated the effects of CPOE on realistic or simulated workflow of *care providers*, 2) were carried out in inpatient settings, and 3) reported on either quantitative or qualitative studies. First, the title and the abstract of the primary set of publications were reviewed in order to find relevant articles. We had two inclusion criteria: 1) the system under evaluation must be a computerized system whereby a provider in an inpatient setting enters patient's therapeutic or diagnostic orders into a computer, and 2) at least one of the evaluation objectives must concern the workflow of providers in order entry and communication processes. Studies that reported users' perceptions of CPOE effects were also included in the review. To detect relevant literature, we used the general definition of the "flow of care-related tasks" of an individual provider or of co-working providers.

1. Among these publications, the titles were evaluated to decide whether or not to include them in the detailed review.

Because this review was focused on inpatient workflow, we excluded studies of ordering systems in outpatients and emergency departments. Studies that had evaluated issues other than clinical workflow, such as return of investments, number of medical errors, and so forth were also excluded. Opinion papers, reviews, letters, and system design and implementation reports that lacked an explicit evaluation focus were excluded as well, mainly because they elaborated upon system features or implementation strategies without really evaluating effects on workflow. Figure 2.2 lists our exclusion criteria.

One hundred and forty-two publications were identified for detailed review. To complete the search, we also examined the bibliographies of included articles, recent reviews of CPOE publications, and an inventory of evaluation publications [31]. We identified 8 publications that did not show up in the primary set of our search. To access unavailable publications or to inquire additional information, we contacted 20 authors (80% success rate). A consensus about the final set of selected publications was reached after discussions among this study's authors.

### 3.2. Analysis process

The first and second authors extracted the main findings of the selected publications and then categorized them based on the positive or negative/challenging effects. The preliminary categories were identified and iteratively revised until a consensus was reached after many discussions. These findings were analyzed at three levels. First, we analyzed them on the basis of our conceptual model. Then we conducted two sub-analysis based on: 1) workflow of individual providers versus co-working providers, and 2) workflow with home grown versus commercial systems.

## 4. RESULTS

### 4.1. Characteristics of selected publications

The review identified 51 publications: 31 journal articles [32-62], 16 proceedings papers [63-78], and four proceedings abstracts [79-82]. Table 2.1 lists them according to the chronological order of the publication year. It also provides additional information, including, study description, the type of systems and clinical settings, and main findings. These 51 publications reported on 45 evaluation studies,

Table 2.1. CPOE-evaluation studies on the concept of workflow and their main findings;

| Authors (Publication type) | Research methods[1] | Study description[2] | Clinical setting and name of the hospital | Name of the system | Type of the system |
|---|---|---|---|---|---|
| Tierney et al. (JA) [32] | Time-motion with a control group | Evaluating time consumption in a CPOE group *vs.* a paper-based control group | Internal medicine, Indianna university school | RMRS | Home-grown |
| Massaro (JA) [33, 34] | Observation; interviews | Evaluating cultural and behavioral transformations after CPOE | A 700-bed hospital, University of Virginia medical center | TDS†[4] | Commercial |
| Gardner & Lundsgaarde (JA) [35] | Questionnaire survey | Evaluating the attitudes of providers about the impact of a clinical system on practice | The LDS Hospital, Salt Lake City | HELP(the Health Evaluation through Logical Processing) | Home-grown |
| Tierney et al. (JA) [36] | Questionnaire survey; time-motion | Evaluating medical students' and house staff's opinions of computerized order-writing | Medicine service, Wishard Memorial Hospital | RMRS | Home-grown |
| Bates et al. (PA) [79] | Before-after: time- motion | Evaluating the effect of CPOE on house staff time-use patterns | Medical and surgical units, Brigham and Women's hospital | BICS | Home-grown |
| Yamauchi et al. (JA) [37] | Questionnaire survey | Evaluating the order entry system by its end-users | 922-bed, Nagoya University Hospital | CHART (Comprehensive Hospital Administration for the Twenty-First Century) | Home-grown |
| Lee et al. (JA) [38] | Questionnaire survey | Evaluating user satisfaction, correlates of satisfaction and self-reported usage patterns | Medical, surgical, and orthopedic services, Brigham and Women's Hospital | BICS | Home-grown |
| Weir et al. (PP) [63] | Questionnaire survey | Evaluating the impact of physician *vs.* non-physician order entry on nurses perceptions of work and communication | Eight Veteran's Affairs Hospitals | OE/RR 2.5 (Order Entry/Results Reporting 2.5) | Home-grown |

1. Only the methods used to study clinical workflow
2. Only the sections that evaluated clinical workflow
3. ↑ (increase); ↓ (decrease); → (no difference)
4. †This information was provided by the authors upon request or completed using additional references referred to in the publications.

| Main finding(s) | |
|---|---|
| **Beneficial features/effects** | **Challenging/problematic/unexpected features/effects** |
| | - 33-minute ↑[3] in time spent on writing orders in the CPOE group compared with the control group during a 10-hour observation period |
| - nurses and pharmacists: relief from illegible and incomplete handwritten orders | - no direct communication between physicians and other caregivers<br>- taking unit secretaries and other nursing personnel out of the ordering loop<br>- requiring more physician-time; perception of many clerical functions transferred from nurses to physicians<br>- mandatory requirement of removing unsigned verbal orders before entering new orders<br>- additional computer charting requirements for nurses |
| - physicians and nurses: alerts for labs and drugs, medication monitoring, TPN ordering, blood orders, transcribed X-ray history, printed computerized patient record, laboratory results and blood-gas data review<br>- nurses: computerized nurse charting *vs.* handwritten chart; computerized treatment plan; computerized nursing acuity | |
| - medical students and residents: the work was more accurate and interesting.<br>- medical students: the work was faster and easier | - residents: the work was not faster and easier<br>- residents: perception of spending more time on writing orders; however, → in the estimates of minutes spent compared to the actual time spent |
| - 27-miniute per day ↓ in the activities that took less time after CPOE implementation | - 44-miniute and 73-miniute ↑ in time spent per day on order entry by medical interns and surgical residents, respectively |
| - better accessibility of laboratory results<br>- better clarity and accuracy of data and data storage | - perception of wasted times with the system; perception of less time for doctors to spend with patients<br>- troublesome manipulation of keyboards<br>- 61% of physicians complained about slow response time |
| - physicians: departmental and preadmission order sets, remote access, and decision support features<br>- nurses: clear and unambiguous orders | - physicians: low speed and too many steps between log on and order entry<br>- nurses: entering key many times and too many steps to order and take off medications |
| | - ↓ perceived control on work by nurses in the POE *vs.* the non-POE environment<br>- → in frequency of contact and ease of access to physicians |

| Authors (Publication type) | Research methods[1] | Study description[2] | Clinical setting and name of the hospital | Name of the system | Type of the system |
|---|---|---|---|---|---|
| Østbye et al. (JA) [39] | Before-after, time-motion; questionnaire survey; interviews | Evaluating the effects of a laboratory order entry system on users' work | Two surgical wards, Central Hospital of Akershus | DocuLive EPR (Siemens) | Commercial† |
| Evans et al. (JA) [40] | Before-after, time-motion; | Evaluating the time use in computerized *vs.* handwritten prescribing environment | An ICU, The John Radcliffe Hospital, Oxford | Hewlett Packard CareVue® patient information system | Commercial |
| Weiner et al. (JA) [41] | Questionnaire survey | Evaluating how users view the effects of a CPOE system | 8 general internal medicine units, The Johns Hopkins Medical Institutions | Ordernet (SMS-Invision system) | Commercial |
| Ash et al. (PP) [64] | Observation; focus groups; interviews | Evaluating the perceptions of physicians about their experience using CPOE | The University of Virginia Medical Center and the Seattle Division of the VA Puget Sound Health Care System | TDS (now Eclipsys Corp.) and CPRS | A commercial and a home-grown |
| Davidson & Chismar (JA & PP) [42, 65] | Interviews | Evaluating organizational changes after implementing CPOE | Various ancillary and clinical departments and specialties | Eclypsis † | Commercial |
| Payne (PP) [66] | Observation; interviews; analysis of support requests | Evaluating the transition to a CPOE system | General and critical care units, VA Puget Sound Health Care System | CPRS | Home-grown |
| Goorman & Berg (JA) [43] | Observation; interviews | Evaluating the compatibility of the model of ordering process in a CPOE system with that of nurses' daily work | A neurological ward, Atrium Medical Center† | TDS/Eclipsys 7000† | Commercial |

| Main finding(s) | |
|---|---|
| **Beneficial features/effects** | **Challenging/problematic/unexpected features/effects** |
| - 5.5-miniute ↓ in time spent on completing and transmitting tests per patient<br>- 3-hour ↓ in time from ordering of tests until the availability of results<br>- ↓ in the number of calls form the laboratories to the wards | - → in the number of calls form the wards to the laboratories<br>- the strongest complaint: the system's long response time |
| | - physicians: 35 seconds ↑ in time to complete a single drug prescribing using the computerized system *vs.* handwriting<br>- nurses: 19 seconds ↑ in time to record drug administration in the computerized system *vs.* handwriting |
| - perceived ↓ in order turnaround time<br>- nurses: legibility; job being easier after CPOE<br>- physicians: remote access | - perceived ↓ in the time spent with patients<br>- problems with downtime and system's response time |
| - order sets; safety alerts; remote access; graphical data display; access to knowledge sources; legibility; access to laboratory data<br>- perceived shorter drug turnaround time<br>- ability to view a patient's record by multiple people | - additional time required to use the system<br>- system inflexibility; poor usability (e.g., difficulty to see a patient's name easily, multiple screens required to enter information, inadequate word processing functionality and space for notes)<br>- delays in servicing computers and printers<br>- switching between different information systems with different interfaces at one hospital |
| - faster retrieval of information<br>- perception of shorter lab and medication order turnaround times; no need for phone calls<br>- order sets; remote access to patient data; decrease in physician initiated calls to nurses<br>- clear order format for nurses<br>- improved pharmacist-physician communication; expanding pharmacists' consulting role | - slower order entering process; difficulty to create nonstandard orders<br>- increased administrative workload in ancillary departments<br>- some redundancy in the pharmacist-physician communication due to uncertainty about physicians' intended orders and also system's allergy alerts<br>- assuming the responsibility for pharmacists to enter complex orders<br>- frustrated calls to clarify order status by both nurses and the laboratory staff<br>- uncertainty about having responsibility of consolidating similar lab orders into one battery of tests between nurses and lab technicians |
| - remote access; safety alerts; legible orders and notes | - redefined roles of physicians, nurses, and clerks; problems with nursing awareness of new orders; problematic clarity of medication orders after pharmacy edits<br>- additional time required to enter orders; difficulty with handling orders during patient transfer or discharge; clutter of order and note screens; problematic accessibility of workstations during rounds; unscheduled downtime; locking of ordering during pharmacy order processing |
| | - an alternative path for order entry in emergencies by nurses contained more screens and took more time than the normal path used by physicians<br>- no possibility to switch between the paths with numerous screens in order to retrieve and enter information<br>- prefixed entries on the screens with no possibility to enter free texts |

CHAPTER 2

| Authors (Publication type) | Research methods[1] | Study description[2] | Clinical setting and name of the hospital | Name of the system | Type of the system |
|---|---|---|---|---|---|
| Wilson et al. (JA) [44] | Questionnaire survey | Evaluating user satisfaction with a CPOE system | A community hospital and an outpatient clinic | CHCS (Composite Health Care System) | Commercial |
| Carpenter & Gorman (PP) [67] | Observation; focus groups; interviews | Evaluating why medication order entry differs from other components of POE | A medical center at the University of Virginia; two campuses of Veterans Administration Puget Sound; a community hospital of El Camino | TDS (now Eclypsis); CPRS; Lockheel/ Tehcnicon/Eclypsis | One commercial and two home-growns |
| Lehman et al. (PP) [68] | Before-after: time-motion | Evaluating pre- and post-CPOE drug turnaround times | Neurosurgery and transplant services, Rush-Presbyterian-ST. Luke's Medical Center | SMS-Invision system | Commercial |
| Murff & Kannry (JA) [45] | Questionnaire survey | Evaluating physician satisfaction with the user interface of two CPOE systems | Internal medicine, Bronx Veterans Affairs Hospital and the Mount Sinai Hospital | CPRS and TDS (now Eclypsis)† | A home-grown and a commercial |
| Shu et al. (PP) [69]; and Bates et al. (PA) [80] | Before-after: time-motion | Evaluating the impact of a CPOE system on physician time use | Internal medicine and surgical services†, Massachusetts General Hospital | BICS† | Home-grown |
| Dykstra (PP) [70] | Observation; focus groups; interviews | Evaluating the impact of CPOE on communication channels | A medical center at the University of Virginia; two campuses of Veterans Administration Puget Sound; a community hospital of El Camino | Technicon/Eclypsis; CPRS; Lockheel/ Tehcnicon/Eclypsis | One commercial and two home-grown |
| Mekhjian et al. (JA) [46] | Time-motion, before-after for medication and radiology orders; comparison of manual- with computerized POE for lab orders | Evaluating the impact of a CPOE system on order turnaround times | Surgical organ transplant unit, and surgical and medical ICUs, The Ohio State University Medical Center | Invision 24 with graphical user interface | Commercial |

5 *Not documented (and the authors or the information could not be accessed).

| Main finding(s) | |
|---|---|
| **Beneficial features/effects** | **Challenging/problematic/unexpected features/effects** |
| - positive correlates of satisfaction: ratings of the system's impact on productivity, ease of use, reliability, and provision of information to help providers write better orders. | - negative correlates of satisfaction: the perceptions of slower computerized ordering process and slow system's response time |
| - expanding pharmacists' roles in ordering practice | - complex and lengthy process of medication ordering for admissions, discharges, or patient transfers<br>- requiring navigating numerous screens; deciding on input variables beyond physicians' areas of expertise; difficulty with processing of unusual orders; usability of the patient medication profile design; difficulty to retrieve outpatient or previous admission's medication lists<br>- problematic changes in roles and responsibilities of providers: taking nurses out of the ordering processes; uncertainty of nurses in verifying pharmacist's order edits; necessity to make nurses aware of new medication orders; responsibilities regarding automatic "stop" and "expiring" orders; and problems with verbal orders in operating suits and ICUs |
| - 2 hours and 26 minutes ↓ in the medication turnaround time | |
| - correlates of satisfaction: the ability to perform tasks in straightforward manner | - performing routine tasks was perceived to be difficult, cumbersome, and time-consuming with the commercial system. |
| - → in time spent on patient-related activities<br>- ↑ in time spent on talking with patients<br>- ↓ in time looking for charts and walking and educational activities | - ↑ in the time spent on writing orders and using the computers (1.9% was recovered mainly in activities such as completing forms, transit, and looking for patient information)<br>- ↑ in the time physicians spent alone<br>- ↓ in the time spent on talking with others, reading and educational activities |
| | - substitution of the interaction with computers for communication with individuals; over-reliance on the system to communicate the orders, plans, and ideas; undermining team cohesiveness by requiring physicians to enter orders in computer rooms; reducing physician-nurse interaction; delay in notification of new orders to nurses; and necessity to do extra efforts to compensate the decreased coordination |
| - 64% ↓ in medication turnaround time<br>- 43% ↓ in radiology order turnaround time<br>- 25% ↓ in laboratory order turnaround time<br>- ↑ in order countersignature by physicians | |

| Authors (Publication type) | Research methods[1] | Study description[2] | Clinical setting and name of the hospital | Name of the system | Type of the system |
|---|---|---|---|---|---|
| Taylor et al. (JA) [47] | Before-after: time-motion | To evaluate the impact of a CPOE system on the medication-ordering process | A 23-bed family-medicine unit, Montefiore Medical Center | LastWord (now called GE Centricity)† | Commercial † |
| Cheng et al. (PP) [71] | Observational case study | Evaluating the effects of CPOE on established workflow | A 15-bed medical/surgical ICU | *[5] | * |
| Horsky et al. (JA & PP) [48, 72] | Simulation: cognitive task analysis; usability assessment | Evaluating the cognitive demands of the ordering task by a CPOE system | Internal medicine, a large teaching hospital in New York | Eclipsys Sunrise† | Commercial |
| Cordero et al. (JA) [49] | Time-motion; retrospective, before-after | Evaluating the impact of a CPOE system on order turn-around time | Neonatal intensive care unit (NICU), The Ohio State University Medical Center | Invision 24 with graphical user interface | Commercial |
| Thompson et al. (JA) [50] | Retrospective, before-after | Evaluating the impact of a CPOE system on order turn-around time | A 11-bed medical/surgical ICU, St. Paul's Hospital | Eclipsys Sunrise | Commercial † |
| Beuscart-Zéphir et al. (PP & JA) [51, 73] | Activity analysis using observation, interviews, and document analysis; usability assessment | Comparing the medication ordering and administration process in paper-based *vs.* CPOE environment | Nephrology and Neurosurgery (The University Hospital of Lille); respiratory, surgery and convalescence (the Denain public Hospital); nephrology, and immunology departments (the Georges Pompidou University Hospital) | MEDASYS DxCare® | Commercial |
| Ali et al. (JA) [52] | Retrospective, before-after | Evaluating the impact of CPOE system on patient care before and after modifications in the system | 25-bed medical ICU, The Ohio State University Health System | INVISION 24 with graphical user interface | Commercial |

| Main finding(s) | |
|---|---|
| **Beneficial features/effects** | **Challenging/problematic/unexpected features/effects** |
| - 92% ↓ in the time from writing a medication order to the arrival of the medication<br>- 120 minute ↓ in the time clerks spent per day<br>- 20 minute ↓ in the time nurses spent per day<br>- 40% ↓ in the time pharmacists spent per day | |
| | - time-consuming and structured order entry; an unfamiliar cognitive model of classifying orders in the system; inconveniency of logging into the system and the consequences of using each other's open accounts<br>- only physicians were authorized to enter medication orders<br>- nurses' responsibility: to ensure that a verbal order has been entered and to associate the pharmacist-edited orders with the physician-entered orders<br>- lack of visual clues (e.g., observing a physician during bedside order entry) to verify the existence of new orders; inconveniency to monitor new orders in the system while working with the bedside systems<br>- delayed implementing orders because of delayed notification of orders |
| | - the system's suboptimal interface affordances made considerable demands on users' internal resources, in particular on the availability of a solid conceptual model of the system |
| - ↓ in medication turnaround time (2.8 *vs.* 10.5 hours)<br>- ↓ in radiology order turnaround time (32 *vs.* 42 min.) | |
| - ↓ in the time laboratory tests were ordered until obtaining specimens (21.5 *vs.* 77 min.) and reporting results (74 *vs.* 148 min.)<br>- ↓ in the time radiology orders were ordered until their completion (29.5 *vs.* 96.5 min.) | |
| | - users tended to adopt a distributed decision-making paradigm in the paper-based situation while the CPOE system supported a centralized decision-making processes<br>- physicians delegated the exact planning of drug administration to nurses<br>- the list of pre-set schedules was not easy to use and confusing |
| - ↓ in the volume of orders related to vasoactive drips, the sedative infusions, and ventilation management | |

CHAPTER 2

| Authors (Publication type) | Research methods[1] | Study description[2] | Clinical setting and name of the hospital | Name of the system | Type of the system |
|---|---|---|---|---|---|
| Horsky et al. (PP) [74] | Simulation: cognitive task analysis; usability assessment | Evaluating data input strategies by clinicians into a CPOE system | Internal medicine, a large teaching hospital in New York † | Eclipsys Sunrise order entry † | Commercial |
| Pelayo et al. (PP) [75] | Activity analysis using observation and interviews; and usability assessment | Comparing physician activity of decision-making in the medication ordering process in a paper-based *vs.* a CPOE system | Nephrology and Neurosurgery (The University Hospital of Lille); respiratory, surgery and convalescence (the Denain public Hospital); nephrology, and immunology departments (the Georges Pompidou University Hospital) | MEDASYS DxCare® | Commercial |
| Campbell et al. (JA) [53] | Observation; interviews | Evaluating unintended consequences of CPOE implementation on medical workflow | Wishard Memorial; Massachusetts General Hospital; Faulkner Hospital; Brigham & Women's Hospital; Alamance regional Medical Center | RMRS; clinical application suite; BICS; Meditech; Eclipsys | Three home-growns and two commercials |
| Jensen (PP) [76] | Retrospective, before-after time-motion | Evaluating the effects of a CPOE system on order turn-around time | 21-bed acute rehabilitation unit, the Providence Portland Medical Center | Horizon order entry † | Commercial† |
| Johnson et al. (PP) [77] | Think-aloud observations (partly on fictional cases); questionnaire survey | Evaluating the cognitive tasks physicians undertake to write admission orders | Internal medicine, Stanford University Medical Center and Palo Alto Veterans Affairs hospital | * | * |

| Main finding(s) | |
|---|---|
| **Beneficial features/effects** | **Challenging/problematic/unexpected features/effects** |
| | - decision support features did not provide information at the time that decisions were made<br>- successful interaction was contingent upon thorough conceptual and procedural knowledge of the system<br>- the screen gave insufficient clues and guidance for selecting the best possible strategy for completing orders |
| | - loss of summarized global view on patient current medications with the computerized system; necessity to navigate several windows to gain all relevant information; necessity to scroll down a list to get the most recent medications; no possibility to see from the screen display how many days a patient was using a medication |
| | - fewer team-wide discussions regarding planning and coordination of care<br>- lack of guarantee for fast and accurate notification of orders to the recipient party<br>- problems related to the verbal orders<br>- extra steps necessary to get "patient overview"; entering new information not previously required; responding to excessive alerts; spending extra time on non-routine complex orders<br>- using different systems poorly integrated with each other; necessity for paper records or printouts to substitute the lack of electronic integration; using computer printouts as flexible, easily transportable, and quick references<br>- rigid, role-based authorizations in executing clinical tasks leading to role standardizations then unexpected task redistributions<br>- problematic electronic data presentations, confusing order option presentations and selection methods; inappropriate text entries |
| - 23% ↓ in medication turnaround time<br>- ↓ in the time of order composition to the time of pharmacy verification | |
| | - in practice, order planning for complex patients was primarily problem-based while the system was based on the mnemonic-based framework |

CHAPTER 2

| Authors (Publication type) | Research methods[1] | Study description[2] | Clinical setting and name of the hospital | Name of the system | Type of the system |
|---|---|---|---|---|---|
| Kaplan et al. (JA) [54] | Retrospective, before-after | Evaluating verbal orders | Hospital wide except the hematology-oncology unit, children's hospital | INVISION Health Care Information System † | Commercial † |
| Kushniruk et al. (JA) [62] & Kuwata et al. (PA) [81] | Simulation: activity analysis using video-recording of activities; screen recordings; interviews | Evaluating the impact of a medication order entry system on cognitive and spatial dimensions of workflow | * | * | * |
| Popernack (JA) [55] | Questionnaire survey; interviews | Evaluating nurses' perceptions of the impact of a CPOE system on daily nursing workflow | Adult, pediatric, and neonatal ICUs, the Pennsylvania State University/Milton S. Hershey Medical Center and the Pennsylvania State Children's Hospital | * | * |
| Wenzer et al. (PP) [78] | Observation; interviews; document analysis; usability assessment | Evaluating the medication work after implementation of a CPOE system | Two internal medicine wards, Randers Central Sygehus† | EPM (Electronic Patient record's Medication Module)† | Commercial† |
| Westbrook et al. (JA) [56] | Before- after, time-motion | Evaluating the impact of a CPOE system on laboratory order turnaround times | 11 wards, Sydney Teaching Hospital | The Cerner Millennium PowerChart | Commercial† |
| Lindenauer et al. (JA) [57] | Questionnaire survey | Evaluating attitudes of attending physicians about the impact of CPOE on personal efficiency | Baystate Medical Center and Frankilin Medical Center | E7000, Eclipsys Corporation | Commercial |
| Pitre et al. (JA) [58] | Before-after; time-motion study and weekly meetings with staff before the implementation and daily meetings for the following first 4 weeks† | Evaluating changes in the pharmacy department's workflow after a CPOE system | Nursing units in general internal medicine and the emergency department, the University Health Network | Quadramed (previously called Misys)† | Commercial† |

| Main finding(s) | |
|---|---|
| **Beneficial features/effects** | **Challenging/problematic/unexpected features/effects** |
| - ↓ in the rates of verbal orders and unsigned verbal orders | |
| | - enforcing a sequential order of activities for medication order entry and administration<br>- cognitive overload on users because of structured and standardized procedures in implementing a long medication list<br>- difficulties regarding ergonomic issues while scanning the information labels on medication bags<br>- inability to access the system when another user was simultaneously accessing the same patient's record |
| - legibility; easier charting of medications; remote access to information; decreasing the chance of missed orders because of highlighting overdue orders; quick access to diagnostic test results and consulting department notes; safety alerts<br>- quicker medication delivery<br>- ↓ verbal communication and phone calls | - computer availability; double charting tasks on paper and on computer; necessity for order cleanup due to a lack of discontinuation of orders upon new order entry<br>- difficulty in getting a snapshot overview on a patient's hospital stay<br>- referring to computers more often to check for new orders |
| | - redistribution of skills among nurses, physicians, and the system<br>- inflexibility for supporting the mutual physician-nurse dependencies; less physician- nurse negotiation for the medication plan<br>- the materiality of space and things such as patient beds, paper records, and computers affected what can be accessed, when, in which order and how<br>- timed log on procedures |
| - 15.5-minute ↓ per test in laboratory order turnaround time | |
| - order sets help in efficient use of the system and have important decision support role | - only 22% reported that the system's user interface supported workflow<br>- only 34% reported that the electronic order entry was faster than the handwritten |
| - → in the overall time required to process an order by a pharmacist in post- *vs.* pre-CPOE<br>- efficient communication among the pharmacists<br>- supporting the medication assessment process by accessing more comprehensive patient information<br>- no need for a reactive, time-consuming communication from pharmacists to physicians regarding hospital guidelines/restrictions or order appropriateness due to decision support alerts | - inflexibilities for the pharmacists in clinically justified decisions if they disagree with physician entered orders<br>- lack of standardized screens for order sets in different clinical services<br>- need for order clarification requests by pharmacists especially for "now doses"<br>- problems associated with the patient transfer form one unit with the system to another without the system<br>- performing extra steps due to lack of an effective interface between the pharmacy system and the CPOE system |

| Authors (Publication type) | Research methods[1] | Study description[2] | Clinical setting and name of the hospital | Name of the system | Type of the system |
|---|---|---|---|---|---|
| Georgiou et al. (JA) [59] | Interviews and focus groups | Evaluating the perceptions of healthcare professionals of the impact of a laboratory order entry system on organizational and communication processes | Different departments, including ICU, orthopedics, transplant, gastrointestinal†, pathology and laboratory departments, Sydney teaching hospital | The Cerner Millennium PowerChart | Commercial† |
| Zamora et al. (JA) [60] | Before-after, time-motion | Evaluating the impact of a CPOE system on medication processing cycle | Medical and surgical wards, the University Health Network | Quadramed † | Commercial† |
| Musser & Tcheng (PA) [82] | Randomized crossover | Evaluating the usage and perceptions of users of a text-based *vs.* graphical user interfaces in CPOE | Post-anesthesia care unit, Duke University Medical Center | * | Commercial |
| Georgiou et al. (JA) [61] | Before-after: observation; focus groups; interviews | Evaluating the impact of a CPOE system on pathology and laboratory services | Different clinical departments and pathology and laboratory departments, Sydney teaching hospital | The Cerner Millennium PowerChart | Commercial† |

Abbreviations: JA (Journal article); PP (Proceedings full paper); PA (proceedings abstract); RMRS (Regenstreif Medical Records System); BICS (Brigham integrated computing system); CPRS (The Veterans Affairs Computerized Patient Record System)

as the results of some studies appeared in more than one publication type. The research designs used were mixed-method (n=5), quantitative (n=25), and qualitative studies (n=21).

Six publications reported on workflow simulation methods: in part [77] or in whole [48, 62, 72, 74, 81]. The majority of studies were conducted in the context of commercial systems, in academic hospitals, and in adult inpatient settings. In the next section, we present the findings based on reported positive and negative/challenging effects.

| Main finding(s) | |
|---|---|
| **Beneficial features/effects** | **Challenging/problematic/unexpected features/effects** |
| - physicians: more efficient order processing; easy to identify exactly when a test is ordered, collected, processed, and test results issued<br>- nurses: accessibility of an order across the hospital; easier and faster exchange of information among professionals<br>- laboratory technicians: more streamed laboratory test reception process; no need to enter order information into the pathology information system | - physicians: time-consuming and clunky order typing because of necessity to access multiple screens; less inter-departmental communication and social interaction<br>- pathology laboratory staff: changes in their responsibility of identifying and rectifying inconsistencies in the order requests; reduced controlling role in data quality checks |
| - 59-minute ↓ in medication turnaround time<br>- 25-minute ↓ in 'now' dose turnaround time<br>- 75% ↓ in verbal and telephone orders | |
| - order entry sessions with the graphical format was mostly preferred and used, and was 27 seconds shorter than the text-based<br>- graphical format: superior for time required to use, ease of use, appearance, speed, and suitability for busy times of the day<br>- the text-based format: superior for flexibility and suitability for patients with more chronic illness | |
| | - shift in responsibility from the laboratory to clinicians on the wards<br>- emergence of "frustrated orders"<br>- problems with adding tests to previously existing specimens<br>- discrepancies in the recorded time of specimen collection and its arrival at the laboratory |



## 4.2. Beneficial effects

Remote access to enter orders or view their status (such as the result of diagnostic tests) was highly appreciated [35, 37, 38, 41, 42, 55, 58, 59, 64, 66]. Such systems enabled multiple people to view the same patient's orders simultaneously [64]. Furthermore, access to knowledge sources, decision support, order sets, graphical display of data, and easier charting of medications were found to be supportive for providers [35, 38, 52, 55, 57, 64, 82].

CPOE systems removed many intermediary and time-consuming tasks for physicians (e.g., looking for data), nurses (e.g., transcribing orders) and ancillary departments (e.g., entering orders into the departmental information systems) [33, 37, 38, 41, 42, 55, 58, 59, 64, 66, 69]. One study showed that clerks, nurses, and pharmacists spent less time per day on the medication process after the implementation [47]. However, in another study, no difference was found between pre- and post-implementation regarding the time pharmacists spent to process medication orders [58]. One study found that physicians had more time to talk with patients after the implementation [69]. Moreover, asynchronous communication through these systems resulted in fewer work interruptions to clarify illegible orders or to inquire necessary information from other providers [42, 58]. Four studies reported that the number of phone calls between co-working providers decreased [39, 42, 55, 60].

CPOE had positive impact on order turnaround times. Six before-and-after studies demonstrated a substantial decrease in the drug turnaround time, varying from 23% to 92% [46, 47, 49, 60, 68, 76]. This reduction was mainly attributed to the removal of certain intermediary tasks between order initiation by a physician, verification by a pharmacy, and administration by a nurse. Three studies compared the time interval between a physician's radiology requests and the completion of the procedures pre- and post-implementation and found a significant reduction of 24% to 69% [46, 49, 50]. Similar shorter turnaround time was also observed for laboratory orders, varying from 21% to 50% [46, 50, 56]. One study

Table 2.2. Usability limitations identified in the selected CPOE literature

| System availability |
| --- |
| • problems associated with downtime [41, 66], accessibility of workstations while on rounds [66], servicing computers and printers [64], poorly interfaced different information systems in one hospital [53, 58, 64, 65]; difficulties due to transfer of patients in a hybrid electronic-paper environment [58, 66, 67] |
| • inability to access the system when another user is accessing the same patient's record simultaneously [62, 66] |
| **Human-computer interaction** |
| • slow response time [37-39, 41]; inconveniency of logging into the system [38, 71, 78]; troublesome manipulation of keyboards [37] |
| • complex and lengthy process of medication ordering, especially in the time of admission, discharge and transfer [38, 43, 64, 66, 67]; difficulty with processing of non-standard orders [53, 67] |
| • no possibility to switch between two paths with numerous screens for order entry in order to enter or retrieve information [43]; difficulty to gain an overview on patient hospital stay [53, 55, 75] |
| • problematic data presentations such as patient medication profile design [53, 67]; clutter of order and note screens [66]; difficulty to see a patient's name on the screen [64]; problematic highlighting of the nursing administration rounds in the system's timetable [51] |
| • no possibility to enter free texts due to prefixed text entries; inadequate word processing capabilities; inadequate space for notes [43, 53, 64] |
| • unfamiliar or confusing cognitive model of classifying orders in the system [53, 67, 71, 74]; suboptimal interface affordances making extra demands on user's internal resources [72]; mismatch between cognitive model of tasks in the system with physicians' cognitive activities for order entry [77] |

found a reduction of 3 hours between the time the laboratory tests were ordered and the time the results became available [39].

By forcing order entry through the system and facilitating remote access, CPOE systems could decrease verbal orders. A study calculated a 75% reduction in the number of verbal and telephone orders [60]. A similar trend was shown in a children's hospital [54]. Three studies showed that the rate of order countersignatures improved [46, 54, 60].



## 4.3. Negative or challenging effects

### *4.3.1. Time issue*

Using CPOE systems was found to be time-consuming for clinicians. Five studies referred to the perception held by physicians that more time was spent on ordering after the implementation [33, 36, 57, 59, 66]. Five studies compared the time physicians spent on ordering using CPOE systems to paper-based systems [32, 39, 40, 69, 79]. A significant increase in time was seen in all studies except one [39] in which a laboratory order entry system resulted in 5.5 minutes less time. One study found that order entry sessions using a graphical format significantly took less time than a text-based format [82]. Two studies mentioned the physicians' perception of having less time to spend with patients as a consequence of spending more time on CPOE systems [37, 41]. One CPOE study found an increase in administration documenting time for nurses [40]. However, most of these studies looked at subsets of a clinician's workflow, and not the overall workflow in a day.

### *4.3.2. Usability issues of CPOE systems*

Usability limitations and their effects on workflow were well discussed in the literature. Table 2.2 lists a number of the difficulties experienced due to interaction with problematic hardware/software or due to an inadequate integration or ineffective interface between different information systems in a hospital. We grouped them in terms of system availability and human-computer interaction in Table 2.2.

The limitations relating to human-computer interaction mainly involved an individual provider's tasks of "entering and/or retrieving orders". To overcome system inflexibilities, providers were sometimes obliged to take additional or alternative steps to continue the work: for example, to double chart on paper and on computer [55] or to use computer printouts as flexible data medium [53]. Providers also sometimes bypassed the system completely: for example, by using a colleague's open logging session [71]. A simulation study showed that a CPOE system may enforce a very sequential and inflexible order of activities, which may be completely bypassed under emergency situations [62].

Ineffective interface between different departmental information systems can cause interruptions for providers working in different departments. Two studies referred to administrative workload increased in the ancillary departments due to transferring orders manually from one system to another, followed by subsequent frustrated calls for clarification [58, 65]. Moreover, some studies reported workflow interruptions due to lack of bedside systems or defected computers and printers. These issues are merely artifacts of inconvenient implementation of the technology and/or its maintenance and not representative of qualitative differences between CPOE versus paper-based systems. Nevertheless, it has been shown that such issues fairly influence workflow [53, 64, 66, 67].

### *4.3.3. Team work*

An important CPOE impact discussed in the literature concerns the structure of tasks that require multiple providers to be involved in teamwork. The application of CPOE systems changes teamwork in two ways: by re-delegating tasks between co-working providers, and by changing communication channels and collaboration mechanisms.

First, after the implementation, the re-delegation of tasks between providers transforms previously assigned tasks. In some cases, CPOE systems enforced predefined and standardized roles and responsibilities. Two studies highlighted the problematic role-based authorization of entering orders, in which only physicians were authorized [53, 71]. For a successful order entry, physicians may in turn be obliged to deal with the requirements of structured data entry. Physicians sometimes perceived it as a clerical task comparing to the lax hand-written practices [33]. It has been reported that the exclusive order entry by physicians may result in leaving nurses out of the ordering loop [33, 67]. Similarly, in one study, the pharmacists reported that the system took away some of flexibilities of their paper-based system to allow them to take clinically justified decisions in cases they disagreed with particular physician orders [58]. However, provision of decision supports and alerts regarding hospital guidelines or drug restriction policies has expanded their role in ordering practice while weakening physicians' autonomy [53, 58, 67].

Shifting of responsibilities was also observed in the processing of laboratory orders. Georgiou *et al.* discovered that a computerized laboratory order entry system shifted some responsibilities of the laboratory staff to the clinicians on the wards [59, 61]. These clinicians were required to check for those laboratory orders that had been issued without the specimens and also to determine their accurate collection times.

Furthermore, the pattern of responsibilities for providers also changes after CPOE implementation. Two studies mentioned a new responsibility for nurses to reconcile the orders edited by pharmacists with the physician-initiated orders [67, 71]. In addition, nurses had to make sure that a verbal order had been entered by physicians, while this issue was not crucial before [71]. In fact, it was the implementation of CPOE and thereby that of organizational rules that highlighted the issue of unsigned verbal orders [54]. Because these changes are not often anticipated beforehand, providers then may be left unsure about the tasks that fall within their responsibility. One study referred to the uncertainty of who should check and take care of automatic "stop" and "expiring" orders: physicians or nurses [67]. A similar uncertainty of having a responsibility caused subtle tension between laboratory technicians and nurses in another study [65].

Second, CPOE systems have changed the traditional communication channels and collaboration mechanisms. After implementation, interaction with these systems may replace interpersonal contacts that may result in fewer opportunities for team-wide negotiations [53, 59, 78]. Studies have indicated that CPOE may maintain a centralized decision making paradigm with physician dominancy despite the fact that in practice nurses may notify physicians of emergent needs for orders [71, 73]. Dykstra referred to systems that compelled physicians to enter their orders in computer rooms while away from other members of a care team [70]. In such cases, providers may assume that the system would communicate their orders, plans, and ideas.

In the absence of direct communication (such as verbal notification) and other visual clues (such as bedside physician order writing) following CPOE implementation, a new imperative has emerged: to notify recipient providers who need to take care of orders timely [33, 53, 66, 67, 70, 71]. Some studies referred to the notifications taking place by means of computerized alerts or printouts. Nevertheless, for busy clinicians moving around, it is not possible to check printers and computers frequently. Hence, a delay in processing orders may occur due to a delay in an acknowledgement of these notifications [70, 71].

## 5. LITERATURE ANALYSIS

### 5.1. On the basis of our conceptual model

The analysis on the basis of our conceptual model showed that the modeling principles of CPOE systems generally make use of a formal, predefined division of tasks and a preconceived relationship between clinical tasks and also between care providers. With regard to division of labor, our analysis highlighted that CPOE systems authorize a formal task structure that includes role-based division of tasks and a consecutive order in task execution. Such a sharp division of tasks can in theory help care providers to recognize their responsibilities clearly and lead to better safety procedures, for example, when a physician decides on details of orders, documents them, or responds to safety alerts [83]. However, studies have shown that a literal translation of this formal and hierarchical authorization in CPOE limits the effective contribution of all providers in the ordering activities [33, 34, 51, 58, 71]. This in turn can jeopardize teamwork in medical practice. For instance, in the formal division of labor, the task of ordering falls under the authorization of physicians. Nevertheless, in practice, order creation is the product of negotiation, sharing of information, redistribution of responsibilities, and informal delegation of the ordering tasks among providers [6, 51, 71]. The model of strict and physician-dominant authorization underlying CPOE therefore may partly mismatch with the negotiated and co-constructed nature of ordering practice.

Studies that analyzed the cognitive tasks of ordering practice by physicians criticized its cognitive model incorporated into CPOE systems [48, 72, 74, 75, 77]. They indicated that these two may not reasonably correspond with each other. They also noted that interaction with these systems may burden physicians with cognitive overloads [48]. One study found that order planning by a physician for complex patients is primarily problem-based in contrast to the mnemonic-based frameworks underlying CPOE systems [77]. Such discrepancies may further compound the user-system interactions.

CPOE systems considerably reduce order turnaround times, which corresponds to timeliness of care. Nevertheless, they may negatively affect the temporal coordination of tasks. The straightforward order of activities with CPOE systems may hinder the synchronization of those tasks that are interdependent. In a study, after physicians entered laboratory orders into the system, their electronic requests were promptly sent to the laboratory departments [61]. The laboratory technicians were then confronted with a number of lab requests without the corresponding specimens, because nurses could not prepare and send them at the same time physicians entered orders. Similarly in another study, after order entry by physicians, nurses received two order printouts, one from physicians and the second from pharmacists after order verification [71]. Lack of activity synchronization among providers can be a source of frustration necessitating extra effort to clarify the issue [61, 66]. Moreover, as Reddy described [84], clinical tasks in the hospital are often accomplished in temporal rhythms. A nurse may know better when to administer a drug or when to draw a blood sample, because these tasks are integrated into the temporal rhythms of their workflow. Yet, using CPOE compels physicians to choose strict schedules for orders that may not always be compatible with the practice [51].

Our analysis revealed that the spatial dimension of medical work also challenges the mediating role of CPOE systems. As they mostly tend to be accessible from fixed workstations, providers working at bedsides may be interrupted because they are obliged to walk to the workstations [66, 71]. As well as providers, patients also move between different units. This implies that the system should be accessible across formal divisional boundaries of hospital units [52, 66, 85]. Therefore, appropriate transit orders should be considered in the computer environment.

CPOE systems have mixed effects on information flow. They enable the communication of legible and complete orders between providers, which has greatly reduced the transcription task workload of recipient parties. However, some studies questioned the affordances of these systems to furnish providers with an overview of patient information [53, 67, 75]. It has also been pointed out that the ability of these systems to integrate different pieces of information and to communicate their contextual meaning is limited [30]. This is compounded by the fact that the predefined data entry options on the screens may limit the sharing of psychological, social, or emotional information relating to patients [43]. It has also been noted that because of fewer team-wide discussions, information accessed through these systems may not be easily interpreted by clinicians [53, 67, 70, 71]. Thus, human interpretation of information is still of critical value for information processing [86].

Last, changes in work structure transform the mechanisms by which clinicians control their work. In the Results section, we referred to the challenge of monitoring newly issued orders through CPOE systems. In such cases, physicians who initiate orders may simply assume that their orders are delivered to the right providers at the right time [70]. However, such over-reliance on CPOE systems may give rise to the late implementation of orders [66, 70, 71].

### 5.2. Individual versus collaborative workflow

Regarding the concept of workflow in the literature, two areas of focus were recognized: that of *one individual* provider and that involving *more* than one provider. The first mainly highlighted the advantages and/or disadvantages experienced by *an individual* provider while interacting with CPOE systems to perform tasks. This has mainly informed us as to how this interaction can be improved (for examples please see [32, 38, 43, 48, 62, 74, 75, 82]). The second area, however, widened the scope of interest to the collaborative flow of tasks between *co-working* providers. This area has shown how the work of different providers is highly interdependent; so that, any change in one's work might positively or negatively affect the others' (for examples please see [33, 42, 51, 58, 61, 66, 70, 71]). This area therefore has informed us how the automation of order entry process can have serious implications for the workflow between providers working in the same or different departments.

Our analysis of these concepts in the literature indicates that the first area dominated the discussion in the literature (Table 2.1) even though the collaborative nature is dominant in the collective clinical workflow, as detailed in our conceptual model (Figure 2.1).

### 5.3. Home grown versus commercial systems

For this analysis, data was available in 41 evaluation studies. Among 5 studies evaluated both commercial and home grown systems, only one study [45] compared the results regarding this variable. In this study, users of a commercial system were dissatisfied and reported it to be difficult, cumbersome, and time-consuming to perform routine tasks.

While workflow evaluations of home grown systems were published before 2001, the majority of studies of commercial systems appeared in later years. Positive and negative effects appeared in both types of systems. Except one mixed-method study [66], the home grown studies were all quantitative. The focus in these studies tended to be on evaluating the time-efficiency of physicians after CPOE. Quantitative studies of commercial systems mainly documented shorter order turnaround times. Contextual effects of CPOE such as changes in roles, responsibilities, and workload of providers, and also changes in collaboration mechanisms were predominantly evaluated in the context of commercial systems.

## 6. DISCUSSION

Our review shows that the impact of CPOE on clinical workflow is double-edged. On the one hand, it shows that the implementation of CPOE systems has resolved many disadvantages associated with the workflow in paper-based practices. CPOE systems have improved workflow efficiency in terms of the legibility and completeness of orders; the availability of decision support features and order sets; the remote accessibility of the system; the possibility to view the same patient data simultaneously by multiple providers; and fewer work interruptions due to asynchronous communication. They have also decreased verbal orders and improved order countersignature. Furthermore, these systems contributed in time efficiency in term of shorter order turnaround times.

On the other hand, our review also reveals that the implementation is accompanied by difficulties in workflow, mainly due to changes in the structure of pre-implementation work. Negative effects included time-consuming user-system interaction; the removal of visual clues available in paper-based systems; the enforcing of predefined and stepwise order of activities as well as role-based relationship between providers; emerging problems in the synchronization of interdependent tasks; and the restricting of opportunities for team-wide discussions.

CPOE systems are implemented within a wide socio-technical context, within which the interplay of diverse social, technical, and organizational factors influence their effects on workflow [5, 87]. Studies of HIS use have shown that to reduce interruptions in workflow, providers may develop “workarounds” [2, 88, 89]. Indeed, many systems may continue to operate only because users devise workarounds to avoid difficulties. The results of such *ad hoc* efforts are variable; they can either smooth the workflow or disturb its balance. It is notable that these workarounds are not registered in or monitored by CPOE systems; thus, they may give a false sense of work support, because despite disruptions the work is still carried out. Such contextual issues in CPOE use will be easily disregarded in design and redesign processes if they are not detected and understood in evaluation studies. Experience shows that with a multifaceted research approach there is a high chance of identifying such contextual issues (see for instance [43, 51, 53, 58, 61, 64, 70, 71]). In fact, multi-method, quantitative and qualitative studies can help not only to answer "what", "where", and "when" questions but also to gain an in-depth understanding of "how" CPOE systems behave in their implementation environment, as well as "what the users' reactions are" and "why" [90, 91]. These studies should take practice-oriented workflows as their starting point.

### 6.1. Individual versus collaborative workflow

The concepts related to an individual provider' workflow and that between co-workings are highly interdependent and equally important in having a smooth clinical workflow. Although we do not question the relevancy of the first concept, based on our analysis of the findings we argue that its dominancy may result in marginalizing the collaborative problem-solving, decentralized decision-making paradigm, and negotiated and co-constructive nature of clinical activities. For example, paying more attention to improving the workflow of individual physicians in order entry process (for instance [92]) may result in overlooking the fact that they are dependent upon the work of other providers. In that sense, even if a system perfectly works for physicians, it may not support the collaborative practice that physicians are reliant upon. Our study therefore suggests that for CPOE to have a more positive impact, besides the individual providers' tasks, it also needs to support the collaborative nature of workflow sufficiently.

Moreover, we suggest that studies of workflow in CPOE environment should widen their units of analysis to cover the collective workflow of an individual provider in the course of *a day* or that of collaborating providers in *a clinical process* such as the medication process. Limited units of analysis may fail to discover that, for example, even though CPOE takes time for a provider it also saves the time that would otherwise be spent on walking to a ward for finding information or on responding to the calls of other providers for clarification of illegible orders or correction of interaction errors.

### 6.2. Home grown versus commercial systems

In this review, the number of publications relating to home grown systems was relatively low. This could be because a small number of academic institutions pioneered in developing CPOE systems. The objective and methodology of evaluation studies in this group are possibly an indication that, in the early years of developments and installations, these institutions invested time and effort on overcoming the resistance of physicians as the primary users. Furthermore, the home grown systems were developed by in-house development teams who were clinically knowledgeable. It is plausible that workflow interruptions and difficulties in system use were detected in informal evaluations and communications, and that the in-house teams could closely monitor and address workflow issues by pilot testing, redesigning, and integrating these systems to local workflows without formally documenting, reporting, or publishing the results. It is also possible that results only appeared in the form of design, redesign, and implementation reports, which were among our exclusion criteria. Thus, some of the findings in this review may not be applicable for home grown systems.

Our review shows that the focus and methodology of evaluation studies have been shifted after 2001—i.e., paying more attention to collaborative workflow and conducting more qualitative studies. This could be the result of researchers' awareness of socio-technico- organizational issues and the call to address them in evaluation studies [90, 93]. Or, it might be because, especially after the IOM's call to build a safer health system [94], more hospitals have been encouraged to invest in CPOE systems. For many health care institutions, commercial systems have been an option to save time, effort, and expertise necessary for system developments. To justify the value of the investment and/or to detect and rectify these systems' detrimental effects, these institutions needed more formal evaluations. As our review shows, most formal evaluation studies of the CPOE's contextual effects are related to commercial systems.

### 6.3. Strengths and weaknesses of the study

Several systematic reviews of CPOE systems have been done so far. Nevertheless, no study to date has analyzed CPOE evaluations exclusively with respect to *clinical workflow*. Yet, as one of the central issues in the deployment of CPOE systems, clinical workflow is exceedingly complex and needs to be better understood [95]. Our conceptual framework based on insights from relevant fields created the necessary background and allowed us to analyze CPOE's multidimensional and collective effects. Another strength of our study relates to the combination of different search terms used and the databases reviewed to find most relevant publications. We also did not confine our review to specific quantitative or qualitative studies.

Nevertheless, our study has several limitations: First, our search strategy identified 51 publications in total. It is possible that the time span we set to detect relevant publications may have missed pertinent studies published before or after that period. The number of CPOE evaluations related to workflow issues shows a growing trend by time. Therefore, expanding the time period to include the publications appeared through 2007 and 2008 might have changed our discussion and conclusion. Second, because of the complexity of workflow related concepts and the lack of agreed upon research methods to evaluate them, many of the discussions around clinical workflow have only been appeared in other forms of publications than the original research papers. A literature review, which is tightly bound by the methods of searching and the content of the articles that meet inclusion criteria, therefore may not well reflect a proper balance of what is known. Yet, it may well direct future research. Third, our study touched upon the effects of usability issues on clinical workflow. However, other search strategies may help to detect all relevant studies evaluating the effects of usability issues on clinical workflow. Next, we analyzed the effects of a broad range of CPOE applications implemented in various inpatient units. Because data related to the details of clinical units and/or features of CPOE systems under study were often incomplete in study reports, we therefore did not associate the reported effects with these factors. Further studies are required to control these factors and to detect such associations: for example, by evaluating the impact of the same system in different specialties or the effects of different systems in similar specialties. Last, as we discussed earlier, some of the findings in this review may not be relevant to home grown systems.

## 7. CONCLUSION

To our knowledge, this literature review is the first to be dedicated exclusively to the impact of CPOE on clinical workflow. Our conceptual framework helped us to analyze the pros and cons of such effects. Clinical workflow is highly contingent and collaborative. Many *in situ* contextual factors such as the kind of specialties, the time through a day and so forth may have an influence on it. Based on the contextual factors, providers may decide to *rearrange* the order of activities or *redelegate* certain responsibilities among themselves [96]. When put in practice, the formal, predefined, stepwise, and role-based models of workflow underlying CPOE systems may show a fragile compatibility with the contingent, pragmatic, and co-constructive nature of workflow. This in turn can cause an interruption in workflow and challenge the integration of these systems into daily practice.

Regarding the diversity of findings in the literature, we conclude that more multi-method research is needed to explore CPOE's multidimensional and collective impact on especially collaborative workflow. This review may inform designers, implementers, and evaluators how to pay closer attention to the collective, multidimensional, and contextual impact of CPOE systems on clinical workflow.



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# Chapter 3

## Same System, Different Outcomes: Comparing the Transitions from two Paper-based Systems to the same Computerized Physician Order Entry System

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## ABSTRACT

**Objective:** To compare how nurses in two different paper-based systems perceive the impact of a computerized physician order entry (CPOE) system on their medication-related activities.

**Setting:** 13 non-surgical, adult inpatient wards in a Dutch academic hospital.

**Methods:** Questionnaire survey of 295 nurses before and 304 nurses after the implementation of a CPOE system. These nurses worked with two different paper-based medication systems before the implementation: 'Kardex-system' and 'TIMED-system'. In the Kardex-system, the structure of the nursing medication work was similar to that of after the CPOE implementation, while in the TIMED-system, it was different. 'Adaptive Structuration Theory' (AST) was used to interpret the results.

**Results:** The response rates were 52.2 % (154/295) before and 44.7% (136/304) after the implementation. Kardex-nurses reported more positive effects than TIMED-nurses. TIMED-nurses reported that the computerized system was more inflexible, more difficult to work with, and slower than the TIMED-system. In the TIMED group, the overall mean score of the computerized process was not significantly different from that of the paper-based process. Moreover, nurses in both groups were more satisfied with the post-implementation process than with the pre-implementation process. Nevertheless, none of groups reported a better workflow support in the computerized system when compared to that of the paper-based systems.

**Conclusions:** Our findings suggest that not only the technology but also large differences between pre- and post-implementation work structure influence the perceptions of users, and probably make the transition more difficult. This study also suggests that greater satisfaction with a system may not necessarily be a reflection of better workflow support.


**Keywords:** Evaluation Studies; Prescriptions, Drug; Medication systems, Hospital; Medical Order Entry Systems; Computer Communication Networks; questionnaires

## 1. INTRODUCTION

The implementation of a computerized physician order entry (CPOE) system is considered as a pivotal transitional step towards the more effective management of medications [1]. A CPOE system is defined as a computer application where a physician directly enters medical orders. Because nurses are also involved in patient care, they inevitably interact with these systems or their outputs. Studies have shown that a CPOE system can eliminate a number of intermediate steps for nurses. For example, they no longer have to deal with illegible and incomplete hand-written orders, which are a common source of extra workload for nurses [2-4]. The system, moreover, facilitates order communication to other parties such as the pharmacy, which in turn saves considerable time for nurses [5, 6].

However, something which has recently received considerable attention is the extent to which these systems change the nature of workflow for health professionals, including nurses [7-9]. In fact, in addition to the literature that reports benefits of CPOE systems, there is a growing number of studies that focus on unintended changes in many aspects of workflow following the implementation [8, 10]. Beuscart-Zephir et al. described the role of nurses in distributed decision making in the medication ordering and administration process [11]. Coleman observed that nurses normally interpret physicians' intents in their orders [12]. Therefore, if nurses were to be bypassed after implementation of a CPOE system, the system would not be able to handle this interpretation effectively. Both studies criticized the fact that the organizational role of nurse was ignored during the design of CPOE systems [11, 12]. Moreover, in a study of perceived impact of CPOE systems, nurses reported a sense of loss of control over their work [13]. Goorman and Berg argued that at least some of the problems with these systems occur because of the clash between the nursing workflow model embedded in the system and actual nursing practice [14]. This evidence indicates that nurse-related medication activities, and more importantly their organizational role in the medication process, deserve more attention in the design, implementation and evaluation of CPOE systems.

Depending on different work organizations, nurses may be assigned different roles and responsibilities. As the implementation of CPOE systems brings a new work organization along with it, this unavoidably transforms their roles and activities. The study of how nurses perceive this transformation in the transition from a paper-based to a computerized work structure can give insight into how this transition can effectively be managed. In 2001, a computerized medication order entry system was implemented in a Dutch academic hospital. Several different paper-based medication systems were in use before the implementation. To compare the perceived impact of this CPOE system on nursing medication practice, we conducted a before-and-after study in two different paper-based medication systems. In particular, we compared the perceived benefits and/or drawbacks of the computerized system with those of the two different paper-based systems. We also examined nurse satisfaction and perceived workflow support before and after CPOE implementation.

## 2. THEORETICAL BACKGROUND

We used the 'Adaptive Structuration Theory (AST)' [15] as a theoretical framework to study the changes that occurred in two different work practices following the CPOE implementation. AST is based on Anthony Giddens' Structuration Theory [16]. This theory is formulated as "the production and reproduction of the social systems through members' use of rules and resources in interaction". DeSanctis and Poole adapted Giddens' theory to study the interaction of groups and organizations with information technology (IT), and called it 'Adaptive Structuration Theory' [15].

AST criticizes the technocentric view of technology use and emphasizes its social aspects. This theory focuses on "social structures, rules and resources provided by technologies and institutions as the basis for human activity" (page 125) [15]. The social structures in this theory include the technology itself, the content and constraints of a given work task, the organizational environment, corporate information, histories of task accomplishment, cultural beliefs, modes of conduct and so on. These structures act as templates for planning and accomplishing tasks and may vary across groups. Designers incorporate some of the structures of institutions into the technology; the structures may be reproduced so as to imitate their non-technology counterparts, or they may be modified, thus creating new work structures within the technology. The AST helps to explain the different outcomes after the implementation of one information system in different work structures.

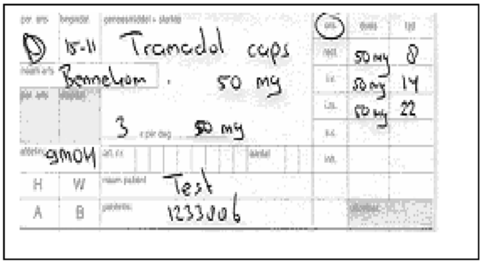
# 3. STUDY CONTEXT

## 3.1. Study environment and the CPOE system

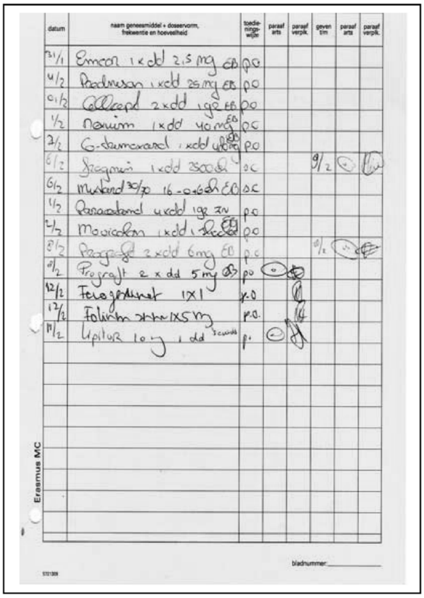
This study was conducted at Erasmus University Medical Center (Erasmus MC) in Rotterdam, a 1237-bed academic hospital in The Netherlands. We studied a commercially available computerized medication order entry system named *Medicatie/EVS*®. To retrieve patient and drug data, *Medicatie/EVS* communicates with the existing hospital information system (HIS) and patient medical record (Patient 98). This system was first piloted in six wards of two specialties from December 2001 to December 2002. It was followed by subsequent implementation in 39 wards from September 2003 to March 2005.

## 3.2. Two paper-based medication ordering and administration processes

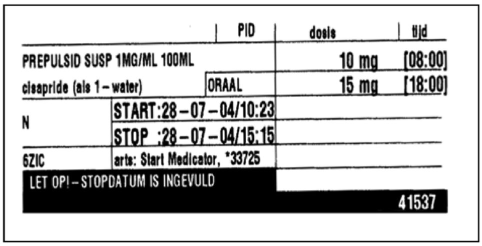
Before the CPOE implementation, Erasmus MC had two different paper-based systems on adult wards: Kardex and TIMED.



a) Kardex system



b) TIMED system




c) CPOE system

Figure 3.1. The medication orders in different medication systems.

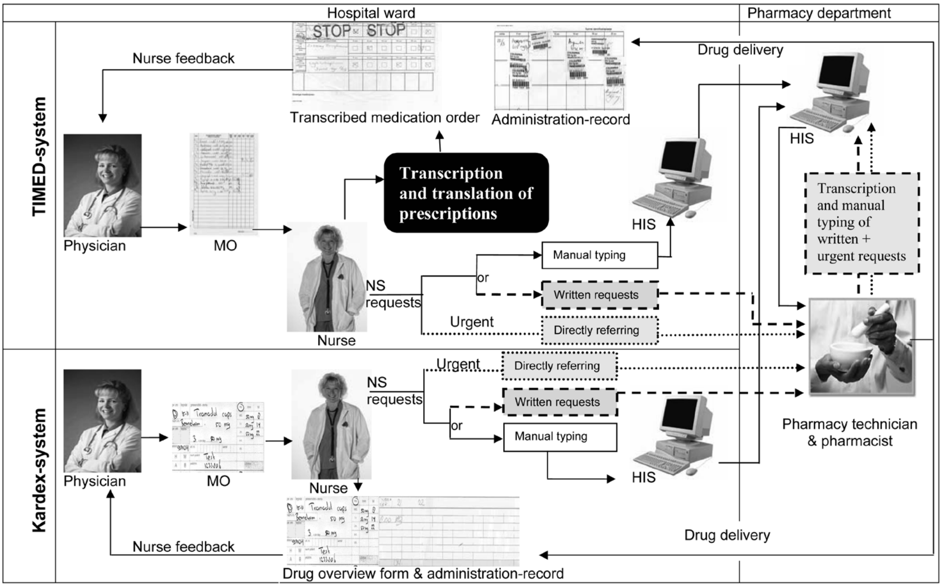



Figure 3.2. The medication ordering and administration processes in Kardex-system and TIMED-system; MO (Medication Order); HIS (Hospital Information System); NS (Non-Stock); for requesting urgent NS drugs, nurses often directly referred to the pharmacy with hand-written requests.

In the Kardex-system, to prescribe medications, physicians wrote a drug's name, dosage form, dosage regimen, administration route, start date, and exact administration time on a special tear-off order form with two additional carbon copies (Figure 3.1a). Nurses could add missing information (e.g., dosage form or strength), but no transcription took place. The original order was put on a Kardex-card for registration of drug administration. This was registered by signing next to the order on the Kardex-card. This registration form had room for ten days and after that a new form for the next ten days could be added on the card. To request non-stock items, nurses had to manually write drug requests and send them to the pharmacy. For urgent medications unavailable in the ward stock, nurses had to refer to the pharmacy personally with the hand-written drug requests. These requests then were entered into the HIS by pharmacy technicians. These processes in the Kardex-system are shown in Figure 3.2.

In the TIMED-system, physicians wrote a medication's name, dosage regimen, administration route, and start date on a pre-printed slip (Figure 3.1b). A nurse had to transcribe a physician's orders, select the suitable dosage forms available in the hospital, and choose their administration times. The nurse, for instance, translated the dosage regimen of an order of three times daily into the exact adminis-

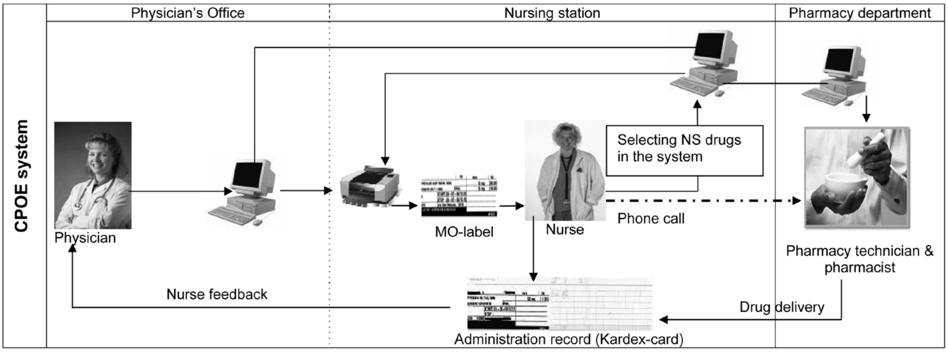



Figure 3.3. The medication ordering and administration process after the CPOE system; this system is available in all the computers throughout the hospital; MO-label (Medication Order-label); NS (Non Stock).

tration times during the day. The transcribed orders together with an administration registration form then were put in the patient medication chart. Each day a new administration form was put next to the transcribed order form (Figure 3.2). Once a drug was administered, this was registered by sticking the flag labels of the administered drugs on the administration form. Whenever flag labels were absent, the nurse had to write the drug name and dosage on the administration form. For urgent and also non-stock medications, the same procedures as in the Kardex-system were followed.

For the sake of clarity, we will refer to 'Kardex units' as wards which used the Kardex-system before the implementation. Likewise, 'TIMED units' are those wards that had the TIMED-system.

## 3.3. The computerized medication ordering and administration process

The CPOE system is available in all physician offices as well as in all workstations throughout the hospital. Only physicians and midwives are authorized for electronic order entry in this hospital. Physicians must enter their medication orders into the system; nurses may not accept any hand-written prescription. A physician enters a medication order by selecting a drug and its dosage form, strength, administration route, dosage regimen, start date and time. A detailed description of the prescription process with the *Medicatie/EVS* has been published elsewhere [17]. After electronic ordering, medication orders are printed on special labels called Medication Order (MO)-labels (Figure 3.1c). Nurses were trained in groups to work with the system.

The printed labels are affixed to a Kardex-card which is specific for the medication administration record. Next to the MO-labels on the Kardex-card, nurses are supposed to provide a signature once they give medications to patients. Transcription of a prescription by the nurse is no longer necessary. Nurses are notified about the availability of drugs in the ward stock by means of codes specified on the MO-labels ("J"=available, "N"= unavailable). Pharmacy technicians control the supply of in-stock items by scanning them at wards two or three times a week. Whenever an MO-label contains a drug that is out of stock, nurses can select it in the system and thereby send an electronic drug request to the pharmacy. Technicians in the pharmacy check these non-stock drug requests twice a day at 8 o'clock and 12 o'clock and provide the requested drugs later that day. The process after the CPOE implementation is shown in Figure 3.3.

Comparison of Figure 3.2 and Figure 3.3 shows that the medication ordering and administration process after the implementation resembles that of the Kardex-system, while it is completely different from that of the TIMED-system. In both Kardex and TIMED units, we compared nurse attitudes towards the computerized process in the post-implementation phase with their attitudes towards the paper-based process in the pre-implementation phase.

## 4. METHODS

### 4.1. Study design and measurements

Our evaluation was based on questionnaire administered to nurses before and after the CPOE implementation. Design of the questionnaire was based in part on previously published questionnaires for the assessment of user satisfaction with CPOE – such as [18] – and was done in a close collaboration with nursing staff. In addition to demographics, the original questionnaire contained 28-40 questions to measure attitudes regarding the paper-based systems (Kardex and TIMED) and the CPOE system. In the present study, we report on the results of the questions that were similar in the questionnaires used in the three systems. The list of these questions is available in Appendix 3.1. These questions asked respondents about: overall reaction towards the medication process (1.1, 1.2, and 1.3), the characteristics of medication orders (2.1, 2.2, and 2.3), registration of drug administration (3.1, 3.2, 3.3, 3.4, and 3.5), the learning and speed of the process (4.1 and 4.2), and managing the non stock medication orders (5.1 and 5.2). These questions were designed to evaluate the attitudes based on a 5-point Likert scale. We also included two other questions which asked the respondents to give their impression of workflow support (6.1) and system preference (6.2).

The questionnaire was checked for the applicability and understandability of its wording by two nurses in each system. The questionnaire was considered ready for distribution after modifications suggested by these nurses. In each phase, a packet containing the questionnaire and a cover letter explaining the aim of the study were distributed by head nurses among all nurses in the target wards. The completed questionnaires were collected by the head nurses or directly sent to the researcher via the hospital's internal mail service.

### 4.2. Course of the study and participants

Nurses working in 13 non-surgical, adult inpatient wards were chosen to participate in this study. Six wards used the Kardex-system and consisted of Psychiatry (three wards), and Hematology and Oncology (three wards). Seven wards used the TIMED-system and consisted of Internal Medicine (six wards) and Neurology (one ward). The CPOE system was implemented in these wards one after another. The questionnaires were sent two weeks before and approximately five months after the introduction of the CPOE system. Since the introduction of the system across the hospital was conducted in a step-wise basis, the distribution of the questionnaire in both phases followed the implementation order (September 2003 to October 2004).

All nurses who were working in the selected units during the course of this study were invited to participate. In the pre-implementation phase, 295 nurses received the questionnaire, of whom 154 nurses responded (52.2 %). In the post-implementation phase, 304 nurses were contacted, of whom 136 nurses responded (44.7 %). Overall, 290 questionnaires were returned. Two hundred and eleven nurses (70.56%) participated in at least one phase of the study. In total, at least 79 nurses were identified as nurses who participated in both phases while 132 nurses completed only one questionnaire. As the recording of the identification number was not mandatory, it is possible that more nurses answered the questionnaires in both phases. One nurse in the post-implementation phase, who did not use computers at work, was excluded from the analysis of one question requiring the use of computers at work.

### 4.3. Data analysis

Analyses using the Kolmogorov-Smirnov (Lilliefors) test revealed that the scores provided by the respondents were often not normally distributed. Therefore, we tested for difference between scores for before and after the implementation using the Mann–Whitney U test. Overall scores of the systems, which were normally distributed, were compared using the *t* tests. The *t* tests were also performed to test for differences between the change scores (mean differences and standard errors in paper vs. electronic system) in Kardex units and change scores in TIMED units. 95% confidence intervals (*CI*s) for means are reported. We used the Spearman correlation coefficient to measure the degree of association between variables and overall satisfaction with the computerized process. The Mann–Whitney U tests were performed to determine changes in ratings of the preference of the systems and the perceived support of workflow (items 6.1 and 6.2) between pre- and post-implementation. We measured the internal consistency of the questions (1.1 through 5.2) using Cronbach's Alpha. An alpha level of .05 was used for all statistical tests. All statistical analyses were performed using SPSS for Windows (version 14).

## 5. RESULTS

Table 3.1 provides the demographics of the different study groups. Most nurses were women, practicing nurses, often used computers both at home and at work, and had no prior experience with an electronic prescription system. With regard to demographics, there were no important differences neither between respondents of pre- and post-implementation phases nor between respondents in Kardex units and respondents in TIMED units. Cronbach's Alpha for questions 1.1-5.1 was 0.84 for the paper-based and 0.88 for the computerized process, representing a high internal consistency of the questionnaire.

### 5.1. Comparison between pre- and post-implementation, and between Kardex and TIMED units

#### *5.1.1. Overall mean scores*

An overall mean score for each nurse was calculated by summing the scores for the 15 items of the questionnaire (1 = minimum, 5 = maximum). Afterwards, the overall mean score was calculated for pre- and post-implementation in Kardex and TIMED units. Kardex-nurses, whose medication process after the implemen-

Table 3.1. Characteristics of Survey Respondents.

| Characteristics | Kardex units | | TIMED units | |
|---|---|---|---|---|
| | Pre-implementation N (%) | Post-implementation N (%) | Pre-implementation N (%) | Post-implementation N (%) |
| Number of questionnaires distributed | 144 | 144 | 151 | 160[1] |
| Number of respondents | 66 | 48 | 88 | 88 |
| Specialty | | | | |
| Psychiatry | 30 (45.5) | 23 (47.9) | – | – |
| Hematology and oncology | 36 (54.5) | 25 (52.1) | – | – |
| Internal medicine | – | – | 76 (86.3) | 73 (83.0) |
| Neurology | – | – | 12 (13.7) | 15 (17.0) |
| Female | 54 (81.8) | 35 (72.9) | 71 (80.7) | 73 (83.0) |
| Age (years old) | | | | |
| ≤23 | 1 (1.5) | 1 (2.1) | 13 (14.8) | 17 (19.3) |
| 24-33 | 20 (30.3) | 14 (29.2) | 25 (28.4) | 27 (30.7) |
| 34-43 | 18 (27.3) | 10 (20.8) | 19 (21.6) | 17 (19.3) |
| 44-53 | 21 (31.8) | 18 (37.5) | 22 (25.0) | 22 (25.0) |
| ≥54 | 5 (7.6) | 1 (2.1) | 5 (5.7) | 3 (3.4) |
| Professional status | | | | |
| Practicing nurse | 52 (78.1) | 38 (79.2) | 65 (73.9) | 63 (71.6) |
| Head nurse | 7 (10.6) | 7 (14.9) | 6 (6.8) | 8 (9.1) |
| Others | 6 (9.1) | 2 (4.2) | 16 (18.2) | 16 (18.2) |
| Home use of computer | | | | |
| Never | 7 (10.6) | 5 (10.4) | 4 (4.5) | 8 (9.1) |
| Sometimes[2] | 11 (16.7) | 5 (10.4) | 5 (5.7) | 11 (12.5) |
| Regularly[3] | 14 (21.2) | 12 (25.2) | 31 (35.2) | 27 (30.7) |
| Often[4] | 33 (50.0) | 25 (52.1) | 46 (52.3) | 41 (46.6) |
| Use of computer at work | | | | |
| Never | 0 (0) | 1 (2.1) | 1 (1.1) | 0 (0) |
| Sometimes | 9 (13.9) | 0 (0) | 5 (5.7) | 4 (4.5) |
| Regularly | 20 (30.3) | 14 (29.2) | 17 (19.3) | 21 (23.9) |
| Often | 36 (54.5) | 32 (66.7) | 62 (70.5) | 60 (68.2) |
| Prior experience with an electronic prescription system | 6 (9.0) | 5 (10.5) | 7 (7.9) | 10 (11.3) |

1. Nine nurses who had been forgotten in the first phase received the questionnaire only in the second phase.
2 Once a month or less.
3 Once in a week to few times per month.
4 Daily to few times per week.

tation was similar to that of before the implementation, gave a higher mean score for the computerized process than for the paper-based process (3.6 *vs.* 3.2; $p<.001$). However, in TIMED units in which the electronic system brought a completely new work structure for nurses, the overall mean score of the computerized process was not significantly different from that of the paper-based process (3.5 *vs.* 3.4, $p>.05$). Figure 3.4 shows median, interquartile range, and whiskers for the overall scores of pre- and post-implementation in these two units. Considering the similarity or differences of work structures in pre- and post-implementation phases, there was a significantly greater improvement in the overall score for Kardex units (i.e., from a paper-based to a computerized process) than for TIMED units (mean difference= -0.29; *CI*: -0.55, -0.02; $p<.05$).

Table 3.2 summarizes the mean scores for individual questions and the significance of difference between pre- and post-implementation within Kardex or TIMED units. It also provides the significance of difference between these units with regard to the change scores.

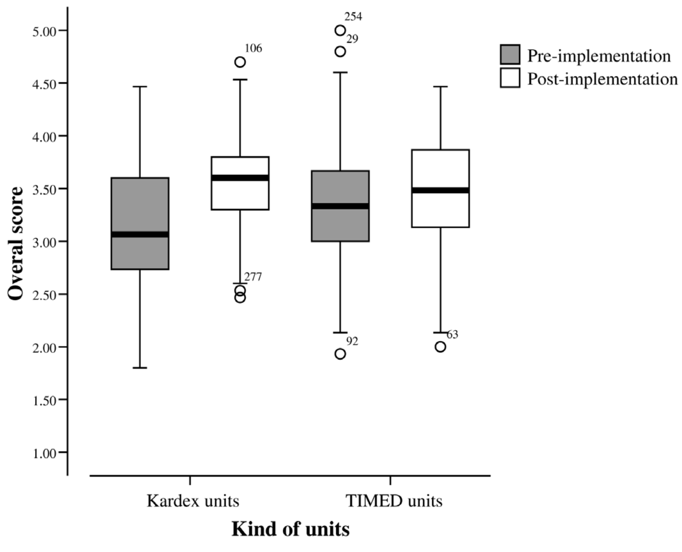



Figure 3.4. Box plots showing median, interquartile range, and whiskers for overall scores of the process in the paper-based systems and the electronic system in different units; in Kardex units the overall score improved after the implementation, $p < .001$; however, in TIMED units, this improvement was not significant, $p > .05$.

Table 3.2. Mean scores to the individual questions in the Kardex and TIMED units categorized based on the paper-based and computerized systems.

| Item# | Questionnaire items | Kardex units | | | TIMED units | | | p value[1] |
|---|---|---|---|---|---|---|---|---|
| | | Mean | | p value[2] | Mean | | p value[3] | |
| | | Pre-implementation (No.) | Post-implementation (No.) | | Pre-implementation (No.) | Post-implementation (No.) | | |
| 1.1 | Overall impression (difficult…easy) | 3.7 (64) | 3.8 (48) | NS[4] | 4.2 (87) | 3.9 (86) | †† | † |
| 1.2 | Overall impression (rigid…flexible) | 3.2 (64) | 3.3 (46) | NS | 3.5 (83) | 3.0 (85) | †† | † |
| 1.3 | Overall impression (frustrating…satisfying) | 2.9 (62) | 3.7 (46) | ††† | 3.2 (84) | 3.5 (84) | † | † |
| 2.1 | The lay- out of the medication orders (confusing…clear) | 3.3 (64) | 3.4 (48) | NS | 3.7 (88) | 3.6 (87) | NS | NS |
| 2.2 | The legibility of the medication orders (bad…good) | 2.1 (66) | 3.9 (48) | ††† | 2.8 (88) | 4.0 (88) | ††† | †† |
| 2.3 | The completeness of the medication orders (bad…good) | 2.9 (66) | 3.7 (48) | ††† | 3.4 (88) | 3.9 (88) | ††† | NS |
| 3.1 | The arrangement of data (unhelpful…helpful) | 3.5 (66) | 3.7 (48) | NS | 3.7 (88) | 3.8 (88) | NS | NS |
| 3.2 | The lay-out of the drug overview form (confusing…clear) | 3.4 (66) | 3.6 (48) | NS | 3.5 (88) | 3.8 (88) | †† | NS |
| 3.3 | The drug overview form (unreliable…reliable) | 2.9 (66) | 3.6 (47) | ††† | 3.2 (87) | 3.7 (88) | ††† | NS |
| 3.4 | The administration record (confusing…clear) | 2.9 (66) | 3.5 (48) | †† | 3.1 (88) | 3.3 (88) | NS | † |
| 3.5 | The administration record (unreliable…reliable) | 3.0 (65) | 3.4 (46) | †† | 3.2 (88) | 3.1 (88) | NS | † |
| 4.1 | The learning of the system (difficult…easy) | 4.0 (65) | 3.9 (48) | NS | 4.2 (88) | 3.8 (87) | †† | NS |
| 4.2 | The speed of prescribing by physicians (too slow…fast enough) | 3.2 (66) | 3.5 (47) | NS | 3.3 (88) | 2.8 (86) | †† | ††† |
| 5.1 | Insight over available drugs in the pharmacy (unsatisfactory…satisfactory) | 2.9 (66) | 3.2 (47) | NS | 2.0 (86) | 2.8 (85) | ††† | † |
| 5.2 | The ordering of non-stock drugs (difficult…easy) | 3.7 (64) | 3.7 (47) | NS | 3.4 (88) | 3.4 (83) | NS | NS |

1 *p* value by 'T-test' for difference between the change scores in Kardex units and change scores in TIMED units.
2 *p* value by 'Mann-Whitney U test' between pre- and post-implementation in Kardex units.
3 *p* value by 'Mann-Whitney U test' between pre- and post-implementation in TIMED units
4 NS: Not significant; †: $p<.05$; ††: $p<.01$; †††: $p<.001$

### *5.1.2. Overall reactions*

In Kardex units, there was greater satisfaction with the computerized process than with the paper-based process (3.7 *vs.* 2.9, $p$<.001) (item 1.3). This was also the case for TIMED units, where satisfaction was 0.3 points higher with the computerized process than with the paper-based process (3.5 *vs.* 3.2, $p$<.05). The comparison between units showed that the improvement in satisfaction (from paper-based to computerized process) was significantly greater in Kardex units than in TIMED units (mean difference = -.5; *CI*: -.93, -.01; $p$<.05).

In contrast with Kardex units, nurses in TIMED units reported that their paper-based process was significantly easier to use than the computerized process that was completely new for them (4.2 *vs.* 3.9, $p$<.01) (item 1.1). They also rated their paper-based process significantly more flexible than the computerized process (3.5 *vs.* 3.0, $p$<.01) (item 1.2). Moreover, learning of the computerized process in TIMED units was more difficult than learning of the paper-based process (3.8 *vs.* 4.2, $p$<.01). Kardex-nurses however reported it to be as easy as their paper-based process (3.9 vs. 4, $p$>.05) (item 4.1). TIMED nurses believed that the ordering process by physicians was slower in the computerized system compared with the paper-based system (2.8 *vs.* 3.3, $p$<.01) (item 4.2). The change in attitudes towards speed in TIMED units was significantly greater than the change seen in Kardex units (mean difference = -0.8; *CI*: -1.3, -0.4; p<.001). This difference probably arose because the electronic system completely changed the structure of medication ordering and administration process not only for TIMED-nurses but also for TIMED-physicians. Specifically, it required these physicians to enter detailed orders into the system instead of concise, paper-based medication orders (Figure 3.1b).

### *5.1.3. Characteristics of medication orders*

Nurses in both groups rated the legibility and completeness of medication orders (items 2.2 and 2.3) higher in the computerized system than in the paper-based system ($p$<.001) (Table 3.2). Interestingly, the degree of this improvement related to legibility was perceived to be higher in Kardex units than in TIMED units (mean difference= -0.64; *CI*: -1.1, -0.2; $p$<.01). The computerized system did not change the clarity of the layout in medication orders (item 2.1) compared with that of the paper-based orders, neither in Kardex nor in TIMED units ($p$>.05).

#### *5.1.4. Registration of administration*

In both units, the computerized system was associated with a greater reliability of the drug overview form ($p$<.001) (item 3.3). In Kardex units, the clarity of administration record in the computerized system was significantly greater than that in the paper-based system (3.5 *vs.* 2.9, $p$<.01) (item 3.4). Likewise, the administration record in the computerized system was perceived to be more reliable than that in the paper-based system (3.4 *vs.* 3.0, $p$<.01) (item 3.5). However, after the implementation, TIMED-nurses, who no longer used the flag labels of the administered drugs for registration purposes, reported no any significant_difference between pre- and post- implementation phases with regard to the clarity and reliability of the administration record ($p$>.05) (items 3.4 and 3.5).

#### *5.1.5. Drug delivery request from the pharmacy*

TIMED nurses reported a better insight regarding the available drugs in the pharmacy after the implementation compared with the situation before (2.8 *vs.* 2.0, $p$<.001) (item 5.1). However, in Kardex units, this difference between two phases was not significant ($p$>.05). Moreover, the electronic system did not facilitate the ordering of non-stock medications (item 5.2), neither in Kardex nor in TIMED units ($p$>.05) (Table 3.2).

#### *5.1.6. System preference and workflow support*

When nurses were asked whether they wanted to change the current process (item 6.2), the majority of the respondents in both Kardex (97.91%) and TIMED units (79.31%) preferred to continue using the computerized system. However, as the Mann–Whitney U tests showed, nurses believed that the computerized system did not support their work processes more than the paper-based systems did (item 6.1); this was the case for both Kardex ($p$ =.07) and TIMED units ($p$ =.38).

### 5.2. Correlation of overall score of the computerized process

Overall score of the computerized process was strongly correlated with the user satisfaction ($r$ = 0.75, $p$<.001), clarity of administration record ($r$ =0.66, $p$<.001, ease of the process ($r$ = 0.63, $p$<.001), and clarity of lay-out of drug overview form ($r$ =0.63, $p$<.001). Overall score was not correlated with professional status, experience with computers at home or work, and the wards where nurses work. Table 3.3 summarizes the correlates of overall score in the computerized process.

Table 3.3. Relationship between overall score of the computerized process and ratings of its specific aspects.

| Item # | Survey items[1] | n.[2] | r[3] | Significance |
|---|---|---|---|---|
| 1.1 | Overall impression (difficult…easy) | 134 | .628 | <.001 |
| 1.2 | Overall impression (rigid…flexible) | 131 | .571 | <.001 |
| 1.3 | Overall impression (frustrating…satisfying) | 130 | .748 | <.001 |
| 2.1 | Layout of the medication orders (confusing…clear) | 135 | .609 | <.001 |
| 2.2 | Prescription legibility (bad…good) | 136 | .493 | <.001 |
| 2.3 | Completeness of medication orders (bad….good) | 136 | .531 | <.001 |
| 3.1 | Arrangement of data (unhelpful…helpful) | 136 | .608 | <.001 |
| 3.2 | Lay-out of the drug overview form (confusing…clear) | 136 | .627 | <.001 |
| 3.3 | Drug overview form (unreliable…reliable) | 135 | .568 | <.001 |
| 3.4 | Administration record (confusing…clear) | 136 | .657 | <.001 |
| 3.5 | Administration record (unreliable…reliable) | 134 | .585 | <.001 |
| 4.1 | Learning of the system (difficult…easy) | 135 | .550 | <.001 |
| 4.2 | Speed of prescribing by physicians (slow…fast enough) | 133 | .467 | <.001 |
| 5.1 | Insight over available drugs in the pharmacy (unsatisfactory… satisfactory) | 132 | .486 | <.001 |
| 5.2 | Ordering of non-stock drugs (difficult…easy) | 131 | .456 | <.001 |
| 7.2 | Specialty | 136 | .204 | <.05 |
| 7.3 | Gender | 134 | .171 | <.05 |
| 7.4 | Age categories | 130 | .182 | <.05 |

1 Items 1.1 to 5.2 are based on a 5-point Likert scale.
2 Not all of the 136 respondents after the implementation answered each question.
3 Spearman correlation coefficient (rho) for the relationship between each item and overall score.

## 6. DISCUSSION

Our study showed that although the system eliminated the workload of transcription and translation tasks for the TIMED-nurses, they showed a less positive attitude compared with the Kardex-nurses. Nurses in both groups benefited from improved legibility and completeness of medication orders and greater reliability of drug overview after the implementation. TIMED-nurses were sometimes less positive about the new medication process than the pre-implementation process, with the new process being associated with increased rigidity and difficulty, and a slower physician prescription speed. These increased problems were not seen by the Kardex-nurses. Furthermore, in TIMED units, the computerized process did not result in a significantly higher overall score compared with the paper-based process. The overall score of the computerized process was most strongly correlated with user satisfaction, clarity of the administration record, and easiness of the process.

Moreover, in our study, nurses in both groups found that the computerized system did not support workflow better than the paper-based systems. However, nurses in both groups favored the medication process after the implementation over the situation before the implementation. It is often expected that the process following computerized physician order entry becomes more efficient for nurses [19]. However, our cases showed that in spite of a higher satisfaction and perceived advantages of the system, none of groups reported a greater workflow support after the implementation compared to that of the paper-based systems. Similar to this finding, in one survey of ICU nurses, 56.7% of respondents commented that the post-CPOE workflow had become less efficient, although they were also generally satisfied with the system [20]. These findings therefore imply that workflow support with a CPOE system is a multi-layered issue and suggest that greater satisfaction with a system is not necessarily a reflection of better support for workflow. Because medical workflow is complex and multidimensional, efficiency of the process in fact depends on the interplay between multiple factors in workflow [21]. A health professional user may be satisfied with some aspects of the workflow involving the system while dissatisfied with other aspects. In a mixed method study, we further investigated this issue in TIMED units [22]. We found that while the CPOE system improved certain non-supportive features of the TIMED-system, it lacked its main supportive features.

Sociologists who study medical practice often assert that the construction of medical practice is intertwined with the capabilities of tools used in daily practice [23, 24]. Two different paper-based orders in our case therefore were the representatives of two different nursing organizational processes. In Kardex units, some of the social structures of the medication process incorporated into the system were similar in the paper-based and computerized processes. Based on the principles of 'Adaptive Structuration Theory' described in our theoretical background, we suggest that the familiarity of the Kardex-nurses with these structures led to more positive perceived effects. In contrast, the implementation of the system imposed new social structures for the workflow of TIMED nurses resulting in less positive perceived effects. It therefore could be the case that the TIMED-nurses, as a consequence of a different work organization, experienced more difficulty in appropriation of the system in the practice.

The concise and semi-structured physician orders in the TIMED system were highly abstract representations of orders. Our results can be understood if we consider that the translation and transcription tasks to process these orders compelled nurses to take a more active role in the medication process. Nurses would here assume a more authoritative position in the medication process than their counterparts in Kardex units. While the roles and responsibilities of nurses in Kardex units remained intact, the implementation of the CPOE system may have changed and challenged the position of nurses in TIMED units. This is in accordance with previous studies that emphasize the organizational context of clinical practice in which the implementation and application of a CPOE system take place [25, 26]. Aarts and Berg in a qualitative study of two hospitals described how changes in the existing organizational contexts resulted in different outcomes of the implementation of the same CPOE system [27]. In our case, TIMED nurses judged the effectiveness of the new process in light of the effectiveness of the paper-based process (Figure 3.4). This suggests that user perceptions can be influenced by *the extent to which* a technology *changes* established work patterns.

### 6.1. Unexpected results and unanswered questions

Unexpected results were also seen in our study. In both our study and the study by Lee et al. [4], nurses were pleased with improved legibility and completeness of medication orders. However, the computerized system in our study did not improve the clarity of the layout in medication orders, even though a relationship between the two had been expected. Clarity of the layout refers in general to the ability of nurses to clearly visualize a medication order or its concepts. Some studies have suggested that the negotiation between nurses and physicians during medical rounds helps a nurse to understand an order better [28]. Although the limited negotiation between physicians and nurses with the implemented CPOE system may explain our finding, another reason might be the fact that the highly detailed medication orders are all printed with black ink, making all orders look alike and prohibiting the use of any of the visual cues that are available in paper-based orders. These factors can reduce the clarity of an order and thereby make it difficult for busy nurses to correctly understand the orders. Hence, the clarity of an order entails more than just legibility and completeness.

Furthermore, in theory, a computerized order entry process should improve communication of nurses with the pharmacy department, since many elements in the order entry process are automated. The CPOE system examined in our study did not achieve this: it did not appear to facilitate ordering of non-stock items from the pharmacy. This quantitative study provides no answers about how and why this was the case. In a qualitative study, we explored how the organizational and social context in which the system was implemented affected its intended behavior [29].

Moreover, to determine a possible carry over effect, we did a sub-analysis on the wards that implemented the system early versus those that implemented it late. No differences in change in satisfaction and overall score were seen between the wards in Kardex units that implemented the system early *vs.* those that implemented it later. While differences in change in satisfaction and overall score were seen between wards in TIMED units that implemented the system early *vs.* those that implemented it later, collinearity made it difficult to determine whether this was due to early *vs.* late implementation or due to other reasons (e.g., type of ward).



### 6.2. Strengths and weaknesses of the study

User satisfaction studies often tend to focus on an IT system's technical characteristics [18, 30]. In our study, we were interested in evaluating the perceived effects of CPOE on different activities in the nursing medication process. To our knowledge no other study has performed a before-after CPOE implementation study of two different paper-based systems. While other studies have extended our understanding of nursing practice in paper-based and CPOE-based environments, they have mostly described the CPOE environment and compared it with a paper-based environment (see, for example [11, 28]). These studies did not use the same pool of personnel in the two environments. We found that a study of similar groups of respondents before and after implementation of a CPOE system can yield valuable insight into the true impact of the system on workflow. Two other strengths of our study are the similarity of respondent groups and the absence of any relevant differences between the two phases (besides the implementation of a CPOE system). These factors reduce the chance that there are other explanations for our findings.

However, our study has limitations that deserve discussion. First, we focused on the perceived impact of the system on nursing practice and did not measure the actual impact of the system on the quality of care (e.g., the quality of medication orders). This was beyond the scope of this study and should be examined more carefully in the future. Another possible limitation is non-response bias which may have arisen during our study. Our results therefore have to be interpreted cautiously. Since the participation rate in this study was fairly good (70.6% of nurses), this would suggest that the impact of non-response bias was limited, though a higher rate would be more convincing for validity purposes. Third, our findings mainly relate to the transitional phase of a CPOE implementation project. The long term impact of a CPOE system would require taking measurements after a longer period of time. By that time users would have become more acquainted with the strengths and weaknesses of the system and thereby more capable of identifying and reporting them.

## 7. CONCLUSION

Implementing CPOE systems reorganizes the medication work. These systems are referred to as transformational technology and nursing practice is not an exception. The pattern of nursing work in general and their roles and responsibilities in particular are all affected. Yet, the perceived impact of the system on nursing practice depends in part on the extent to which the system changes existing work patterns. Use of AST allowed us to explain why the outcome of transition from a paper-based to computerized process can vary widely across groups that are using the same information technology. However, our approach does not explain how these two groups appropriated this technology in their practice. Observational studies are needed to describe and explain the appropriation process.

Our study suggests that not merely the CPOE system, the technology itself, influences the perceptions of its users. The size of the differences between pre- and post-implementation work processes can also play an important role. Large differences can in fact make it much more difficult for health professionals to switch from a paper to a computerized system. The strengths and limitations of a new system for existing work organizations should therefore be carefully considered beforehand. If a difficult transition is expected, activities such as extra support or training sessions can be planned to alleviate that. This insight should inform strategies for change management when these systems are being designed, implemented, and maintained.

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# APPENDIX 3.1. QUESTIONNAIRE ON EVALUATION OF DIFFERENT MEDICATION SYSTEMS

*Please select the option that best represent your opinion for the following questions:*

**1. Overall impression**

What is your general impression about the TIMED-system/Kardex-system/CPOE system[1]?

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1.1. | | difficult | 1 | 2 | 3 | 4 | 5 | easy |
| 1.2. | | rigid | 1 | 2 | 3 | 4 | 5 | flexible |
| 1.3. | | frustrating | 1 | 2 | 3 | 4 | 5 | satisfying |

**2. Characteristics of medication orders**

What is your opinion about the medication order?

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2.1. | The lay- out of the medication orders is | confusing | 1 | 2 | 3 | 4 | 5 | clear |
| 2.2. | The legibility of the medication orders is | bad | 1 | 2 | 3 | 4 | 5 | good |
| 2.3. | The completeness of the medication orders is | bad | 1 | 2 | 3 | 4 | 5 | good |

**3. Drug overview and drug administration record**

What is your opinion about the registration of administered drugs?

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3.1. | The arrangement of data is | unhelpful | 1 | 2 | 3 | 4 | 5 | helpful |
| 3.2. | The lay-out of the drug overview form is | confusing | 1 | 2 | 3 | 4 | 5 | clear |
| 3.3. | The drug overview form is | unreliable | 1 | 2 | 3 | 4 | 5 | reliable |
| 3.4. | The administration record is | confusing | 1 | 2 | 3 | 4 | 5 | clear |
| 3.5. | The administration record is | unreliable | 1 | 2 | 3 | 4 | 5 | reliable |

**4. Speed and ease**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 4.1. | The learning of the TIMED-system/ Kardex-system/CPOE system is? | difficult | 1 | 2 | 3 | 4 | 5 | easy |
| 4.2. | The speed of prescribing by physicians is | too slow | 1 | 2 | 3 | 4 | 5 | fast enough |

**5. Managing of non stock drugs**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5.1. | Insight over available drugs in the pharmacy is | unsatisfactory | 1 | 2 | 3 | 4 | 5 | satisfactory |
| 5.2. | The ordering of non-stock drugs is | difficult | 1 | 2 | 3 | 4 | 5 | easy |

1. The kind of system in each questionnaire was dependent on the system used in the respondents' wards at the time of each survey.

**6. Workflow support**

6.1. Does the TIMED-system/Kardex-system/CPOE system support your work processes?

O Yes
O I am not sure
O No

6.2. Do you like to start using the CPOE system?/Do you like to go back to the handwritten TIMED-/Kardex-system?

O Yes
O I am not sure
O No

**7. Personal data**

7.1. Professional status

O Practicing nurse
O Head nurse
O Student nurse
O Others ………………………

7.2. Specialty

………………………

7.3. Gender

O Male
O Female

7.4. Year of birth

………………………

7.5. Home use of computer

O Never
O Sometimes (once a month or less)
O Regularly (once in a week to few times per month)
O Often (daily to few times per week)

7.6. Have you worked with an electronic prescription system before?

O No
O Yes, a patient data management system
O Yes, Medi/Medicator
O Yes, with program named……………………

7.7. Do you use computers at work?

O Never
O Sometimes (once a month or less)
O Regularly (once in a week to few times per month)
O Often (daily to few times per week)

Responding to the survey can be anonymous. However, if you fill in your name, we can ask for further clarification if something is not clear when we analyze your responses.
Results of this survey will be reported fully anonymous.

Name ………………………………………………………………
Personnel identification number ………………………………………………………………

Thank you very much for your cooperation.

# Chapter 4

## Computerized Provider Order Entry System – Does it Support the Inter-Professional Medication Process? Lessons from a Dutch Academic Hospital

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## ABSTRACT

**Objectives:** To assess the effects of a CPOE system on inter-professional workflow in the medication process.

**Methods:** Twenty-three semi-structured interviews with physicians, nurses, and pharmacists were conducted in a Dutch academic hospital. In addition, the handwritten and system-generated documents used daily were collected for analysis. Data was analyzed on the basis of three conceptual themes in the inter-professional workflow: division of tasks, flow of information, and task coordination.

**Results:** The CPOE system reorganized the existing work procedures, affecting the workflow among the three professional groups both advantageously and disadvantageously. The system resulted in the reassignment of tasks and reallocation of areas of expertise in the medication process. Moreover, patients' medication-related information became fragmented in both the paper records and in the electronic records, as well as in different professional domains. The system provided limited support for professional groups to coordinate their tasks temporally. It also made it difficult to build mutual intelligibility upon new changes in the medication plan. To integrate tasks, the professional groups had to bypass the system or add new steps and extra coordinative tasks.

**Conclusion:** We identified several workflow integration issues after the implementation of a CPOE system. Our insights into these issues can help ensure that the system design or redesign properly integrates all tasks, information, and areas of expertise of professional groups into those of the physicians.


**Keywords:** Medical Order Entry Systems; Computerized Physician Order Entry; Clinical Workflow; Evaluation Studies; Collaboration; CPOE.

## 1. INTRODUCTION

The deployment of computerized provider order entry (CPOE) systems in hospitals is increasingly encouraged, especially after the Institute of Medicine (IOM) advocated these systems in its two consecutive reports [1, 2]. Despite all the interest in and potential benefits with regard to implementing these systems, the real implementation and application rate is relatively low [3]. Their implementation especially in inpatient settings has proved to be difficult, partly because CPOE systems have been shown to support clinical workflow poorly [4-6].

An issue that is gaining attention in the literature is that the workflow model embedded in CPOE systems does not match actual workflow between professionals [7]. These systems enforce a linear, sequential, and unidirectional model of care processes, while clinical workflow is distributive, collaborative, and interruptive [8]. Moreover, the design of these systems is often narrowly focused on the work of physicians, with the result that the collaborative and multi-professional nature of medical workflow has been overlooked [9, 10]. Studies have shown that, for example, nursing records may have important medication data that are critical for safe management of medications but they may be overlooked when these systems are used [11, 12].

There is evidence to suggest that CPOE systems transform the roles and responsibilities of care professionals and the way they carry out their tasks and establish and maintain work relationships [13-15]. Such transformations can frequently cause interruptions or overloads in the work of care professionals [6]. To compensate for such breakdowns and to ensure a smooth workflow, professionals may frequently be forced to deviate from the underlying workflow model required by these systems [8]. Despite the importance of the topic, the literature to date has paid little attention to how well the design of these systems takes into account the *multi-professional* and *interdependent* nature of clinical workflow. In fact, very few studies have evaluated the impact of CPOE systems specifically on the *inter-professional* relationship in the medication process.

The objective of this study was to analyze the effects of a CPOE system on inter-professional medication work in a Dutch hospital. In a quantitative, before-and-after implementation study, nurses reported that the computerized system did not support their workflow in the medication process better than the paper-based systems did [16]. A mixed-method study in internal medicine wards showed that although the system improved the main non-supportive features of the paper-based system, it lacked its main supportive features for nurse-physician collaboration [17]. Intrigued by these findings, we aimed at further evaluating the workflow among the three main professional groups involved in the medication process: physicians, nurses, and pharmacists. For this purpose, we conducted a qualitative study, in which we examined the role of the system in integrating the work of one professional group with that of the others. In particular, we were interested in identifying areas of the inter-professional medication work which are either supported or impeded by the implementation. The insights from this study can help in the redesign of both systems and care processes, thereby creating a better fit between the system and the multi-professional nature of the medication process.

## 2. THEORETICAL BACKGROUND

Our study was inspired by Wears and Berg, who pointed out that "many of the difficulties do not result from bad parts of the systems but are inherent in the perspectives and theories of medical work (and the role of IT in this work)" on which these systems are founded [18]. The medication process, for example, involves multiple health professional groups. Although they may be spatially distributed throughout a hospital, their work is highly interconnected because they are dependent upon each other in terms of skill, knowledge, expertise, and physical assistance [19]. This interdependency, combined with the *ad hoc* nature of medical work, makes it highly collaborative. For health care information systems (HISs) to fit in this work, they should adequately support collaboration among different professional groups [20].

To examine the interplay between the collaborative nature of health care work and HISs, we drew upon studies of medical work carried out in the social sciences and in the field of computer-supported cooperative work (CSCW). Three themes were identified to be relevant to conceptualize the workflow between professional groups using information systems: division of tasks, flow of information, and task coordination [21-23].

In the medication process, an effective division of tasks is required that takes into account the work domains of different professional groups [21]. This can help to avoid possible conflicts among co-working professionals and enable them to construct actions as well as interactions. However, the conditions of the practice greatly influence how strictly to follow this division [24]. Moreover, the medication process is information-intensive. Each professional domain collects and documents a set of patients' medication-related data. The medication data produced in different professional domains should be communicated timely and clearly and integrated with that of others in order to enable collaboration among them [22]. Strauss called this "information work" [24]. However, the *ad hoc* nature of the medication process can cause a medication plan to change frequently. Different professional groups therefore are required to coordinate their interrelated tasks and also to ensure a shared understanding of the medication plan [23].

Figure 4.1 provides a visual model of the inter-professional workflow in the medication process among physicians, nurses and pharmacists. It also depicts the relationship among the three concepts discussed above. In this model, the division of tasks among the three professional groups serves as a core. On the basis of this division and the flow of information gathered in different professional domains, these professional groups can coordinate their interdependent tasks.

## 3. METHODS

This study is based on a qualitative study of a CPOE implementation at Erasmus University Medical Center, a 1237-bed, academic hospital in Rotterdam, the Netherlands. This hospital began to implement a commercial computerized medication order entry system (Medicatie/EVS®, iSOFT, Leiden, the Netherlands) in 2001. A detailed description of Medicatie/EVS can be found elsewhere [25]. It took 5 years to implement the system hospital-wide in both inpatient and outpatient settings. The last inpatient unit implemented the system in March 2005. Medicatie/EVS was chosen for implementation because of its compatibility with the hospital's existing information systems. The system has been integrated into other existing information systems in the hospital except the patient data management system used in the intensive care units (ICUs). Medicatie/EVS can be accessed in all physicians' offices as well as through every computer that is connected to the hospital network.

Order entry by physicians into this CPOE system has been mandatory since the introduction of the system; in principle, nurses and pharmacy staff do not accept hand-written prescription orders. As a result, for hospitalized, non-ICU patients, physicians directly enter almost all medication orders into the system. Nurses then receive printed medication-order labels (MO labels), which they affix to a paper-based, medication administration record (Kardex-card). Nurses register the administration of a prescribed medication by placing a signature in front of each MO label. Details of these documents have been published elsewhere [17]. Nurses use the electronic system to request non-stock medications from the pharmacy. The medication ordering and administration process after the CPOE system in this hospital has been described in detail elsewhere [16, 17].

We conducted 23 semi-structured interviews between November 2006 and June 2007. The first and the second authors, who have a background in Medicine and Health Informatics, carried out the interviews. The interviews were in-depth, one-on-one, and face-to-face. The interviewees were among the informant key users of the system. In clinical wards, we interviewed 12 nurses and eight physicians, who acted as a link between the implementation team and the clinical end-users. They were recruited from medical specialties, including general internal medicine, gastroenterology, nephrology, hematology, and pulmonology and surgical specialties, including general surgery, urology, and neurosurgery and pediatrics. We also interviewed two hospital pharmacists—one of them was also the project leader of the implementation team—and one pharmacy technician.

The majority of the interviewees had experienced working with the paper-based medication systems in the hospital before implementation of the CPOE system. They also had everyday interaction with the electronic system after implementation. All the interviews were performed in the interviewee's working environment. This allowed the interviewers to observe how the interviewees used the system in the medication process. This also made it possible for the interviewees to provide us with a concrete example in the event that something was difficult to explain in words.

During the interviews, we reviewed and discussed the medication process, the interviewees' role in the process, and the effect of the system on their work. We were specifically interested in the effects of the system on the areas of medication work shared between two or three professional groups and requiring their close collaboration and coordination. The interviews were voice-recorded and transcribed and the transcripts were analyzed on the basis of the three themes defined in our conceptual model (Figure 4.1). The first two authors analyzed data and the results were discussed among the other authors. To analyze their role in the workflow, we also examined the documents used in daily work, both handwritten artifacts (including medication administration records, what-to-do lists, and appointment forms) and system printouts (including MO labels and the patients' current medication overviews [AMO]). These documents were accessed through both the interviewees and the implementation team.

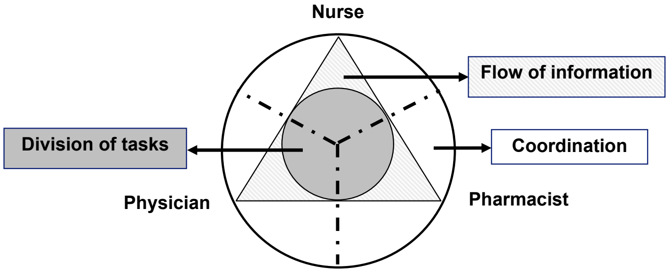


Figure 4.1. A conceptual model for inter-professional workflow in the medication process.

## 4. RESULTS

The results are presented here on the basis of the three themes defined in our theoretical background. Per theme, we particularly focused on workflow between two or more professional groups in the medication process.

### 4.1. Division of tasks

By forcing strict levels of authorization for executing tasks, the CPOE system reinforced professional boundaries. In some cases, this was perceived as beneficial. All professional groups had no doubt that the electronic medication orders had been initiated by physicians because only physicians were authorized to do so. The pharmacy's doubts about the legitimacy of nursing staff to request non-stock drugs were, for example, considerably removed because this could be simply checked in the system. Furthermore, nurses were happy that they were no longer questioned by other professionals about who made changes in an order, and when and why. Only physicians could change medication orders in the new situation, and all changes were registered in the system.

In other cases, however, this strict task division negatively affected workflow by reallocating areas of expertise and by reassigning tasks. The concept of physician order entry in this system enforced a central position for physicians in the order entering process. This meant that, for example, physicians were sometimes forced to decide on the details of orders that were beyond their areas of expertise. One physician, although generally satisfied with the system, commented:

> *"When you have to put 10 prescriptions, then you have to check for all [details], [for example] let's go to IV: IV white, IV peripheral, IV cen-*

*tral… or just IV; it doesn't matter… these are very specialized." (February 2007)*

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Physicians also had to react to safety alerts related to drug administration interval recommendations that could normally be handled by nurses. Nurses frequently referred to their need for such decision supports for their own work; however, they had no access to it, nor did they have access to the responses of the physicians to the alerts given at the time of ordering.

Order entry by the system removed order decryption and transcription tasks for nurses in the handwritten practice; however, the centralized decision-making by physicians violated the nurses' work domain in some instances. Nurses experienced difficulties in implementing physicians' detailed medication orders, particularly with regard to time and route of administration. For example, they often had to adjust the administration timing to fit into nursing work routines, and they did so by manually registering these adjustments on the order labels. Although this approach worked well for available drugs in the ward stocks, problems arose when such adjustments required nurses to request non-stock drugs from the pharmacy. For instance, before the implementation of the CPOE system in surgical wards, nurses could, on their own initiative, change a patient's IV antibiotics to oral forms after three days of infusions. After the implementation, however, they had to remind it to physicians and wait for them to change the orders in the system, because the pharmacy would refuse the nurses' requests for drugs in the absence of electronic orders.

It emerged from the interviews that the boundaries between professional groups with respect to the decision-making process may blur in practice. Physicians and nurses often referred to instances in which physicians delegated the decision-making to nurses and the nurses were supposed to take action independently, especially in hectic situations. The following quote from a neurosurgery nurse spells the point out:

*"…In such [emergency] conditions we administer the drugs by ourselves and we do not wait for MO labels. It depends on trust-making between doctor and nurse…. When you start to work here, you do not get someone like a doctor to work with you and supervise your work completely. Sometimes the physician says "You do this and if you have*

> *a problem then contact me". … Sometimes you have to make a decision." (February 2007)*

### 4.2. Flow of information

Using the CPOE system enabled physicians to have an overview of the availability of drugs or the alternatives at the pharmacy. This in turn decreased interruptions caused by the pharmacy calling to discuss an alternative for an unavailable prescribed drug. Furthermore, the system improved the flow of patient-specific, medication-related information from physicians to nurses and to the pharmacy. This was especially the case due to legible and complete electronic medication orders, saving many callbacks to physicians for order verification and prescription reason inquiries. The following note from a nurse highlights this:

> *"In the paper-based medication system it was hard to read the handwriting of doctors and sometimes you had to show it to three people, each one telling you something different. But now the prescriptions are readable and you know when to start what, when to stop it, and which doctor wrote it." (February 2007)*

A pharmacist also explained:

> *"Sometimes physicians don't want to order the medication that is selected by the system, but another one; then they enter the reason [into the system] why they want to have another drug." (November 2006)*

In routine daily work, nurses received large numbers of MO labels after physicians entered their orders into the system. This required nurses to sort the labels out per patient and put them into the correct administration records. Nurses perceived this step to be highly error-prone. They frequently stressed the necessity to be extra vigilant when working with these small labels, mainly because their uniform black and white structure sometimes caused nurses to mix them up for different patients. While comparing the new process with the paper-based ordering process, an internal medicine physician remarked on this issue:

> *"… [Now] I don't think that there is less [possibility for] mistakes because of MO labels. Because there is a very small place for comments [on MO labels] and everything is very, very tiny and small." (June 2007)*

To ensure an accurate flow of information, nurses therefore had to ensure that they had attached the correct medication labels to the right patient's Kardex-card. For this purpose, nurses were obliged to double-check once a day each patient's MO labels with a medication overview printed out from the system (AMO). Moreover, in order to decrease the chance of missing certain information such as the remarks at the bottom of the labels or the stop dates for drugs, the first nurse who noticed this information was supposed to mark them with a colored highlighter pen so they would be easily noticeable for others as well. During the double-checking phase, nurses looked for any probable discrepancy between the physicians' orders and the MO labels they had collected in a patient's paper-based administration record. This procedure was perceived by them to be extremely time-consuming.

The improvement in information flow was unidirectional: from physicians to other professional groups. Unfortunately, the system lacked the functionality to allow information transactions in the reverse direction. Because nurses recorded medication-related information on the Kardex-card, the medication data became fragmented in the electronic and the paper-based systems. During prescription by the system, physicians therefore had practically no easy access to the administration records, which were affixed on a mobile medication administration cart. Because the system was not available at the patients' bedsides, both physicians and nurses used a printout of the system (AMO) to gain an overview of a patient's current medications. Nevertheless, this printout could not provide all the medication information needed during medical rounds because it was only a list of what had been prescribed, not what had been administered, or when and how often. To develop comprehensive and integrated patient medication information, this information therefore had to be communicated directly between physicians and nurses.

The flow of information through the system between nurses and the pharmacy was insufficient, although it had been improved compared to the way it was before the implementation. To compensate, both groups were using phone calls to acquire necessary information, as was reflected in the interviews with nurses and the pharmacy technician.

### 4.3. Task coordination

Coordination through the system was mainly asynchronous. The medication-related tasks among professionals were therefore coordinated by other methods of communication and not only through the system. In fact, none of the professional groups actually counted on the system for secure coordination. While phone calls played an important role in coordinating interdependent tasks between professionals from different services (such as physicians and pharmacists, or nurses and pharmacy technicians), physicians and nurses who worked closely together still relied on face-to-face communication.

In most of the specialties interviewed, physicians and nurses discussed the overall medication plans in medical rounds, during which the majority of the decisions on changing medication plans were made. For reference, nurses often made notes on these decisions or, in some wards, they asked physicians to issue preliminary, concise, hand-written medication orders before the orders could be entered into the system. Without these rounds, there was little possibility for a shared understanding of the medication plan to be developed; both groups therefore depended on direct communication and discussion.

Nevertheless, despite discussions during medical rounds, the necessity to have synchronized discussions and order entry process was frequently pointed out by physicians and nurses alike. Both reported it to be common for a patient, for instance, to receive an extra dosage of a medication that should be stopped or to miss one or two dosages that should be started earlier. A physician commented:

> *"... [In the paper-based system] There was less confusion for the nurses…because at the time you were writing [the prescription at the bedside], they were with you, and they could see what you wanted and what your plan was. I found it better and easier." (June 2007)*

If a change was necessary during the evening or night shifts, physicians would have to inform nurses directly. Or, if nurses were busy with other duties at that moment, they would need to coordinate the change through a paper-based form called "appointment form". This form was primarily a communication medium between nurses and physicians, helping them to coordinate laboratory tests and radiology requests. However, after implementation of the system, they also used it to communicate some of their medication related tasks, especially during evening and night shifts; physicians could write the related changes to the medication plan and/or nurses could use the form to ask any of their medication-related questions.

It was considered risky to rely simply on the system and on the printed labels to coordinate these changes timely. In fact, it was possible for a medication order label to be lost among other papers in the nursing station, or for a printer to fail to print out orders. In such instances, none of the nurses or physicians would be aware of and be able to resolve the problem quickly, unless they noticed the printer's red warning light in time or performed a double-check of AMO and the printed MO labels. It was also possible that nurses received unexpected new order labels or changes in a patient's medication plan. In such cases, they often contacted the prescribing physician, as one senior head nurse noted:

> *"…in such a case [a change in the medication plan], physicians usually tell us; otherwise, if we see there is a controversy between the medication label and our notes, then we [will] call physicians and ask for the reason". (January 2007)*

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Similarly, the procurement of non-stock drugs required nurses to take extra coordinative steps beyond the system. Because the system was not available at the bedside, physicians entered the orders later in their offices. Due mainly to the time pressure caused by other clinical responsibilities after their medical rounds (e.g., operations, outpatient visits, and laboratory results inquiries), they often delayed entering their orders into the system. As a result, nurses were able to send the electronic drug requests to the pharmacy only later in the day. These late non-stock drug requests forced nurses to call the pharmacy when they wanted the drugs the same day:

> *"If I put it [a non-stock drug request] in the computer before 12 o'clock, I will get the drug in the afternoon. But after that time, I need to call [the pharmacy technicians] to tell them that I need it today. Then they will put it in our ward container so that I can get it today. If I put the request in after 12 o'clock and I don't make a phone call, the drug will be here tomorrow." (A nurse, December 2006)*

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The pharmacy technicians checked the electronic requests per ward/per patient twice a day at 8 and 12 o'clock. This way of checking orders was due to an internal policy at the pharmacy to cope with wholesaler delivery times and with the high workload in managing the drug supply for the entire hospital during the course of a day. To emphasize the necessity of same-day drug delivery, this coordination redundancy therefore had become a part of routine and was referred to by nearly all the nurses interviewed.

## 5. DISCUSSION

The CPOE system in our study reorganized the existing work procedures, affecting the workflow among the three professional groups both advantageously and disadvantageously. We noticed that the system mainly benefited physician-pharmacy and nurse-pharmacy workflows, while impeding the physician-nurse workflow. Our study also identified instances in which the system inappropriately integrated the three professional domains, forcing them to bypass the system (e.g., paper-based adjustments to the electronic medication orders), to take extra steps (e.g., double-checking the orders), and to perform extra coordinative tasks (e.g., paper notes, phone calls, or face-to face communication).

### 5.1. practice-oriented inter-professional workflow

Our analysis of the benefits and pitfalls revealed that the workflow model underlying this CPOE system overlooked the overlaps and interdependencies that exist between professionals involved in the medication process. As a result, it challenged their effective collaboration by reassigning tasks, reallocating the areas of expertise, and reinforcing strict boundaries around professional domains. These findings are in accordance with the argument of Gorman *et al.* [7], supporting that under this system the workflow is indeed conceptualized as linear, stepwise, and unidirectional: the flow runs from physicians to the other professional groups. Yet, as elaborated upon in our theoretical background, the medication work is highly distributive and collaborative without a sharp division of tasks among collaborating professionals. Our findings are also in accord with those studies that have emphasized that CPOE systems alter roles and responsibilities established in hand-written practices over a period of years [13, 14, 26]. They also support the argument that these systems may result in centralized decision-making by physicians in the medication process [27]. Physician dominancy in the ordering phase can cause nurses to experience difficulties in their workflow, as seen in our study. Nevertheless, studies have shown that nurses are capable and experienced in managing certain medication-related issues independently, such as handling time adjustments in drug-drug interactions [28, 29].

In the case we studied, the unilateral flow of information from physicians to other professionals together with the limitation of feedback in the reverse direction led to medication-related information becoming fragmented in both the paper records and in the electronic records, as well as in different professional domains. Physicians thus had no easy access to the medication-related information produced by nurses. This condition could be improved by the deployment of an electronic medication administration registration system [30]. However, it must be taken into account that a similar lack of effective data integration has also been found in a highly advanced CPOE with computerized medication administration registration [12]. Therefore, for a safe and aligned medication process, it is fundamental that the interrelated pieces of medication information produced by different professionals are effectively integrated while these systems are being designed and implemented.

We also found that the providers had limited support through the system to coordinate their tasks temporally. Care professionals are busy and mobile, working mainly in places other than around computers and printers. CPOE systems enable providers to enter or change orders from locations outside of clinical units. This is often accompanied by a lack of visual clues such as the presence of a physician at a bedside or the physical existence of paper orders [8]. This can have detrimental effects on providers' situation awareness [31]. The awareness of orders can be improved by proper and timely notifications to the intended professionals. In an approach to identify and address workflow changes after CPOE, it is described how real-time, visual alerts as orders are processed can help different professional groups to maintain their situation awareness [32].

Furthermore, the implementation also impeded shared understanding with regard to changes in patient medication plans. Studies have shown that negotiation between co-working professionals is critical to creating a shared sense of a care plan and to adjusting the work of one professional group with that of another [33, 34]. In our study case, these purposes were served by the medical rounds, which enabled physicians and nurses to negotiate their overall medication plans. Nevertheless, this was not helpful with regard to the details of orders and also to changes that were made beyond rounds: extra communication methods such as paper-based notes, phone calls, and face-to-face communication were used to supplement the information registered in the system. Other CPOE studies have also reported similar coordination redundancies among professional groups for clarification purposes [4, 15]. These methods in turn can increase the workload of already overburdened professionals and can also be a source of interruption.

In this chapter, we reported on the basis of common themes that emerged in the work of specialties we studied. However, it is noteworthy that there were subtle differences among the specialties concerning the way they organized the medication process using the same system. Other social and organizational factors were also influential. First, their work was greatly dependent on the nurse-physician relationship in different wards and the way they co-constructed their interrelated medication tasks around the same system. For example, while the electronic orders were considered necessary in some units to authorize administration of a drug, in others a physician's verbal order was still being accepted by nurses. Moreover, the implementation team in this hospital took great efforts to customize the system based on the wishes of different wards. For example, the hematology wards in this hospital were using a number of different IV-routes in the paper-based system, which were not present in the CPOE system. Because of the complexity of hematology therapy, the hematology department requested adding different IV-routes to the system. However, the generalization of such customizations to other specialties sometimes resulted in annoyance, confusion, and workflow obstructions.

The last, our study identified workflow integration issues in one of the successful implementation sites where all of the physicians were entering their orders directly into the system and the system was fully being used at the time of this study. This is consistent with the argument [5, 35] that CPOE systems may be operational only because providers devise workarounds to bypass the difficulties rather than have the system respond to their needs. There are other examples of how clinicians work around workflow blocks to continue their work after the implementation of an information technology [36]. Similarly, in our case study, professionals frequently bypassed the system and added extra coordinative tasks to integrate interrelated work. The outcome of such workarounds may be varied that merits attention (see further).

### 5.2. Computerized vs. practice-oriented inter-professional workflow

Our study shows a mismatch between the developer's computational workflow model and the real-world, pragmatic inter-professional workflow. It shows how and why a system that is intended to automate and improve one critical step in the medication process thoroughly impacts the other phases as well, both advantageously and disadvantageously. The insights gained in our study invite developers to work closely with different professional groups involved in a clinical process in order to understand, design, and embed more practice-oriented, inter-professional workflow models in HISs. These clinicians are in a unique position to provide feedback on the development process of complex HISs and their impact [37]. Their extensive experience and rich knowledge of a pragmatic workflow would allow developers to accommodate these systems on the basis of users' needs, concerns, and work contexts.

### 5.3. Strengths and weaknesses of the study

Our study is a qualitative evaluation study having triangulation of different sources of qualitative data as its strong point. To our knowledge, this study is one of the few CPOE studies that specifically focused on the inter-professional workflow among key professionals with a bird's eye view of the medication process. Many of the CPOE studies looked at subsets of individual professionals' workflow and not at the overall workflow in a clinical process in the course of a day. As our study also showed, having an overall view of a clinical process, especially one shared among different departments across a hospital, can help to recognize and take into account the conflicts that may exist among their goals and incentives [38]. However, our study has limitations as well. Although it provides a general overview of different specialties, specific workflow impediments may not be well generalized to all specialties in this hospital. Furthermore, some of the impediments in workflow were produced because there was no bedside order entry system or electronic administration system in place. Next, this CPOE system is widely used in other hospitals throughout the country. However, differences exist in the ways the same system has been introduced and applied in these hospitals. In several hospitals, for instance, nurses are allowed to enter orders into the system. Hence, it is possible that the site used in our study is not truly representative of all sites using the same system.

### 5.4. Recommendations for future research

Diverse social, technical, and organizational factors can influence a CPOE system's effects on workflow [6, 16]. In depth qualitative studies are necessary to understand the interplay between these factors following the implementation of a system. Ethnographic studies, for example, are needed to identify context-specific requirements of workflow (e.g., in surgical *vs.* non-surgical specialties) in order to consider them in the (re)design of a CPOE system. Studies also needed to understand and solve *in situ* workflow impediments. In-depth workflow analyses are able to characterize the providers' responses (such as workarounds) aimed at bypassing the workflow impediments [39]. More importantly, the outcome of these responses in terms of the workload of professionals and patient safety should be carefully evaluated in future studies. Finally, a same CPOE system may be implemented in different context of different hospitals. Thus, evaluation of inter-professional workflow with the system in different contexts can provide valuable lessons for system (re)design, implementation, and integration into workflow.

## 6. CONCLUSION

With regard to inter-professional medication workflow, the implementation of a CPOE system is a double-edged sword. Our study not only contributes to a deeper understanding of the interdependent nature of medication-related tasks among professional groups working in the same or different services, but it also identifies where the problems lie with the CPOE system implemented. In our case study, the system caused the physicians to dominate other groups, whose work became contingent on the timely and appropriate execution of physicians' tasks. In order to distribute the benefits of work efficiency fairly, the real-time, *ad hoc*, and interdependent nature of the medication process has to be considered in the design of these systems. Nurses' and pharmacists' inputs into this process should also be taken into consideration. Only then can CPOE systems support actual inter-professional relationships in the medication process.

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# Chapter 5

## CPOE in Non-surgical versus Surgical Specialties: A Qualitative Comparison of Clinical Contexts in the Medication Process

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## ABSTRACT

**Background:** Computerized provider order entry (CPOE) systems are implemented in various clinical contexts of a hospital. To identify the role of the clinical context in CPOE use, we compared the impact of a CPOE system on the medication process in both non-surgical and surgical specialties.

**Methods:** We conducted a qualitative study of surgical and non-surgical specialties in a 1237-bed, academic hospital in The Netherlands. We interviewed the clinical end users of a computerized medication order entry system in both specialties and analyzed the interview transcripts to elicit qualitative differences between the clinical contexts, clinicians' attitudes, and specialty-specific requirements.

**Results:** Our study showed that the differences in clinical contexts between non-surgical and surgical specialties resulted in a disparity between clinicians' requirements when using CPOE. Non-surgical specialties had a greater medication workload, greater and more diverse information needs to be supported in a timely manner by the system, and thus more intensive interaction with the CPOE system. In turn these factors collectively influenced the perceived impact of the CPOE system on the clinicians' practice. The non-surgical clinicians expressed less positive attitudes compared to the surgical clinicians, who perceived their interaction with the system to be less intensive and less problematic.

**Conclusion:** Our study shows that clinicians' different attitudes towards the system and the perceived impact of the system were largely grounded in the clinical context of the units. The study suggests that not merely the CPOE system, the technology itself, influences the perceptions of its users and workflow-related outcomes. The interplay between technology and clinical context of the implementation environment also matters. System design and redesigning efforts should take account of different units' specific requirements in their particular clinical contexts.

**Keywords:** clinical context, CPOE, medication, medical order entry systems, surgical, non-surgical

## 1. BACKGROUND

The successful deployment of computerized provider order entry (CPOE) systems requires a thorough understanding of the clinical workflow that these systems are intended to support [1]. Many diverse socio-technical factors in clinical workflow influence the deployment of CPOE systems [2, 3]. One of these factors, as found in a recent systematic review, is the context of the clinical environment [4]. Ash et al. in a cross-site qualitative study pointed out the importance of context, including the clinical context of a unit in which CPOE systems are put to use [5].

Depending on the patients' needs, hospital care is delivered by various clinical specialties, each one having its own clinical context. The clinical context of a specialty consists of the interrelated conditions within which the examination and treatment of patients take place. The clinical profile of patients and their needs influences how this clinical context is shaped. The clinical context in turn influences both the way clinicians work and their work requirements. In order to determine the impact of the clinical context on CPOE use, Callen et al. compared the use of a computerized test management system between emergency departments and hematology wards [6, 7]. The study showed that different clinical contexts highly impacted the clinicians' use of and attitudes towards CPOE. The research suggested that the contextual variation between clinical units should be taken into account when these systems are deployed. Nevertheless, only a limited number of studies have paid attention to this factor.

Many studies of workflow with CPOE systems include both surgical and non-surgical specialties in their evaluations (see for instance [8-10] ). In a review of the literature [1], we found only a limited number of studies that specifically compared the workflow-related outcomes with respect to the type of specialty [11-13]. Kaplan et al. found that non-surgical physicians issued a larger rate of verbal orders than surgical physicians did after a CPOE system was in place [11]. Bates et al. evaluated the effect of computerized order entry on non-surgical and surgical house-staff time [12]. They found that although both groups spent more time on computerized order writing than on writing orders on paper, ordering with the CPOE system was more time-consuming for surgical staff than for non-surgical staff. They reported that the non-surgical staff recovered some of the time spent in activities that were accomplished more quickly after CPOE. Lee et al. studied the level of satisfaction with the same CPOE system and found that non-surgical clinicians were significantly more satisfied than the surgical clinicians [13].

Interestingly, all three studies used quantitative research methodology; however, none of the three evaluated *why* different outcomes between the specialties were seen. To answer this question, qualitative studies are known to be suitable methods [14]. Nevertheless, to our knowledge, no study to date has qualitatively compared the use of CPOE in the clinical context of non-surgical versus surgical specialties. No other study has identified the role-playing elements in their clinical contexts that affect the impact of CPOE, as well as the clinicians' use of and attitudes towards the system.

The objective of this study was thus to explore and understand which elements of a clinical context play a prominent role in the deployment of a CPOE system and how these elements affect workflow efficiency with the system. Understanding this issue, we believe, can help to identify and address the specialty-specific workflow requirements in design, implementation, and maintenance of CPOE systems in order to correspond better to existing needs. For this purpose, we conducted a qualitative study in which we compared the impact of a CPOE system on the medication process of two different clinical contexts in surgical and non-surgical specialties in a Dutch academic hospital.

## 2. METHODS

### 2.1. Study setting and the CPOE system

This study was conducted at Erasmus University Medical Center, a 1237-bed academic hospital in Rotterdam, the Netherlands. This hospital has been using a vendor-based CPOE system, Medicatie/EVS® (Leiden, the Netherlands) in all inpatient settings except intensive care units (ICUs) since March 2005. The pharmacy department was responsible for both implementing the CPOE system and training its users in the hospital. As computerized physician order entry is mandatory in this hospital, physicians order electronically almost all medication orders for non-ICU, hospitalized patients. Since this hospital is a teaching hospital, the residents order the majority of the medication.

For medication order entry, a physician selects a drug and its dosage form, strength, administration route, dosage regimen, start date and time in Medicatie/EVS® (Figure 5.1). The system generates safety alerts for drug-drug interactions, overdose, and duplicate orders. A detailed description of Medicatie/EVS®

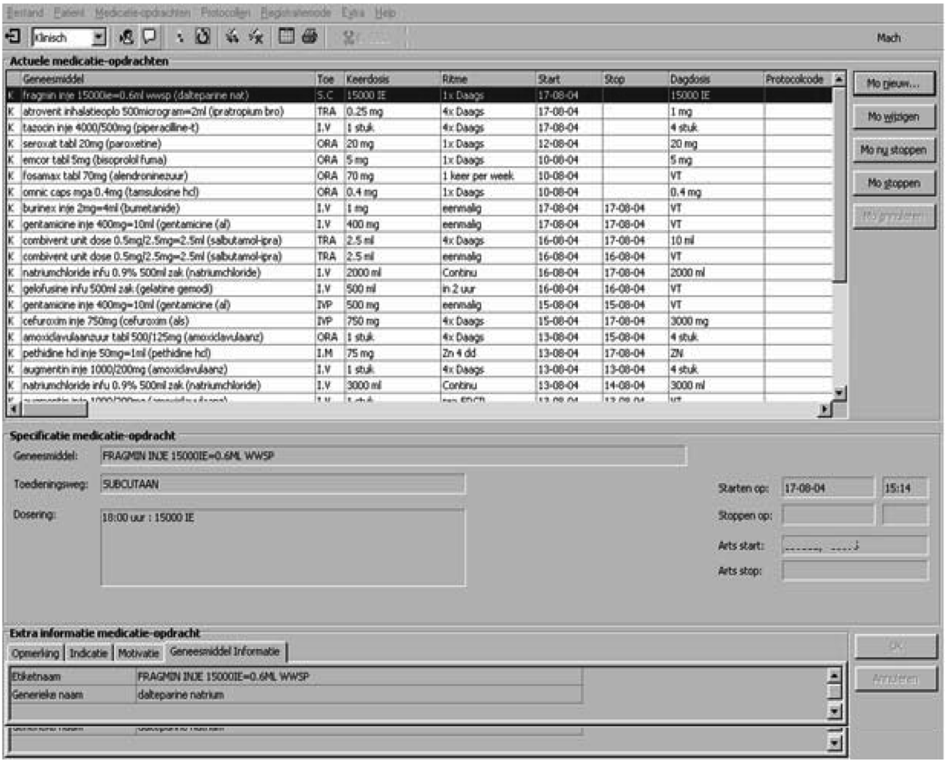


**Figure 5.1.** A screen shot of the CPOE system for physicians.

has been published elsewhere [15]. After physicians enter electronic orders, nurses receive medication orders printed on special labels called medication order (MO) labels. MO labels are then affixed to a Kardex card, which is the paper-based administration registration record. Supply of in-stock medication is controlled by the pharmacy technicians who scan in the ward stock two or three times per week. Whenever an MO label contains an out-of-stock drug, nurses can select the drug in the system and thereby send an electronic drug request to the pharmacy. The system's features are the same in all clinical wards. The details of the medication process, the MO labels, and the administration record have been described elsewhere [16-18].

### 2.2. Study design and data collection

The two types of non-surgical and surgical specialties were chosen for this study because firstly, the differences between their patients' clinical profiles and con-

Table 5.1. Wards and professional status of the interviewees in each specialty type

| Specialty type | Wards (# of interviews) | Interviewees' professional status |
|---|---|---|
| Non-surgical | General internal medicine (two), gastroenterology (two), nephrology (three), hematology (four), pulmonology (one), psychiatry (one), metabolic diseases (one), and pediatrics (two) | Six attending physicians, two residents, two head nurses, and six practicing nurses |
| Surgical | General surgery (three), urology (one), neurosurgery (one), and pediatric surgery (one) | An attending surgeon, a surgery resident, a head nurse, and three practicing nurses |

sequently between their clinical contexts are easily distinguishable. Secondly, in our prior study [17], we noticed some subtle but serious differences between these two types of specialties regarding the impact of CPOE on workflow that merited further evaluation. In this study we aimed at exploring the issue in greater detail, and therefore we collected additional data.

The first and the second authors conducted 25 interviews in total with physicians, nurses, and pharmacists between November 2006 and February 2009. During the interviews we reviewed and discussed the impact of the system on the interviewees' roles in the medication process, their medication-related tasks, their communication and collaboration with other care professionals, and, whenever appropriate, their specialty-specific requirements in the process.

For the purpose of the present study, we used 22 interviews with (16 non-surgical and six surgical) physicians and nurses. Table 5.1 provides details of their wards and professional status. The interviewees were among the respondents to our e-mail invitation sent to the key informant users and those recommended by the head of departments. Participation in the study was voluntary; no incentives were provided for participation. In each specialty type, we purposefully recruited the interviewees from both attending and resident groups. Similarly, we had both head nurses and practicing nurses in each specialty type. This diversity among interviewees helped us to get a better overview of various perspectives concerning the use of the system. It also helped us to get a deeper understanding of the existing clinical contexts. At the time of our study the interviewees had enough experience with the system to report on the process.

The interviews were in-depth, semi-structured, one-on-one, and face-to-face and conducted in the interviewees' own clinical settings. This allowed us to observe how they were using the system and its printouts in the medication process. The field notes of these observations were also considered for analysis. All the interviews were voice-recorded.

### 2.3. Data analysis process

Interviews were transcribed verbatim and analyzed. The analysis sought to elicit inter-specialty differences as reported by clinicians. In this step, we adopted the approach explained by Ash and Guappone for data analysis of a topic that is more known about: using "code lists or templates designed ahead of time" [19]. Drawing upon both the literature and our own experience in this study field, we used the following list of codes to analyze the transcripts:

- qualitative differences between non-surgical and surgical services in the clinical context of the medication process which influence the use of a CPOE system,
- clinicians' attitudes towards CPOE in each specialty type,
- the specialty-specific requirements in the post-CPOE medication process.

For the analysis, the interview transcripts of non-surgical physicians were contrasted with those of surgeons. A similar analysis was conducted for the non-surgical versus surgical nurses.

## 3. RESULTS

The results are presented on the basis of the themes that emerged regarding the difference between the clinical contexts of surgical and non-surgical specialties. These themes were: 1) the clinical profile of patients and their medication orders, 2) information needs and communication patterns of clinicians, and 3) clinicians' attitudes towards the system.

### 3.1. Clinical profile of patients and their medication orders

The clinical profiles of the patients admitted to each specialty greatly influenced the load of the medication work and, consequently, the clinicians' interaction with the CPOE system. Patients in non-surgical units generally had several morbidities and 'medication' was one of the most important interventions to control their illness. Although the number of patients admitted to these two types of specialties was reported equally, the number of medications to start, stop, and change per patient was noticeably higher in the non-surgical units. Non-surgical physicians referred to the workload especially related to newly admitted patients; occasionally they had to issue some 20 prescriptions for a single patient. The higher number of medication orders made them interact more with the system for structured order entry. For non-surgical nurses as well, procuring and administering these medications to patients was an extended process.

In contrast, care in the surgical units was mainly surgery-oriented. During interviews, surgeons emphasized the importance of surgery and that in their units, surgical care is far more predominant than medication work. They did not consider medication work as their 'core business' and pointed out that their patients did not generally use many medications, and if they did, these medications were mainly controlled by other physicians than surgeons during their hospital stay. For example, for patients who had undergone a kidney transplant, the medication work was predominantly conducted by nephrologists. In the case of pain management issues, anesthesiologists were involved. This meant that the number of medications started by surgeons would have been few. During the weekly ground rounds, which were performed together with other physicians, patients' medications were controlled by an internist. One of the surgeons referred to this as an 'automatic backup'. The system supported the surgeons in sharing medication information during their consultation with the internist.

The diversity of the medication orders was reported to be greater in non-surgical units than in surgical ones. The surgeons stated that three groups of medications (i.e., analgesics, antibiotics, and anti-thrombotic agents) comprised almost 80% of the medications used in surgical units. As most of these were normally available in these units' medication stocks nurses did not need to request them from the pharmacy. In contrast, nurses in non-surgical units reported normally having patients using a number of various medications not available in their unit's stocks, requiring them to put timely requests through the system to obtain these medications from the pharmacy.

### 3.2. Information needs and communication patterns of clinicians

As emphasized by our interviewees, higher numbers of medication changes generally followed the higher level of medication use in a unit. This is considered an indicator of a dynamic medication process. To meet this dynamic medication process required clinicians to have timely access to the patients' diverse and most up-to-date information for decision-making as well as for monitoring the effects. The system fell short of furnishing physicians with the full information required, especially in non-surgical wards, because on the one hand, the system was not available when decisions were being made at the patient's bedsides. And on the other hand, when orders were being entered in the physicians' offices, the medication administration records were not available to enable the monitoring the effects. This differed from the flexible and transportable paper-based system which had both medication records and information on the patient's clinical condition available at the bedsides. As a result, non-surgical physicians referred to the cognitive load of having to recall many patients' details from memory. One senior gastroenterologist noted:

> *"…We lost information in the system. If you think of a drug fever in a patient, it will take considerable amount of time and puzzling before you get all the information together—the temperature, changing doses, and medication—, until you discover that a patient's fever has to do with that particular drug…If a patient is using several groups of drugs and has several types of illnesses, especially elderly patients and complicated post-ICU patients, this becomes really important."*

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As the load of medication orders was higher in non-surgical units and ordering them by the system was time-consuming, non-surgical physicians reported issuing many verbal orders. Based on a rough estimate by a non-surgical resident, 5–10 orders in each on-call shift of a resident were first communicated verbally. These verbal orders were entered into the system later on—even a few days later—by the initiating physicians or sometimes by their physician colleagues upon request by nurses.

Non-surgical clinicians were more concerned about the ability of the system to support their on-time communication with nurses than surgeons were. Access to the most updated medication information required non-surgical clinicians to communicate closely. While non-surgical physicians referred to the need to have nursing collected data integrated with their own, for surgeons the verbal communication of this information by nurses seemed sufficient. To integrate diverse information manually, non-surgical clinicians stressed the necessity of applying other methods of communication such as direct notification, phone calls, and co-existing paper-based orders besides the electronic orders. A hematology resident highlighted:

> *"…[with this system] I don't think you can communicate effectively with the nurses, because you always have to tell them or write it down for them, I don't think these computers can replace that."*

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However, the surgeons in our study thought that there was no need for additional communication of orders to nurses beyond the system. While at the time of our research, directly informing nurses about issuing the prescription labels was made mandatory by the implementation team, a surgery resident told us:

> *"…they (nurses) will just receive prescription labels … then they look at the names and put them on the Kardex cards. So, we don't have to call them. But, I think it would be polite if you went along the system and told the nurses that you've put in an order for a drug for Mr. A. It would be good but it isn't a must."*

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Our interviews with nurses also revealed that the communication of orders by the system without verbal notification was considered less problematic by surgical nurses than by non-surgical nurses. This was because surgical nurses received fewer medication orders and if they did, those orders were mainly routine medications that they could manage even without being informed by the surgeons. A surgical nurse explained:

> *"…we know in some operations it is quite normal to have antibiotics. So when we see it [the MO label] we say, 'Yes, OK!' Because, most patients receive antibiotics before the operation starts".*

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The technical problems affecting access to information such as system downtime, printer problems, as well as the support shortcomings of the maintenance team were predominantly put forward by non-surgical rather than surgical clinicians. Non-surgical clinicians were concerned that any unavailability of this "vital system", as one senior attending put it, even for a short period, could hinder their workflow to a great degree. Usability issues, such as the suboptimal presentation of medication information on the computer screen and MO labels were discussed mainly by non-surgical physicians and nurses. It is noteworthy that surgical clinicians experienced these issues less frequently and perceived them as less of a hindrance to their work. Among non-surgical clinicians, however, these problems appeared to be more frustrating. One non-surgical clinician echoed this frustration when he said:

> *"The problem is that although people on the project team are very willing, what a doctor wants is just a running system. He is not an ICT*

> *person [who can] solve the implementation problems. It is not my job, I'm a doctor. It is not my problem if an ICT solution does not work, that is an ICT problem."*

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### 3.3. Clinicians' attitudes towards the CPOE

There were subtle differences between the two types of specialties in clinician's attitudes to CPOE. Non-surgical physicians sometimes expressed less positive attitudes towards the post-implementation medication process than surgical physicians did. In this regard, surgeons expressed more confidence in the CPOE system than non-surgical physicians did. The following quote from a surgery resident spells it out:

> *"I am glad that Medicator [the name users have given to the CPOE system in this hospital] is here now. It's a very good system and a clear program. I don't see any problems [while working with the system] at the moment."*

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However, non-surgical specialists viewed a structural difference between the pre- and post-implementation medication process, especially in the prescribing phase and also in communicating orders with nurses, which sometimes affected their workflow negatively. These specialists often mentioned that the supportive features of the system were somehow offset by the problems they were experiencing in the medication process. For most of them, unavailability of information at the time of decision-making, especially for complex patients as mentioned above, was among its biggest flaws. While comparing pre-implementation bedside order-writing on paper to the electronic order entry in the physicians' offices, an attending physician explained:

> *"In theory, if you work in a very structured way, you visit a patient and then you go to your computer to order medications. The main worry is on the busy on-call shifts with lots of beeping, telephones, and calls from the emergency room. So, it may well be the case that the paper of notes [taken during bedside visits] goes into the pocket of the physician and he runs to the emergency department and starts working there, and three hours later he remembers that he has to do order entry on the*

*ward. Although he can access the system from there, the worrying thing is that the doctor who visited a patient is looking at, let's say, potentially unreliable information and working with a scrap of paper which gives him clues on what to do and what to look for. That is not the best a physician can offer to his patients."*

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There were perceptions among non-surgical specialists that the system served the pharmacy department's workflow more than it served the clinicians' workflow on the wards. One nephrology resident commented:

*"I think Medicator is more or less for the pharmacy [so that they can] see what to deliver; it's not really very good for the practitioners."*

~

Similarly, the lack of ownership in implementing this system was an issue among the non-surgical specialists. A non-surgical specialist commented:

*"In my opinion, the system made a wrong start, and that is because the system was developed particularly by the pharmacists. I can understand the initiatives led to starting the project by the pharmacists, but as the system was introduced it was a pharmacist's system. For the pharmacists it makes things more controllable and easier, although if you look at the prescription process as a chain of events there are many possible flaws in the system."*

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Surgical nurses also seemed to be happier with the system than non-surgical nurses were. While non-surgical nurses referred to the problems especially at the beginning for both physicians and nurses, they reported that they were used to these problems because they "could not change the situation anyway". However, the surgical nurses thought that the CPOE system itself worked pretty well. Their main reason for that was the legible medication orders issued by the surgeons themselves. These nurses reported that the system freed them from preparing the list of medications to be signed by surgeons, as was sometimes the case before the implementation.

Last but not least, the two groups of nurses also held different attitudes towards the sources of the problems causing disruption in their workflow. Surgical nurses thought the problems were caused by the way the users (i.e., surgeons, nurses, and the pharmacy staff) worked with the system and did not associate problems with the system itself. For example, a surgery head nurse stressed that after the implementation nurses perceived their workload to be highly dependent on whether the surgeons entered orders directly after medical rounds or did this later on. Another surgery nurse added:

> *"You know, what I noticed is that it is not a priority for the physicians [surgeons]. They think it's the last thing to do. They don't actually know that we need them to order some medicine."*

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Non-surgical nurses noted the complexity of the post-implementation medication process. These nurses mentioned that the interplay between users and the system-generated printouts demanded extra cognitive efforts as opposed to the paper-based system in which they had all a patient's medication orders on a single sheet. In spite of having legible orders, as majority noted, having to sort out the MO labels per patient resulted in the cognitive overload. A non-surgical head nurse noted:

> *"Every day lots of stickers [MO labels] come from Medicator. They [Nurses] have to put lots of stickers onto the Kardex cards. Sometimes the names of patients, [set in] very small [print], look alike; [then] sometimes one patient's stickers get put on the Kardex card of another patient. So tell me: Is it the nurse's fault or because it [the information] is [in] very small [print]?"*

~

## 4. DISCUSSION

In this study we examined the role of the clinical context in CPOE use. We found that three main elements of the clinical contexts influenced the impact of a CPOE system, and the clinicians' use of and attitudes towards CPOE. The first element is whether the clinical process that a CPOE system is intended to support is one of the *core* activities of a unit. This element defines the load of physicians' and nurses' tasks that are related to a CPOE system. The second element is how information-intensive the process is. This affects the diversity of information needed by clinicians in a clinical process and the communication load among them for gaining access to the information and making sense of it. This element plays a role in determining how well a CPOE system fulfils the information need. The third element is how time-intensive and urgent are the tasks that a CPOE system is intended to support. This influences the need to synchronize the interrelated tasks in a clinical process through a CPOE system. The interplay between these three elements defines the workload of a clinical process in general and the load of clinicians' interaction with the CPOE system in particular.

Our study showed that the differences in clinical contexts between non-surgical and surgical specialties resulted in a disparity between clinicians' requirements when using CPOE. For example, because of the greater use of medications in non-surgical specialties, non-surgical clinicians had a greater and more diverse information needs to be supported in a timely manner by the system. Furthermore, the greater medication workload made their interaction with the system more intensive. These factors in turn collectively influenced the perceived impact of the CPOE system on the clinicians' practice. As a result, the clinicians' different attitudes towards the medication process, the CPOE system, and the sources of problems were largely grounded in the clinical context of the units. In our case, the non-surgical clinicians generally expressed less positive attitudes compared to the surgical clinicians.

Our study underscores Callen et al.'s findings in that the difference between the two types of clinical contexts results in different clinicians' use of and attitudes towards a CPOE system [6]. In our study, non-surgical clinicians were heavy users of the CPOE system and their *core business*, the medication process, was greatly dependent on the efficient usability of the system and its round-the-clock operation. This group required diverse and timely access to the medication-related information for management of patients' medication plans. Their higher medication workload made them interact with the system further and, consequently, to experience and discover the system's usability problems to a greater extent. Experiencing problems, in turn, led the non-surgical clinicians to complain more about the system. This finding differs from Lee et al.'s study in which non-surgical physicians were more satisfied than surgical physicians [13]. Lee and colleagues attributed their finding to the surgeons' lesser experience with their CPOE system at the time of the survey, the inefficient order entry process for medications such as anti-thrombotic agents and analgesics, and the more time surgeons spent on order entry process [12, 13]. However, the surgeons in our study found order entry quite efficient through this CPOE system; it enabled quick and easy order entry of medications used in surgical units. Although the overall structure of the medication process for surgical units looked similar to the non-surgical ones (described in detail elsewhere [16, 17]), the surgical clinicians had considerably less interaction with the system. They had less difficulty, for example, with information access and communication, although similar issues afflicted them as well.

Verbal orders are considered as a risk for medication errors in hospitalized patients [20]. CPOE systems reduce the number of verbal orders [11, 21]. However, verbal communication of orders still exists after CPOE implementation [11]. Consistent with Kaplan et al.'s finding [11], non-surgical physicians in our study reported a similarly high rate of verbal orders. Kaplan and colleagues however did not explain why this was the case. Our qualitative study suggests that the higher rate of verbal orders seen in non-surgical specialties has to do with the greater workload of the medication process for them. Therefore, we argue that here again the three elements in the clinical context of non-surgical specialties, that is, the number of medication orders to enter, their communication load, and the urgency of their implementation, played a role in physicians' use of verbal orders.

Our findings have important implications for CPOE implementation in the mixed clinical contexts of a hospital. Depending on which kinds of orders a CPOE system is intended to support, for example medication, laboratory, radiology or other ancillary orders, the units which will use these orders the most should be identified. Identifying the heavy unit-users of an order entry module is an important issue in the deployment of CPOE systems. This not only helps the mindful investment of time and budget by considering those specialties that would benefit most from the implementation, but it also helps to involve them early in a CPOE implementation project and accommodate their work requirements better after implementation. Such an approach can facilitate managing the change process from paper-based systems to electronic systems [22].

This study suggests that not merely the CPOE system, the technology itself, influences the perceptions of its users and workflow-related outcomes of the implementation. But, the interplay between technology and clinical context of the implementation environment also matters. The study also suggests that workflow support or the lack of it with a CPOE system is dependent on the clinical context in which it is being used. Therefore, the impact on one specialty's workflow and its clinicians' attitudes should not be taken for granted as an indication generalizable to the entire hospital. The voice and choice of each specialty group should be taken into account in implementing and redesigning CPOE systems. These implications are especially relevant in the context of commercial systems, especially because many institutions do not have the expertise to tailor less flexible vendor-provided systems to the differing needs of specialties. This also calls for vendors to take a more active role in implementing such systems and become team players [23].

The last but not least, we have reported on a successful implementation site—as defined by Ash et al. [24]—where more than 80 percent of orders are entered by physicians electronically. However, the efficient use of the system for different specialty types in such successful sites merits further attention. Hospitals should take potential problems in workflow, experienced in the context of the implementation and reported by heavy users, more seriously and invest in on-time and proper solutions. This in turn will benefit the safety of the process, as one of the motivations for implementing such information systems. In fact, as Aarts and Gorman state, safety requires "an approach that addresses the complex interactions between people, and their technologies in specific work environments" [25].

### 4.1. Strengths and weaknesses of the study

To our knowledge, no study to date has qualitatively compared workflow with a CPOE system in surgical and non-surgical services. Triangulation of data at the interviewers' level (i.e., two researchers) and interviewees' level (i.e., diverse clinicians and their professional status in each specialty type) is also one of strengths of our study. One advantage of the diversity at the clinician level was that while the attending physicians referred to the issues related to the implementation process, the residents mainly reported on the practice-oriented issues. This helped us to understand the effect of different factors on workflow. Moreover, rather than focusing on the many advantages that this system has brought to the work of clinicians in both specialty types, we mainly paid attention to identifying the specialty-specific pitfalls and their requirements in the medication process. We believe that this way of thinking about operating systems can help distinguish the interplay between different factors in practice and help redesign both the system and the care process in a more productive way. Our study should *not* be dismissed as merely non-surgical clinicians' dissatisfaction with the system.

There are weaknesses in our study. Most of our interviewees came from non-surgical units. We think this is mainly because the primary list of the key informant users that was used for inviting the participants included more non-surgical than surgical clinicians. Nonetheless, this imbalance might have affected our findings. Next, this chapter detailed the differences between the two specialties in terms of the impact of CPOE on the work of clinical *end-users*. It should be noted that we did not study the impact of CPOE on the clinical *outcomes of patient care* in these specialties, which should be carefully studied in future.

## 5. CONCLUSION

Our findings reinforce the importance of the clinical context in CPOE deployment. This study shows different perceived effects in the same organizational processes with one system in different clinical contexts. This finding highlights the role of various socio-technical elements of a clinical process that affect the outcome of an information technology implementation.

Our study also points out that the heavy unit-users of a CPOE system should be distinguished and involved early in an implementation project. In order to integrate the function of a system with the context-oriented practices of care professionals, system redesigning efforts should focus on end-user's needs and concerns in their particular clinical contexts. The use of one CPOE system in different clinical contexts should be carefully evaluated in future studies. This will help to identify how well one system responds to the specialty-specific requirements of various units and what customizations will benefit these requirements.



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# Chapter 6

## Evaluating the Medication Process in the Context of CPOE Use: The Significance of Working around the System

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## ABSTRACT

**Objective:** To evaluate the problems experienced after implementing a CPOE system, their possible root causes, and the responses of providers in order to incorporate the system into daily workflow.

**Methods:** A qualitative study in the medication-use process after implementation of a CPOE system in an academic hospital in The Netherlands. Data included 21 interviews with clinical end-users, paper-based and system-generated documents used daily, and educational materials used to train users.

**Results:** The problems in the medication-use process included cognitive overloads on physicians and nurses, unmet information needs, miscommunication of orders and ideas, problematic coordination of interrelated tasks between co-working professionals, a potentially faulty administration phase, and suboptimal monitoring of the medication plans. These problems were mainly rooted in the suboptimal usability of the system, the inconvenient technology implementation, the uneasy integration of coexisting electronic and paper-based systems, and certain organizational factors with regard to procuring drugs affecting the technology use. Various types of workarounds were used to address the difficulties, including phone calls, taking multiple paper notes, issuing paper-based and verbal orders, double-checking, using other patients' procured drugs or another department's drug supply, and modifying and annotating the printed orders.

**Conclusion:** This study shows how providers are actively involved in working around the interruptions in workflow by bypassing the technology or adapting the work processes. Although certain workarounds help to maintain smooth workflow and/or to ensure patient safety, others may burden providers by necessitating extra time and effort and/or endanger patient safety. It is important that workarounds having a negative nature are recognized and discussed in order to find solutions to mitigate their effects.

**Keywords:** clinical workflow, CPOE, medication, medical order entry systems, workarounds

## 1. INTRODUCTION

The implementation of computerized physician order entry (CPOE) systems thoroughly transforms existing work practices. This transformation benefits certain aspects of workflow such as better documentation of orders and shorter order turnaround times [1, 2]. Nevertheless, it also challenges other workflow aspects such as collaboration between providers [3, 4]. As a result, workflow issues have been found highly relevant not only for a successful implementation of CPOE systems but also for patient safety practices [5-7].

Studies of the actual use of health care information systems (HISs) in successful implementation sites have raised concerns about how and with what consequences these systems are operational in practice [6, 8-10]. Georgiou and colleagues found that providers responded in different ways to the workflow issues faced after a CPOE implementation, ranging from soft responses and workarounds to hard responses such as new organizational rules [9]. Vogelsmeier and colleagues characterized two categories of workarounds in working with an electronic administration record: those related to workflow blocks introduced by technology and those related to organizational processes not reengineered to effectively integrate with the technology [10]. Koppel and colleagues showed that workarounds are the result of difficulties with the technology as well as of interactions between the technology and other factors such as "environmental, technical, work-processes, workload, training, and policies" [11]. It has been noted that workarounds developed in the use of a CPOE system may blur the workflow problems generated by these systems [6]. Such studies serve to focus attention on the organization of the work with CPOE systems and how it may be affected in a positive or a negative way. In other words, for a smooth as well as a safe workflow, it is highly relevant to evaluate and to understand how health care providers use, misuse, or bypass these systems in practice. However, despite the importance of the issue, only a few studies have attempted to characterize different responses of providers in the implementation environment and their consequences for clinical workflow.

Studies have pointed out the complexity of the medication-use cycle in hospitals, which highly influences CPOE use [12, 13]. In our previous studies on the impact of a medication order entry system on inter-professional communication and workflow, we found that providers often took additional steps beyond the system to cope with disruptions [14, 15]. Intrigued by this finding, in the present study we aimed at investigating how the parties involved in or affected by the implementation handled breakdowns in the medication-use process. These parties were physicians, nurses, the pharmacy department, and the implementation team, whom we will refer to hereafter collectively as "the work organization". Rather than merely focusing on the relationship between these responses and patient safety practices, which is *per se* of great importance, we attempted to extend the approach to explore their consequences for the structure of clinical workflow. More specifically, we were keen to evaluate and to understand the difficulties or breakdowns that take place in the medication-use process in the context of CPOE, their probable root causes, and the responses of the work organization to address them. This, we believe, can provide an insight into how these responses influence the providers' workflow as well as into which strategies can help to improve the situation.

## 2. BACKGROUND

The implementation of an information technology such as a CPOE system is a process of mutual transformation in which the organization and the system transform each other [16]. Wynne referred to the "practical *contextualization* of technology" by users in which they develop informal operating rules by adapting general principles to specific circumstances in order to make the technology work in that situation [17]. This "*contextualization*" process may not follow the full scope of technology, so its driving local interests may be at cross-purposes with the overall technological system. In fact, it is largely the emerging practices resulting from the interaction between a technology, the implementation environment, and its users that determine its outcome rather than its rule-following specifications [17]. To address workflow issues and to ensure that the system operates in such an interaction process, the *sharp end-point users* and the context of the technology use play important roles [18].

"Workaround" is generally defined as a plan or method to circumvent a problem *without* eliminating it [19]. In a medical context, Kobayashi and colleagues have defined workarounds as "informal temporary practices for handling exceptions to normal workflow" [20]. In their view, workarounds represent alternative ways that providers devise to work around the breakdowns in normal workflow. Tucker and Edmondson called that "first order problem solving behavior", which "attempts to remedy the immediate problem but does not try to change underlying conditions that created it" [21]. A study of workarounds after the implementation of an electronic administration record suggests that providers devise workarounds as a means of "first order problem solving behavior" [10]. For the purpose of this study, we define workarounds as informal rules or work methods – not formally considered and outlined in the system design – employed in working with a system to handle a workflow problem [15].

Workarounds may prove to be successful in terms of dealing with in situ workflow blocks and then letting providers finish the daily course of tasks. They may even be used as organizational solutions for difficulties that recur. Yet, as described by Kobayashi and colleagues, they might be unavailable, unstable, or unreliable [20]. More importantly, workarounds – especially unsuccessful ones – can unnecessarily increase the workload of providers as well as their cognitive efforts. A careful analysis of work processes to elucidate unsuccessful workarounds can therefore be one important step towards improving workflow and increasing the system adoption rate.

## 3. METHODS

### 3.1. Study site and the CPOE system

We studied a vendor-based CPOE system (Medicatie/EVS®) at Erasmus University Medical Center, a 1237-bed academic hospital in Rotterdam, The Netherlands. A detailed description of Medicatie/EVS® has been published elsewhere [22]. The hospital began to implement the system in 2001. It took 5 years to implement the system hospital-wide in both inpatient and outpatient settings. The last inpatient unit implemented the system in March 2005. The system has been integrated into other existing information systems in the hospital with the exception of the patient data management system (PDMS) used in intensive care units (ICUs). Except in ICUs, almost all medication orders relating to hospitalized patients are entered by physicians using this CPOE system. The medication administration record (MAR) is still paper based.

### 3.2. Data collection methods

The focus of this study was on the five phases of the medication-use cycle: 1) prescribing, 2) communication of orders, 3) dispensing, 4) administration, and 5) monitoring (Figure 6.1). Three main data sources were collected and used in this study: 1) transcripts of interviews with clinical end-users, 2) artifacts used in daily work, and 3) educational materials to train physicians and nurses to use the CPOE system.

In late 2006 and early 2007, we conducted 21 semi-structured interviews with clinicians involved in the medication-use cycle. Interviews lasted between 25 to 70 minutes (mean interview time 48 minutes). All interviews were conducted in the interviewee's work place, where they could show how they worked with the system in the medication process. All interviewees except one had the experience of working with the paper-based systems that preceded this electronic system. In adult inpatient settings, we interviewed 6 physicians and 12 nurses. They were recruited from key users of the system, representing nonsurgical (including general internal medicine, gastroenterology, nephrology, hematology, and pulmonology) and surgical specialties (including general surgery, urology, and neurosurgery). In the pharmacy department, we interviewed two hospital pharmacists and a senior pharmacy technician. One of the pharmacists was the project manager of the implementation team, and she was involved in patient direct care after the implementation.

The interviews were audio-taped and transcribed verbatim. The interview topics covered the personal background, work experience with the CPOE system and its preceding paper-based system in this hospital, interviewees' roles and tasks in the medication process, their communication and coordination with other professionals, the use of the system and other patients' records for entering and retrieving the medication related information, and the benefits of the system in the medication process as well as the problems experienced in daily work. Depending on an interviewee's role, the questions were organized and directed to cover the five phases of the medication-use process mentioned above.

Moreover, we also collected several paper-based documents and computerized printouts used in the medication process. These documents included: 1) printed orders (MO labels), 2) patient administration records (Kardex cards), 3) patients' current medication overview (AMO list, which contains a patient's latest medication orders), and 4) appointment forms and "what to do lists".

After physicians enter orders electronically, nurses receive them on a 3.5×10 cm self-adhesive prescription label for each medication. These labels contain patient and medication information. Nurses affix these labels onto Kardex cards. Next to the MO labels on the Kardex card, there are empty spaces where nurses sign when they give medication to the patient. The system can also generate three differ-

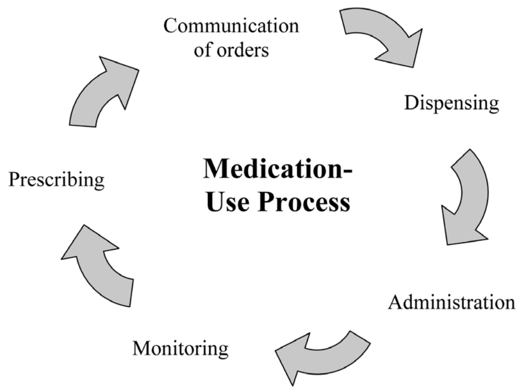


**Figure 6.1.** Five phases in the medication-use cycle

ent types of AMOs that are primarily used by nurses. They have been instructed with regard to the affordances of each type of AMO during their training sessions and in their educational manuals. They print out one AMO per patient each 24 hours. The "appointment form" is originally used to regulate nursing work such as laboratory and radiology requests. Detailed information about MO labels, Kardex cards, and one type of AMO have been published elsewhere [15].

### 3.3. Analysis of data

This study draws upon process mapping in the five phases of the medication-use process after implementation of the CPOE system (Figure 6.1). The definition of workaround mentioned above guided us to identify workarounds developed in our case study. As the interview transcripts were our main data source, the interviewees' own words guided the analysis. To analyze, we read every line of the transcripts and coded them on the basis of problems encountered, their possible root causes, and the informal methods (workarounds) that emerged to address them. The analysis was primarily conducted by the first author and the results were discussed among the others. "Atlas Ti" software was used to assist in analysis of the data set.

## 4. RESULTS

We present our findings based on the five phases in the medication-use cycle (Figure 6.1). In each of these phases, we focus on the problems – interruptions and workflow blocks – encountered and on the workarounds devised to cope with

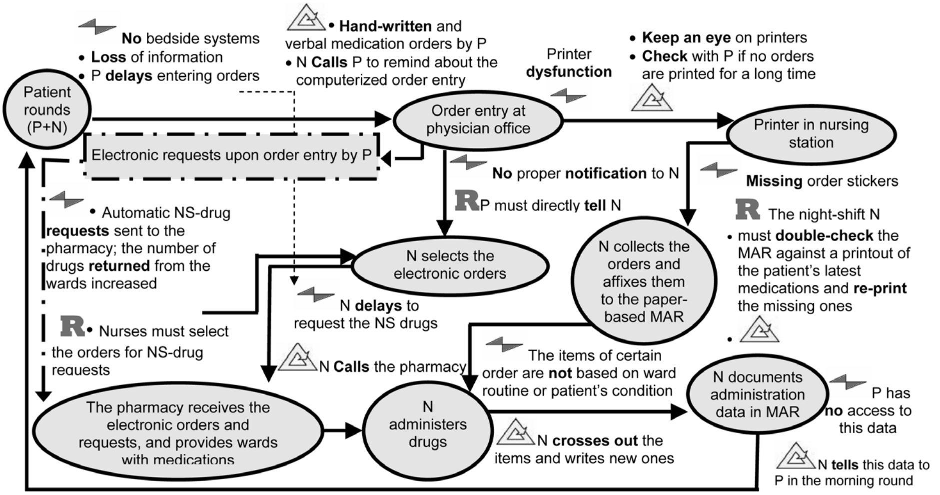


Figure 6.2. Pragmatic medication-use cycle after CPOE implementation; ( : breakdowns in workflow; : workarounds; "**R**": new organizational rules; P: physician; N: nurse; MAR: medication administration record; NS: non-stock).

them. It is noteworthy that in real practice these phases are highly interrelated and they overlap without a clear-cut distinction between them. For example, issues in the prescribing phase may partly overlap with those in the monitoring phase. Table 6.1 provides details of the problems encountered, their probable root causes, and the resulting workarounds that emerged to address them. Figure 6.2 schematically shows some of the breakdowns in workflow, workarounds devised to address them, and certain new organizational rules defined after the implementation.

### 4.1. Prescribing

Physicians visit their patients with nurses during morning rounds. Because the CPOE system is not accessible at patients' bedsides, physicians may first check the patient medication record in the system in their offices and take a hand-written summary to the bedside. Otherwise, they may rely on the AMO lists. Mostly, however, they rely on their memory, especially when the patient has been in the hospital for a few days. An AMO is primarily used by nurses who decide which kind to print in a given ward. Because different AMO lists contain different information, the one printed by nurses may not meet the information needs of physicians. One physician noted:

> *"…we use a printout [one type of AMO printed by nurses in this ward] that is archived in the nursing file. And we look at it and see what a patient is using today, but 'what was he using yesterday?' The answer is 'I don't know!'". (P1[1]).*

~

After the rounds, physicians return to their offices and enter the electronic medication orders. During medical rounds, in order to avoid interruptions caused by physicians needing to travel to their offices to enter orders for each patient, physicians may take a brief note of orders on paper or rely on memory. In busy wards with a number of patients and numerous changes in orders, this can cause problems. An attending physician explained the situation as follows:

> *"My main worry, especially with regard to the junior doctors, is that you ask a great deal from them. When they are attending with me here for the first day, I ask them to make round for 16 patients. And they have to know after 16$^{th}$ patient exactly what they want to change in the medication of the first patient. That is what I am asking from them. … During the round you cannot walk from the bedside to Medicator for each order. So, when the system was introduced, that was signaled as something that would be a problem; then we got the friendly and very specific answer that 'the problem is known and in the future we will look to see how to solve it.'" (P1)*

~

According to a formal agreement, after the CPOE implementation, nurses should not accept hand-written medication orders. However, to organize their daily nursing work after the medical rounds – and before physicians are able to issue the electronic orders – it is possible that nurses ask physicians to issue temporary medication orders on paper. The main reason, as nurses reported, is that it may take a few hours before physicians issue the electronic orders. Nurses associated this mainly with the time pressure that results because physicians are committed to other clinical duties after the medical rounds: for example, the coverage of emergency patients in their daily shifts, outpatient visits, operations, or educational responsibilities.

1. "P" stands for "physician", "Ph" for "pharmacist", "PhT" for "pharmacy technician" and "N" for "nurse". The interviewees' numbers are based on the alphabetical order of their names to preserve confidentiality.

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Table 6.1. Problems encountered in clinical workflow, their probable root causes, and resulting workarounds

| Problems encountered | Probable root causes |
|---|---|
| ***1. Prescribing*** | |
| • information loss<br>• not having an overview of current patient medications | • patient's clinical condition, order entry system, and medication administration record are not available at the time of decision-making or order entry phases. |
| • order entry is in the physician's office away from the patient and co-working colleagues;<br>• lag between the order-entry time and that of decision-making when the memory is fresh | • lack of bedside systems<br>• asynchronized decision-making and order entry |
| • delay in entering the orders of newly admitted patients, especially when they are admitted after morning rounds or during evening shifts when physicians are busy | • time-consuming process of order entry |
| ***2. Communication of orders*** | |
| • Communication of necessity for an urgent action: changes in orders such as stopping and starting medications that have been decided upon during morning rounds but have not yet been entered into the system (often happens daily) | • lack of bedside systems and busy work schedules of physicians (especially residents) after morning rounds, keeping them from entering orders right away |
| • verbal communication of orders | • busy evening or night shifts for residents<br>• emergency situations |
| • failed or delayed communicating of orders entered into the system | • lack of proper order notification to nurses apart from the physical existence of MO labels, such as a highlighted new order in the system<br>• printer dysfunction or empty rolls of MO labels<br>• MO labels may be lost among other papers in the nursing station<br>• other colleagues may pick them up by mistake |
| • discrepancy between the decisions made in the morning rounds and the orders entered into the system and received by the nurse<br>• ambiguity for nurses when they receive a medication order not discussed earlier<br>• miscommunication of ideas between physicians and nurses through the system | • asynchronized decision-making and order entry phases when the physician's memory is fresh<br>• asynchronized decision-making and order entry phases, not at the same time that physicians are with nurses<br>• usability issues of the system (e.g., same-day start and stop dates) |
| • nurses may not notice if there are medication orders requiring special attention especially if they are not emphasized earlier or are out of routine; or they may notice it only later | • MO labels are highly detailed and printed with black ink making all orders look alike.<br>• lack of proper notification in instances when nurses must pay particular attention to the non-routine issue of a special medication |
| ***3. Dispensing*** | |
| • High number of returned non-stock drugs from the wards to the pharmacy | • An automatic drug request was sent directly to the pharmacy following each non-stock order entry or its changes during a patient's hospital stay<br>• whole box delivery for each drug request |

| Resulting workarounds |
|---|
| |
| • when the patient is there for days, physicians rely merely on their memory<br>• for new patients that they do not know: physicians check the information in their offices before doing rounds, make a patient summary, and take it with them to the bedside |
| • summarized paper-based notes of orders taken during medical rounds such as "patient number 3: change medication", "patient number 9: start new medication" and so forth; relying mostly on memory<br>• physicians write the orders in an appointment form and sign it<br>• nurses write orders in an appointment form and ask physicians to sign it during rounds |
| • verbal or paper-based orders for the most important and urgent medications<br>• calls from nurses to remind physicians to enter medication orders |
| |
| • physicians must emphasize the order verbally, then write it down and sign it for nurses (e.g., in nurses' notes, what to do list, appointment forms);<br>• or, nurses should directly inquire for confirmation once more after rounds by direct communication or a phone call |
| • nurses write down in the administration records or other nurses' notes that physician X prescribed medication Y on day Z<br>• they also call physicians to follow up receiving the electronic versions of verbal orders |
| • checking printers<br>• checking with physicians to ensure order entry by them<br>• physicians should call nurses or to tell them directly if they have entered a new order<br>• nurses may need to check the electronic orders, one by one for each patient, to see which orders are new, and then make their prints, which is a time-consuming process<br>• in a few wards, the unit secretary is assigned to collect MO labels and distribute them to the nurses responsible |
| • nurses phone physicians for clarification: for example, if they receive something new or different from what that has already been discussed<br>• physicians need to call if they enter an order while away from the wards, especially in a case that needs special attention |
| • physicians should directly tell the responsible nurses or call to signal the need for special attention |
| |
| • Nurses were involved in selecting electronically those non-stock drug requests that were necessary in the wards<br>• The pharmacy switched from checking the physician orders to checking the nurse requests |

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| Problems encountered | Probable root causes |
|---|---|
| • Delayed nurse-initiated order request sent to the pharmacy | • delay in receiving electronic medication orders in the course of the day due to the lack of bedside systems, on one hand, and busy work schedules after morning rounds for residents, on the other hand<br>• nurses' drug requests would be canceled in the absence of electronic orders<br>• lack of proper notification of the latest requests through the system to the pharmacy technicians; time-consuming process of checking drug requests per patient per wards |
| • lack of in-stock drugs because of periodical variation in the flow of patients who use these drugs | • the pharmacy technicians would cancel a drug request if it is an in-stock drug |
| • dispensing of non-stock drugs that are expensive and need explanations for their prescription (e.g., penicillin group 4) | • necessity of multiple communications for dispensing expensive drugs and lack of adequate coordination between pharmacists, physicians, and nurses about the final result |
| ***4. Administration*** | |
| • drug administration without the electronic orders or their MO labels | • verbal or paper-based orders during the medical rounds, due to lack of bedside systems<br>• busy physicians especially during evening and night shifts |
| • the nurse taking part in the morning round may not be the nurse who distributes the drugs during drug administration time | • verbal orders for stop or start orders that have been decided upon in morning rounds |
| • incompatible drug administration times for some medications | • structured order entry and centralized decision making by physicians<br>• usability issues when physicians use default times in the system |
| • busy nurses working in a highly interruptive environment may miss important information while administering drugs | • detailed information on each MO label, written in small letters and black ink; although highly legible, the labels burden nurses with a high cognitive overload with regard to reading them carefully |
| ***5. Monitoring*** | |
| • wrong or incomplete sets of MO labels on patients' Kardex cards<br>• the nurse may easily mistake look-alike information such as patients' names and then puts the wrong MO labels on the wrong patient's Kardex card | • printer dysfunction or MO labels lost among other papers in the station<br>• MO labels of different patients are printed at the same time in a mixed order with no easily distinguishable visual clues between them<br>• a high cognitive overload on nurses with respect to separating MO labels of different patients and reading them carefully, due to the materiality of each single MO label to be affixed to the correct Kardex card and to look-alike MO labels containing information items in very small print |
| • Lack of temporal overview regarding the period of medication use; a patient receives a drug that should have been stopped earlier | • usability issues: for physicians, getting a temporal overview of the medications is not easy on the screen<br>• getting an overview of the administration data is not easy during morning rounds or in the time of order entry. This makes the monitoring of medications for physicians very difficult |
| • flawed monitoring mainly because the drug administration data is not practically available either during the morning round or at the time the physician enters the order | • the Kardex cards, which contain administration information, are affixed to a movable medicine cart that is generally left in the medication room |

| Resulting workarounds |
|---|
| • calling back to physicians or directly communicating with them to remind them and to request an electronic order entry<br>• asking other physicians to order if the first physician is busy and cannot do so right away<br>• calling the pharmacy if an order request is placed in the computer after 12-2 pm<br>• checking the medications of other patients to see whether the same drug has already being requested and is now available in another patient's medicine box; nurses take it and write a note to refill it as soon as they receive the drug from the pharmacy<br>• asking patients to bring their home medications to the hospital, especially for the first few days |
| • using the in-stock supply of other departments and writing down the names of the medications in order to return them after pharmacy technicians have come to scan and to re-stock supplies |
| • calls from pharmacy technicians to nurses to inquire about home medications (whether the patient has brought the drug in, how many days the patient will stay, etc.)<br>• calls from pharmacists to physicians to replace the drug with an alternative<br>• pharmacy technicians also use a local computer program to document the processes of inquiry from nurses and physicians and the name of patients and drugs. If they receive a similar request, technicians should first check this program before responding to an inquiry from nurses |
| |
| • nurses start administration of drugs based on physicians' verbal or paper-based orders, even if they do not have the electronic orders; meanwhile, nurses write the medication orders by hand either on Kardex cards where MO labels are affixed or in other nursing records<br>• nurses call back physicians to remind them to enter orders<br>• the next shift nurse may ask other doctors to issue the electronic orders |
| • nurse one should communicate it verbally to nurse two.<br>• nurse one may put an "S" mark on an AMO or on a Kardex card in front of the name of the medication that is to be stopped |
| • nurses cross out the items and add new ones that best match the temporal rhythms of nursing work and/or patients' conditions (e.g., before or after meals, before sleeping time, and so on) |
| • to emphasize the most important information such as the stop date or the comment section with a highlighter pen on the MO label |
| |
| • double-checking of MO labels in the Kardex card with the AMO every 24 hours<br>• putting a reminder in the station for nurses to alert them with regard to patients' names that are similar |
| • nurses remind or call physicians if they notice such issues |
| • before morning rounds, physicians may have briefing sessions among themselves to verbally communicate the most critical events that happened the previous night<br>• physicians mainly rely on nurses' memory and their verbal communication of the administration information |

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Similarly, it is possible that new patients are admitted after medical rounds or during evening shifts when physicians are busy. Because these patients are mostly using a number of medications at the time of admission, it is time-consuming for physicians to enter them into the CPOE system if they had not been admitted to this hospital on previous occasions or if their orders have not been entered in the CPOE system in ambulatory care clinics of the hospital. Therefore, in response to the nurses' telephone requests for medication orders, according to an informal agreement between physicians and nurses, for most important and urgent medications, physicians may give verbal orders or issue short paper-based orders on the appointment forms. However, the formalized hospital rule is that verbal orders should be used only when physicians are on call and outside the hospital and then are unable to enter orders into the CPOE system.

### 4.2. Communication of orders

Both physicians and nurses reported a number of problematic issues that emerged in their communication. As mentioned earlier, physicians may be forced to communicate orders verbally and/or through paper-based orders before issuing the electronic orders. A nurse commenting on verbal orders told us:

> *"…when physicians are not available, they can give oral orders and then we give the necessary drugs to the patient. However, it has to be registered somewhere. Nurses may want the physicians to enter orders into Medicator later and issue stickers afterwards. This is very important in order to make the process legal." (N11)*

In the event that physicians delay entering electronic orders or enter new orders that are not expected by nurses, they need to tell nurses directly or call them. This is mainly because, apart from seeing the printed MO labels, there is no other order notification for nurses such as actually observing the physician enter an order or a list of newly entered orders. As nurses are busy with care activities in patients' rooms or elsewhere, they may notice the labels only later in the day. To address this issue, the implementation team made two rules during the implementation process: first, after any new electronic order entry, physicians should notify the responsible nurses either face-to-face or by means of a phone call, and the second, nurses should check the printers for new orders before they start their rounds of drug administration. However, with regard to the first rule, as nurses declared, it largely depends on which physician is on duty and how busy s/he is. Nevertheless, it became evident that physicians may not perceive this extra task as a fixed rule. A physician told us:

> *"…I enter a prescription in this computer and I order the print in another location. The nurses will get it and see it is prescribed by a physician. [Then] it is ok and there is no problem. … But, I think it is polite to call them. In our department, it doesn't matter whether I call or not; it will work. And if the nurses aren't sure, they will call me then". (P6)*

~

Similarly, communicating orders only by electronic means carries the risk of a miscommunication of ideas. To address this, clinicians use added communicative methods such as extra face-to-face contact and phone calls. As mentioned earlier, the lack of bedside possibilities to issue electronic orders promptly after each patient visit delays the order entry process and forces physicians to rely on their memory or on their brief paper-based notes. This can result in physicians entering an order different from what had been decided upon earlier – and that nurses had written in their notes – during morning rounds. This forces nurses to seek more clarification from physicians.

Furthermore, nurses receive a number of highly detailed MO labels, printed in black ink on a small sticker, making them all look alike. These labels lack visual clues to identify their special items. Therefore, if a special issue arises, such as the administration of a drug outside of the routine time, physicians need to call nurses to ask verbally for special attention to be paid to the matter.

### 4.3. Dispensing

Erasmus University Medical Center has two systems of drug dispensing in clinical units: one for frequently used medications (in-stock) and the other for rarely used medications (non-stock). In-stock medications are controlled by the pharmacy technicians two or three times a week by scanning the drugs in the ward stocks. The logistics of ward stocks is based on a scientific analysis of supply and demand on a yearly basis as well as on the cost of the drugs and their expiry dates. In this way the pharmacy has been able to efficiently control the costs of in-stock drug supplies. However, nurses complained about the shortages of their in-stock supply caused by the flow of patients using specific drugs more than usual. Meanwhile, because of the concern that electronic requests for in-stock drugs would generally be rejected by the pharmacy department, the nurses overcome the shortage by borrowing from the in-stock supply of other departments. This informal process occurs especially during evening or night shifts.

In the first year of implementation, the medication orders that physicians entered into the system were automatically put on the drug delivery list that was accessed by the pharmacy department. This in fact removed the workload of typing non-stock drug requests into the hospital information system by nurses or taking the requests to the pharmacy. Similarly, the pharmacy technicians did not need to transcribe the orders and then enter them into the pharmacy system, as was the case before the CPOE implementation. However, both clinical wards and the pharmacy department experienced problems because of this functionality during the early months after implementation. As a result, they both agreed to turn off this function of the system.

All electronic non-stock medication orders were automatically put in the "order request list" of the pharmacy system. The pharmacy technicians sent these medications to the wards after checking the request list. When physicians changed these non-stock orders, the pharmacy received these changes as pending requests that had to be fulfilled. For example, if a physician had ordered a non-stock drug once a day for a patient, a whole box of the drug would have been delivered to the ward. This was mainly done because delivery of whole boxes did not require extra labelling of boxes and could be handled by personnel without pharmaceutical training. However, patient deliveries should contain a label with the patient information, which in turn required pharmacy technician involvement. As a result, if the dosage was changed: for example, three times for a drug during a patient's stay, the pharmacy department would have delivered three boxes of the drug because any change in the dosage was configured as a new request by the system. As a result, nurses had to return the remaining drugs (i.e., many intact boxes) to the pharmacy.

The pharmacy department also experienced that many of the non-stock drugs delivered to the wards were returned to the pharmacy without actually being used. Handling the high number of returned drugs in fact added to the workload of both the nurses and the pharmacy. The implementation team, the pharmacy department, and the nurses therefore agreed to stop using the automatic transfer of requests. Instead, nurses now have to electronically select those non-stock electronic medication orders that are necessary for their patients. Only when nurses select these orders in the system are nurse-initiated, electronic requests sent to the pharmacy. Although the involvement of nurses in requesting non-stock orders has solved the problem of controlling the drug supply, the work condition in the wards after implementation (e.g., delayed electronic order entry by physicians) still remains a source of frustration.

To cope with the high workload in managing the drug supply for the entire hospital during the course of a day (wholesaler deliveries), the pharmacy technicians normally check the requests per patient per wards twice a day: at 8 a.m. and 12 p.m. After these checks, the technicians provide the wards with their non-stock drugs in patient-labelled minigrip (zip-lock), plastic bags for 5 days, mainly due to safety concerns. For safety reasons, any non-stock drug request without the corresponding patient identification would generally be cancelled by the technicians. In the meantime, if the requests are sent during the afternoon – mainly due to physicians who delay entering orders into the system – nurses also need to call the pharmacy to ensure a timely drug delivery. As one head nurse noted, every nurse needs to know this, and if a busy nurse does not pay particular attention to the time at which she requests the drugs, they will be delivered the next day. While the management of non-stock medications has been found problematic by nurses, the pharmacy does not perceive it as a pressing issue. In this regard, a pharmacist told us:

> *"Normally, they (non-stock medications) are home medications and the patients are asked to bring them to the hospital. So this should not be a problem."(Ph2)*

Meanwhile, a nurse noted:

> *"For the patients coming from home, we need to request and prepare all their medications [both home medications and those started at the hospital] from the pharmacy department before the next shift arrives the following morning." (N10)*

Also complex is the management of expensive drugs, antibiotics with restriction, non-formulary drugs that are a second choice if started in the hospital, and drugs that are not delivered without an accompanying explanation because of safety concerns. Some drug orders should be accompanied with an explanation because they are not available in the pharmacy and require procurement from the wholesaler or they are not registered in the Netherlands. In these instances, during the order entry phase, physicians are asked to document their reasons for prescription. When confronted with orders such as home medications, the pharmacy technicians first call nurses to inquire whether the patient has brought them in. If not, the pharmacists are then involved to evaluate these orders and, if it is the case, to call physicians and suggest an alternative available in the hospital. However, it often happens that these orders are coordinated only through verbal communication among the pharmacists, physicians, nurses, and the pharmacy technicians; and they are not changed in the system. To avoid repeating the procedure when the same requests are received from nurses, the pharmacy technicians are using a simple computerized data base in their own system:

> *"We enter the order requests in there and whatever actions we take, for example, calling the nurses, calling doctors and proposing an alternative by the pharmacist, we enter all of these into this program. In that way, if we get the same request next time, we can look back at the history to see what we have done or what our colleague has done in that instance". (PhT)*

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Although information is typed into this program by the technicians, this has been perceived as less time-consuming and more efficient in the management of medications than normal calls to the wards to inquire about the same issues.

### 4.4. Administration

In theory, nurses should wait for MO labels and then administer drugs on the basis of these. They then record the administration by signing next to these labels on the Kardex cards. In this way, nurses do not need to transcribe the physician-written orders for documentation purposes. However, their work depends largely on the complete and timely availability of these labels at the time of administration.

In nearly all the wards in which we interviewed, it was reported that nurses sometimes start administering drugs that are available in the ward stock even before receiving the corresponding electronic orders and their printouts from physicians. Their reference for administration is the verbal and/or the concise paper-based orders that have been issued by physicians during medical rounds. Alternatively, they may refer to their own notes taken during these rounds. For documenting the administration, they manually write these orders where their corresponding MO labels will be affixed. However, they consider their work incomplete if they do not receive the printouts of the electronic medication orders for documentation purposes. To be complete, they call back physicians to remind them to enter the electronic orders:

> *"… but sometimes you have to call and remind them that it is already 2 or 3 hours later and you have still not received the labels. This costs us a lot of extra time because we never forget and we always have in mind that we gave the medications to the patients but have not yet received the labels". (N10)*

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One issue that emerged during the interviews was that it is possible that the nurse taking part in the medical round is not the nurse who administers the next round of medications. In such cases, the verbal communication between nurses to coordinate the administration of a drug plays an important role. However, because of its mostly verbal nature, the efficiency of this communication in terms of transferring the changes in orders precisely is questionable.

Furthermore, nurses may experience some discrepancies between the physician-initiated orders and ward routine or the patient's condition when they are planning to administer drugs. To resolve such discrepancies, nurses may need to modify the orders. This is evident especially with regard to the time of administration. To appropriate the orders at the time of administration, it is possible that nurses travel to the nursing station, log into the system, and change the time and print a new MO label. However, this would interrupt their activities at times when concentration is highly necessary. To avoid this interruption, they simply cross out the items and add new ones that best comply with the situation (e.g., before or after a patient has eaten, before sleeping, and so on). However, an important point is that these changes by nurses are only registered on the labels and not in the CPOE system. More importantly, they are not communicated to the physicians.

Moreover, because of the highly structured and look-alike nature of orders, nurses highlight the most important information on each MO label with a highlighter pen so that it will not be missed by them or their colleagues. They may also annotate the administration records themselves to create some visual clues as recommended by the implementation team. For example, to highlight a "stop" date, they may use a colorful marker to write "stop" in large letters, use a colorful stamp with a “stop” sign, or put a cross next to the dates on the Kardex card, indicating in advance that the drug should be discontinued.

### 4.5. Monitoring

Monitoring of the medication plan may be done by nurses and physicians. Nurses reported cases of patients who had incomplete or wrong MO label sets on their Kardex cards. Our informants attributed this to different root causes. First, it is possible that the printer fails to print the MO labels because of a technical problem. Second, after MO labels are printed, it is possible that they get lost among other papers in the nursing station or they may have been left forgotten in the pockets of busy nurses. Third, at the time of affixing labels onto the Kardex cards, nurses may make mistakes because of look-alike labels and very small information items or because of their constantly disrupted working place (e.g., a question from a colleague while labels are being placed). Since these problems were known and witnessed, and after nurses complained of too many errors, the implementation team set a rule for the double-checking of medication orders every 24 hours. For double-checking, mostly the night shifts (in only a few wards, the day shifts) check the order labels affixed to the Kardex cards against the AMO (the list of the patient’s latest medication orders). The AMO is printed after midnight because then the date on the AMO will be the same as the day when the nurse uses AMO for discussion in the morning round. These checks therefore take place after midnight when nurses are less busy but generally tired and less alert.

Despite the double-checking every 24 hours, nurses reported instances in which a drug had already been started by a physician but after a few days it was not shown on the Kardex card: this resulted in it not being started on time. Such issues are important because if a physician forgets to enter an order the nurse may follow up the order based on her notes or on the physician’s verbal orders; however, if nurses do not start or stop medications on time, there is no way for physicians to notice and monitor that. This is mainly because their practical reference for the medication plan is the CPOE system and its printout and not the administration record. The administration records are affixed on a moveable medicine cart that is normally left in the medication room. For all practical purposes, this makes the records inaccessible for physicians at the time of order entry and/or medical rounds.

## 5. DISCUSSION

Our study revealed a number of problems encountered throughout the medication-use cycle following the CPOE implementation. These problems differed in their nature and affected one or more providers (Table 6.1). They included cognitive overloads on physicians in the prescribing phase and their unmet information needs, miscommunication of orders and ideas between physicians and nurses, problematic coordination of interrelated tasks between co-working professionals leading to delayed tasks, potentially faulty administration phases with high cognitive overloads on nurses, and suboptimal monitoring of the medication plans by providers. These problems are mainly rooted in the usability issues of the system, the inconvenient technology implementation, the uneasy integration of coexisting electronic and paper-based systems in the correlated phases, and certain organizational factors affecting the technology use such as the complex logistics of procuring drugs in the hospital.

To address the problems, the work organization devised various types of workarounds, including many phone calls within and between professional groups, taking multiple paper notes that summarized the information in the system or the decisions made, issuing paper-based and verbal orders, double-checking, using other patients' procured drugs or another department's drug supply, using paper notes or computer-based programs to coordinate exceptions within the professional groups, and modifying and annotating the printed orders to appropriate them in routine practice. Some of the workarounds such as non-stock order requests or double-checking by nurses were defined as new organizational rules. Moreover, workarounds such as nurse-initiated calls or direct communication were aimed at accelerating the performance of interrelated tasks, while others such as physician-initiated calls or the double-checking of orders were devised for better safety features in the integration between the electronic system and the paper-based administration system. These workarounds affected clinical workflow to varying degrees: some eased and accelerated the performance of tasks while others burdened already busy providers with an extra workload. Although the providers in our study recognized the workload caused by these workarounds, they valued highly the *situatedness* of them to overcome local obstacles and considered them necessary for the efficient functioning of their medication process.

In accordance with the findings of Vogelsmeier and colleagues [10], we identified workarounds related to workflow barriers introduced by technology and its technical components: these included the lack of bedside systems, printer dysfunction, and an underlying assumption in the system that any change in an order constitutes a new order. We also identified workarounds related to organizational processes not reengineered to effectively integrate with the technology such as making the administration records more accessible for physicians and nurses at the time of decision making.

More importantly, we found that these two patterns of workarounds are intertwined in practice: one pattern influences and is influenced by the emergence of the other. As we saw in our study, the linking of a number of social, technical, and organizational factors influenced the development of the workarounds observed. For example, the lack of bedside systems and the concomitant delay in order entry by physicians, the lack of timely notification of the latest orders for nurses through the system, the need for nurse-initiated electronic requests in the clinical wards, the lack of proper notification of the latest electronic requests to the pharmacy technicians through the system, and the internal policy at the pharmacy with regard to when to check these requests influenced the emergence of additional calls made by nurses to the pharmacy following each non-stock drug request. Moreover, our findings confirms that of Kobayashi and colleagues [20]: namely, to stabilize workflow, the development of a workaround may have a cascading effect initiating a series of further workarounds (e.g., nurse involvement to request the non-stock orders was followed by phone calls to the pharmacy to ensure timely drug delivery).

Very similar to Georgiou and colleagues' study of a laboratory order entry system [9], at our study site the terminological difference between "orders" and "requests" also resulted in some organizational dysfunctions in both the clinical wards and in the pharmacy department. The drug delivery following each order entry by physicians for non-stock drugs resulted in a very high percentage of returned drugs from the wards. To manage this problem, the pharmacy switched from checking automatic requests based on physician orders to checking nurse requests. Nurses easily adopted this order-requesting method because it was similar to what they had been doing in their paper-based systems. Therefore, a tacit knowledge of work guided the work organization to consider this method. Nevertheless, the system was also accompanied by a delay on the part of physicians entering orders into the system in contrast to the paper-based system, in which immediately after the morning rounds nurses had all medication orders at hand to start requesting. After the implenmentation, to accommodate workflow following delayed electronic requests made by nurses, using a technical solution such as a proper computerized notification of the latest new requests to the pharmacy technicians may have had facilitated their awareness at the pharmacy.

Studies have shown that the implementation of CPOE systems decreases the number of verbal orders [23, 24]. However, as seen in our study, they are still used in certain circumstances. The fact that these orders are entered only later by the responsible physician or even his/her colleagues simply for documentation purposes (*if not entirely forgotten*) challenges the value of the retrospective studies of medical errors and quality of care with these systems. Our study demonstrates that neatly documented orders in a CPOE system may not thoroughly represent what has happened in real practice. Workflow and medication errors should be studied in prospective, observational studies.

The need for timely and proper notification of orders to the providers intended has long been recognized in CPOE studies [25]. Health care professionals are busy and mobile, working mainly in places other than around computers and printers. CPOE systems are often accompanied by a lack of visual clues to identify new orders, such as the presence of a physician at a bedside or the physical existence of paper orders or requests. To maintain awareness, a number of solutions have been designed: these include real-time, visual alerts and electronic inpatient whiteboards as orders are processed [26, 27].

Our study revealed that how the work organization was actively involved to contextualize the system in the medication-use cycle by accommodating local conditions [17]. It is already known that the effectiveness of CPOE systems to a large extent depends on how this process and its associated challenges are approached and dealt with [9, 16]. However, the changes required and the workarounds developed to facilitate workflow happen in unexpected ways, which calls for careful management of change processes. One reason is that the providers, who are involved in this "contextualization", might choose feasible solutions based on their tacit knowledge of work: however, these solutions might be in conflict with other aspects of work in the same or other work units in a hospital [28]. Therefore, to prevent "workarounds" that burden providers (e.g., extra time and effort being required) or endanger patient safety, we agree with the approach proposed by Tucker and Edmondson to have "problem solving coordinators" to foster boundary-spanning support, especially when innovations cross boundaries [21]. These coordinators should be actively involved in evaluating the work structure after CPOE implementation in close collaboration with the end-users. Their approach to managing change should incorporate both the redesigning of the system as well as the work processes. In fact, to develop work-affording systems, “co-realization” [29] or “evolution-in-use” [30] in the context of actual use can be promising. These types of approaches can contribute to finding solutions that benefit all parties involved in a productive way.

### 5.1. Limitations of the study

This study focused on analyzing problems encountered in the medication-use process. However, it must be noted that the advantages of the CPOE system in this process were not discussed in this chapter. Therefore our study should not be construed as presenting simply the negative effects of the system. Moreover, in this study we did not make a direct comparison with the pre-implementation medication-use process, mainly because the interviews were conducted at least one and half years after the implementation, thus making it difficult for interviewees to make a precise comparison. Hence it is possible that some of the problems might have been present in the pre-implementation phase and were not the result of the CPOE implementation.

## 6. CONCLUSION

Our study further reinforces the complexity of the medication-use process in a CPOE context that connects providers from different professional groups within and between departments and their competing interests and conflicts. It shows how the features of a CPOE system affect and are affected by the work practice over time. It demonstrates that providers are actively involved in bypassing the technology or in adapting the work process to cope with difficulties in their workflow. This in many instances takes the form of a workaround that providers devise for good reasons: to maintain a smooth workflow and/or to ensure patient safety. However, in certain instances these workarounds burden providers with extra time and effort or endanger patient safety. It is important that the workarounds of a negative nature are recognized and discussed with the parties involved in order to find solutions to mitigate negative effects.

To conclude, one can find unsuccessful instances behind successful implementation sites where CPOE systems are operational in daily practice. Our findings call implementers and evaluators to pay closer attention to recognizing and addressing such issues in actual practice in order to reap a CPOE system’s full benefits. Insight into these contextual issues can help them to understand the *in situ* operation of a CPOE system in its use context and help to design strategies to lessen the number of disruptions in workflow and their possible negative consequences.

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# Chapter 7

## Conclusion

# CONCLUSION

This aim of this PhD thesis was to gain insight into the impact of CPOE on clinical workflow. It attempted to describe what attributes of clinical workflow affect and are affected by the deployment of a CPOE system. The study shows that clinical workflow is a multi-layered issue with diverse socio-technical elements that challenge the deployment of CPOE systems. Drawing upon the findings in previous chapters, I will outline the effective attributes of clinical workflow that interplay with a CPOE system and impact the implementation outcomes.

The findings in this PhD study underscore that clinical workflow:

- is *collective* (Chapters 2 and 3): comprised of many interrelated and interdependent tasks of an individual provider and/or co-working providers. A CPOE system is aimed at automating certain phases in a clinical process to support related clinical tasks while it unintentionally and adversely interrupts the other interrelated tasks;
- is *collaborative* (Chapters 2, 4, and 6): involving multiple professional groups whose tasks in a clinical process are highly interdependent. Even if a CPOE system intends to automate one step of the workflow pertaining to an individual provider, its impact spans the work of other co-working professional groups. The distribution of clinical tasks in the temporal and spatial dimensions of clinical workflow also makes collaboration among care professionals necessary. Thus, the ability of a CPOE system to coordinate different dimensions of work simultaneously should be enhanced;
- is tightly coupled with the *organizational context* of work in a clinical process (Chapters 2 and 3). A CPOE system changes the roles and responsibilities of providers, which have been shaped in the organizational context of paper-based systems over a period of time. These changes sometimes have side-effects. A set of known tasks and responsibilities disappears and a set of new ones emerges. The primary providers may either not be fully aware of these changes or they may be unsure as to whether they are responsible for these new tasks and functions;
- is tightly coupled with the *clinical context* of work in a clinical process (Chapter 5). The clinical context influences whether a CPOE system meets clinicians' needs. Different clinical contexts make work requirements different. The same CPOE system may support work requirements in one clinical context but fall short of satisfying clinicians in another;
- is *contingent*, requiring *pragmatic* efforts on the part of providers to deal with interruptions in the smooth flow of work (Chapters 2 and 6): As CPOE

systems transform the organization of clinical tasks and the way providers collaborate with each other, health care providers respond pragmatically to the problems that arise in the daily workflow. To avoid or to recover from a disruption in the workflow following CPOE implementation, providers may bypass the system and devise workarounds to continue the work. Yet, such efforts may increase their workload or reduce the reliability of their work tasks.

In the following paragraphs, I further discuss the interaction between CPOE and these workflow elements on the basis of the findings in each chapter.

To gain an understanding of the nature of clinical workflow and its effective socio-technical elements, I began by undertaking a review of the literature, as reported in Chapter 2 [1]. Reviewing relevant fields about the nature of clinical workflow and its interplay with health care information systems (HISs) provided a foundation for determining what areas and methods seem most likely to shed new light on the impact of CPOE systems on workflow. In the model developed for clinical workflow, I defined two spaces that shape workflow: a "formal task-structure" space, and a more "informal" space that I labeled "co-constructed" task-structure space. The integration of organizational knowledge of health care work (e.g., information about available capacities and accessible resources) and medical domain knowledge helps to define "who" does "what", "when", "where", and "how" by employing "which resources", and in "what relation" to other tasks and providers (i.e., sequentially, simultaneously, or in any other order). Meanwhile, other characteristics of clinical work influence the formal task structure: 1) the constant change in the order and priority of clinical tasks as a patient's illness unfolds; 2) distribution of clinical tasks among multiple care professionals who are sometimes geographically far from each other and may have different goals, preferences, values, incentives, and motivations; 3) the temporal distribution of clinical tasks; and 4) the fact that clinical tasks are highly information-intensive. These characteristics make clinical workflow highly co-constructive, collaborative, contingent, and pragmatic.

The review of CPOE literature demonstrated that the modeling principles of CPOE generally make use of a formal, predefined division of tasks and a preconceived relationship between clinical tasks and also between care providers. Therefore, in many instances, the workflow model underlying these systems may not reasonably correspond to actual workflow. Although such a sharp division of tasks and preconceived relationships, for example in the medication process, may lead to better safety procedures and shorter order turnaround times, it may also jeopardize the collaborative nature of the ordering practice in which physicians, nurses, and pharmacists are all role players and upon which they are reliant. This study also pointed out that the focus in the literature was mainly geared towards the workflow of individual providers – more precisely, physicians – when they interact with these systems to perform tasks. However, the study demonstrated how the collaborative and collective nature of workflow challenges the use of CPOE systems.

In Chapter 3, I addressed the different outcomes observed in the transition from two different paper-based systems to the same CPOE system in nursing practice [2]. Before the CPOE implementation, nurses in this study worked with the Kardex system and the TIMED system. In the first, the structure of the nursing medication work was similar to the structure after the implementation, while in the second it was different. The study showed that although the CPOE system eliminated the workload of transcription and translation tasks mainly for the TIMED nurses, these nurses demonstrated a less positive attitude compared to the Kardex nurses, with the new process being associated with increased rigidity, difficulty, and slowness. These increased problems were not seen by the Kardex nurses. Using the Adaptive Structuration Theory (AST) to interpret the outcomes, I explained that the two different paper-based orders represented two dissimilar work structures and organizational processes. The implementation of the system imposed new and unfamiliar social structures for the workflow of TIMED nurses, resulting in less positive perceived effects, while the social structures of the workflow for Kardex nurses remained intact. I argued that the translation and transcription tasks to process the concise and semi-structured orders in the TIMED system may have compelled TIMED nurses to take a more active role in the medication process. These nurses would assume a more authoritative position in the medication process than their counterparts in Kardex units. While the roles and responsibilities of nurses in Kardex units remained intact, the implementation of the CPOE system may have changed and challenged the position of nurses in TIMED units. The study indicates that not only the technology but also the organizational structure of work – and, more precisely, the large differences between pre- and post-implementation work structures – influence the perceptions of users and probably the level of difficulty in the transition phase.

Interestingly, in this study, although nurses in both groups were more satisfied with the post-implementation process, none reported better workflow support with the CPOE system when compared to that of the paper-based systems. I argued that workflow support with a CPOE system is a multi-layered issue; because medical workflow is complex and multidimensional, the efficiency of the process in fact depends on the interplay between multiple factors. The study suggested that a greater satisfaction with a system may not necessarily be a reflection of better support for workflow. A health professional user may be satisfied with some aspects of the workflow involving the system while dissatisfied with others. The findings in this study put forward the importance of the collective work of professionals in clinical workflow.

In Chapter 4, I evaluated the effects of a CPOE system on inter-professional workflow by applying a bird's eye view of the medication process [3]. This is a complex clinical process shared among multiple health professional groups, who may have competing, and sometimes conflicting, goals, interests, and incentives. Although they may be spatially distributed throughout a hospital, their work is highly interrelated because they are dependent upon each other in terms of skill, knowledge, expertise, and physical assistance. The study examined the role of the CPOE system in integrating the work of one professional group with that of the others among physicians, nurses, and pharmacists. In particular, I analyzed how the system has affected division of tasks, flow of information, and task coordination among the three professional groups. The study established that the reorganization of the existing work procedures affected the workflow both positively and negatively. It also identified instances in which the system inappropriately integrated the three professional domains.

The study showed that the workflow model underlying the CPOE system overlooked the overlaps and interdependencies that exist in practice between professional domains. As a result, it challenged their effective collaboration by reassigning tasks, reallocating the areas of expertise, and reinforcing strict boundaries around them. This led to physician dominancy in the medication process, which in turn caused nurses to experience difficulties in their workflow. The unilateral flow of information from physicians to other professionals together with the limitation of feedback in the reverse direction led to medication-related information becoming fragmented in the paper records and in the electronic records, as well as in different professional domains. The study also highlighted that the providers had limited support through the system to coordinate their tasks temporally. The asynchronous communication of orders sometimes contributed to a lack of mutual intelligibility with regard to orders. Moreover, the lack of proper visual clues undermined the situation awareness. To address these problems, providers used extra communication methods such as paper-based notes, phone calls, and face-to-face communication to supplement the information registered in the system.

I concluded that for a safe and aligned medication process, it is fundamental that the interrelated pieces of medication information produced by different professionals are effectively integrated. To achieve this, the input of nurses and pharmacists needs more careful consideration in the design of these systems so that they may better correspond to and support actual inter-professional relationships in the medication process.

In Chapter 5, I aimed to identify the role of the clinical context in workflow and how it influences the use and impact of a CPOE system [4]. For this purpose, I conducted a qualitative study and compared the post-CPOE medication process between non-surgical and surgical specialties that used the same CPOE system. The study showed that the perceived impact of CPOE and clinicians' attitudes towards it partially differed between these specialties, with non-surgical clinicians reporting less positive effects. Further analysis of the clinical contexts revealed that the load of the medication work, the need for greater and more diverse information, and consequently the clinicians' interaction with the CPOE system were more noticeable in non-surgical specialties. For managing medication plans, non-surgical physicians and nurses required access to patients' integrated medication information and, to compensate for its lack, they therefore were communicating intensively beyond the system. Furthermore, these clinicians perceived their interaction with the system to be more intensive and more problematic.

The study showed different perceived effects in the same organizational processes with one CPOE system but in different clinical contexts. It demonstrated that not merely the CPOE system – the technology itself – influences user perceptions and the outcome of the implementation. The interplay between the technology and the clinical context of the implementation environment matters as well. The study also suggested that workflow support or the lack of it with a CPOE system is dependent on the clinical context in which it is being used. I recommended that the voice and choice of each specialty group and its work requirements should be taken into account in developing and implementing CPOE systems in hospitals.

In Chapter 6, I evaluated and described how providers at Erasmus MC responded to the problems experienced after the CPOE implementation in order to integrate the system into their daily workflow. This study aimed at studying and analyzing the less obvious and informal operation of the system in the medication process. The focus of the study was on the problems experienced and the workarounds devised to circumvent them. The problems differed in their nature and affected one or more professional groups. They included cognitive load on physicians to recall many patients' details from memory and their unmet information needs, miscommunication of ideas between physicians and nurses, problematic coordination of interrelated tasks between co-working professional groups leading to delayed tasks, a potentially faulty administration phase with high cognitive load on nurses, and suboptimal monitoring of medication plans by providers. The analysis showed that these problems were mainly rooted in the inconvenient technology implementation and its usability issues, uneasy integration of coexisting electronic and paper-based systems in the correlated phases, and some organizational factors affecting the technology use such as the complex logistics of procuring drugs in the hospital.

To address the problems experienced in the medication process, providers devised various types of workarounds, including numerous phone calls within and between professional groups, taking multiple paper notes summarizing the information in the system as well as the decisions made at bedsides, issuing paper-based and verbal orders, double checking, using other patients' procured drugs or other departments' drug supplies, and modifying and annotating the printed orders to appropriate them in routine practice. Certain workarounds such as the electronic non-stock order requests by nurses or the double checking of the administration records with prescribed orders were defined as new organizational rules.

Workarounds identified in the study served different purposes: they were intended to accelerate the performance of interrelated tasks and/or to serve better the safety features in integrating the electronic prescription system and the paper-based administration system. Moreover, these workarounds affected clinical workflow to varying degrees: some eased and accelerated the performance of tasks while others burdened already busy providers with an extra workload. Although the providers recognized the workload caused by these workarounds, they highly valued the *situatedness* of them to overcome local obstacles and considered them necessary for the effective functioning of the medication process. The study also demonstrated how the features of the CPOE system affected and was affected by the work practice over time. It also showed that neatly documented orders in CPOE systems may not thoroughly represent what happens in real practice. The fact that many verbal orders, paper-based orders, and order changes happen in practice without them being registered in the CPOE system challenges the value of those retrospective studies that use system-generated data for studying medication errors and quality of care. Thus, I recommended that the impact of CPOE systems on clinical workflow and on medication errors should be examined further in prospective, observational studies.

The strength of this PhD study lies in the mixed methods used and the selection of frameworks for interpretation of the results. This study challenges the propensity of most current order entry system designs that are based on poorly understood characteristics of clinical work, resulting in inadequate support for collaboration and information exchange among clinicians. The study by no means provides a comprehensive set of attributes of clinical workflow that affect and are affected by a CPOE implementation. Nevertheless, it provides evidence from a case study that designers need to incorporate findings, along with the principles derived from the social, cognitive, as well as the information sciences, into the development process of such complex information systems. This requirement is attested to by the many failures to experience the full value of CPOE implementations as well as the challenges to users in their everyday work.

This PhD study reinforces the complexity of clinical workflow and the importance of understanding its multiple socio-technical elements that affect the outcome of HISs. For HISs to fit neatly and support clinical workflow, a practice-oriented model of the clinical processes, which carefully takes into account its socio-technical elements, should direct their development process. This study shows that clinical workflow to a large extent is "co-constructive"; multiple providers, different professional groups, local organizational processes, and the various clinical contexts, all leave an imprint in this co-constructive workflow. These systems should be developed and implemented in a way to accommodate and to support these elements. To inform this process, the operation of HISs should be considered comprehensively in their *context of use*.

In conclusion, clinical workflow involving health care information systems is a multilayered issue. It needs a careful evaluation in order to understand its multidimensional aspects and to ensure more gains than losses in the workflow. To this end, in any implementation project, enough time and expertise should be devoted to evaluating a system within the context of its use. Furthermore, a close collaboration among designers, implementers, and the clinical end-users should be promoted in order for everyone to be "team players" in the system's implementation and maintenance.

Finally, on the basis of insights gained in this study, I recommend two main changes in the underlying models of clinical workflow processes in such complex health care information systems: a shift from modeling the single tasks of providers to modeling their *collective* tasks in the course of a day, and a shift from designing for the work of an individual provider to designing for the work of *col-*

*laborating providers*. Given the many advantages these systems have brought to both clinical workflow and patient safety, it is worth making the journey by paying close attention to providers' daily clinical workflow involving these systems and by redesigning both the systems and the workflow until an optimal fit is achieved.

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# SAMENVATTING

## INTEGRATIE VAN KLINISCHE WORKFLOW EN INFORMATIESYSTEMEN: NIET MEER WACHTEN OP GODOT

*Een samenvatting voor de geïnteresseerde leek.*

## INLEIDING

Twee vrienden wachten op een zekere Godot die nooit komt. In zijn absurdistische toneelstuk geeft de Nobelprijswinnaar Samuel Beckett uitdrukking aan de stemming van de mensheid die kort na de Tweede Wereldoorlog nog weinig vertrouwen heeft in de toekomst en vergeefs wacht op gebeurtenissen die wijzen naar een beter leven [1]. Zo lijkt het ook gesteld te zijn met de automatisering in de zorg. Gebruikers koesteren hoge verwachtingen van informatietechnologie en worden keer op keer teleurgesteld, wanneer deze niet uitkomen. In mijn proefschrift wil ik betogen dat een goed begrip hoe mensen hun werk plannen en uitvoeren, perspectief kan bieden aan informatietechnologie die niet zoals Godot een fata morgana blijft, maar daadwerkelijk een realiteit kan worden.

De gezondheidszorg heeft altijd geleden onder inefficiënties en grote kans op medische fouten als gevolg van versnipperde patiënteninformatie en het gebrek aan afstemming tussen zorgverleners. Informatiesystemen werden binnengehaald om aan de versnippering een einde te maken. De belangrijkste gedachte was dat zulke systemen het werk van zorgprofessionals kunnen ondersteunen, de werkprocessen efficiënter maken en daardoor het aantal medische fouten zou verminderen. De invoering is echter gepaard gegaan met veranderingen van de manier waarop zorgprofessionals hun taken uitvoeren en werkrelaties onderhouden. Deze veranderingen zijn de kwaliteit van werk en zorg niet altijd ten goede gekomen.

Onderzoekers zijn zich ervan bewust geworden dat informatiesystemen onverwachte en zelfs negatieve effecten op werk kunnen hebben. In een onderzoek naar de implementatie van elektronische voorschrijfsystemen in een aantal Amerikaanse ziekenhuizen vonden Emily Campbell en haar collega's dat de medische workflow het meest negatief beïnvloed werd [2]. Gebruikers verloren het overzicht op de patiënt, vonden dat de computers lastig te gebruiken waren en dat afgesproken procedures in de organisatie doorbroken werden. De gesignaleerde problemen maakten inbreuk op de patiëntenzorg en beïnvloedden niet alleen de patiëntenveiligheid, maar droegen ook bij aan een negatieve houding ten opzichte van de automatisering. Het gevolg was dat de gebruikers op allerlei manieren probeerden systemen naar hun hand te zetten, te omzeilen en zelfs te misbruiken.

Robert Wears en Marc Berg merkten op dat het probleem niet zozeer ligt in het feit of systemen op de goede manier ontwikkeld worden, maar dat goede systemen niet noodzakelijkerwijs goed aansluiten bij de manier van werken van zorgprofessionals [3]. Met andere woorden, er ontbreekt een "fit" tussen systeem en werk. Een aantal onderzoekers beweert dat het model van werk waarop het ontwerp van informatiesystemen is gebaseerd, niet overeenkomt met de werkelijkheid. Die werkelijkheid is veel complexer en rommeliger.

In mijn proefschrift staat de vraag centraal hoe klinische workflow en informatiesystemen geïntegreerd kunnen worden. Het sleutelbegrip 'klinische workflow' zie ik als een reeks van taken en activiteiten waardoor patiëntenzorg op de rails wordt gehouden. Het gaat zowel om activiteiten van individuele als van samenwerkende zorgverleners, en de manier waarop zij de samenwerking gestalte geven. In mijn studie situeer ik workflow in een ziekenhuis en daarom hanteer ik het adjectief 'klinisch'. Klinisch werk wordt bij uitstek gekenmerkt door multitasken, het verdelen van aandacht, samenwerken, onderbrekingen, oog en oor hebben voor mensen en reageren op gebeurtenissen en incidenten. Om de juiste systemen te ontwikkelen die geïntegreerd zijn met klinisch werk, is het noodzakelijk dat het onderliggende model van workflow correct is. Dit is niet haalbaar zonder een goed begrip te hebben van de workflow-processen, de context waarin ze plaatsvinden en hoe informatiesystemen in de praktijk er deel van uitmaken. Het is noodzakelijk dat meer proces en gebruikers georiënteerde studies van informatiesystemen worden uitgevoerd om het ontwerpen en implementeren ervan te verbeteren. Zo'n aanpak, waarin werkprocessen, gebruikers en technologie een gelijkwaardige rol spelen, wordt de sociotechnische benadering genoemd [4]. Het bestuderen van klinische workflow is daarom relevant voor elk te ontwikkelen en implementeren informatiesysteem.

Mijn promotieonderzoek werd geïnspireerd door een debat in de medische informatica literatuur volgend op een studie van Ross Koppel en zijn collega's naar het gebruik door arts-assistenten van een elektronische voorschrijfsysteem dat tot grote frustratie over inefficiëntie aanleiding leidde en het maken van medische fouten in de hand werkte [5]. De publicatie riep heftige reacties op, variërend van de kritiek dat een verouderd systeem werd bestudeerd tot het feit dat door de gebruikte onderzoeksmethoden de bevindingen geen algemene geldingskracht konden hebben. Los van de kritiek waren de auteurs erover eens dat voor het ontwikkelen van een elektronisch voorschrijfsysteem een goed begrip van de onderliggende workflow cruciaal is. Daarom richtte ik mijn aandacht op het onderzoeken van de klinische workflow bij het voorschrijven van medicijnen in een ziekenhuis met gebruik van een informatiesysteem.

## HET ONDERZOEK

Mijn onderzoek ging over de integratie van klinische workflow en elektronisch voorschrijven van medicatie in een ziekenhuis. In de Amerikaanse vakliteratuur staat elektronisch voorschrijven van medicatie bekend als ‘computerized physician order entry’, afgekort CPOE. Deze afkorting hanteer ik in deze samenvatting. CPOE is het proces waarin zorgprofessionals direct medische opdrachten of orders invoeren in een computersysteem. Aan praktisch elke klinische actie, zoals het aanvragen van een laboratoriumonderzoek of röntgenonderzoek en het toedienen of stoppen van medicatie, gaat een medische order vooraf. CPOE systemen zijn daarom nauw gerelateerd aan de klinische workflow: het gaat om het verwerken en afhandelen van medische orders. Het voorschrijven van geneesmiddelen is de belangrijkste groep. Bij het medicatieproces, waar voorschrijven deel van uitmaakt, zijn vele professionals betrokken, zoals artsen, apothekers en verpleegkundigen die geneesmiddelen toedienen aan patiënten. In zekere zin kunnen ook patiënten tot de workflow gerekend worden. Zij zijn het, die uiteindelijk de medicatie moeten nemen. Het proces is enorm tijdsintensief en er wordt veel informatie uitgewisseld. In het proces worden afdelingsgrenzen overschreden, want ook andere afdelingen zoals de apotheek zijn erbij betrokken. Daarom is medicatie een van de meest complexe processen in het ziekenhuis. Ik heb met name gekeken hoe de klinische workflow en CPOE wederzijds beïnvloed worden. Mijn onderzoeksvragen waren de volgende.

- Welke aspecten van de klinische workflow worden het meest beïnvloed door de implementatie van CPOE?
- Wat zijn voor- en nadelen van het CPOE systeem, vergeleken met het handmatige systeem van voorschrijven en toedienen van medicatie
- Hoe verandert CPOE de samenwerking tussen verschillende professionals?
- Welke eigenschappen van de klinische workflow spelen een prominente rol bij het in gebruik stellen van CPOE en hoe wordt de efficiency beïnvloed?

- Wat zijn de problemen en zelfs ontwrichtingen in het proces van voorschrijven tot toedienen van medicatie en mogelijke oorzaken in de context van CPOE? Hoe worden deze problemen aangepakt?

Om deze vragen te beantwoorden heb ik onderzoek gedaan naar het elektronisch voorschrijfsysteem Medicatie/EVS van de firma iSOFT in het Erasmus MC in Rotterdam. Ik heb daarbij zowel kwantitatieve als kwalitatieve onderzoeksmethoden gebruikt. Gegevens uit de praktijk werden verzameld door middel van vragenlijsten voor en na de implementatie van CPOE. Daarnaast heb ik gebruikers geobserveerd en geïnterviewd en ten slotte heb ik documentatie bestudeerd. Deze documentatie omvatte beschrijvingen van het CPOE systeem, handgeschreven dossiers, geprinte medicatielijsten en opleidingsmateriaal.

In hoofdstuk 2 beschrijf ik een literatuurstudie en een theoretisch model om de invloed van workflow op CPOE te kunnen begrijpen. In hoofdstuk 3 vergelijk ik de overgang van twee verschillende, op papier gebaseerde medicatiesystemen naar CPOE. Ik keek met name hoe verpleegkundigen die de verschillende systemen gebruikten de overgang waardeerden en hoe hun werk als gevolg van de implementatie veranderde. In hoofdstuk 4 worden de effecten van CPOE op de samenwerking van professionals in de medicatie workflow bestudeerd. Aandacht hadden de verdeling en coördinatie van taken en de informatiestroom tussen de drie belangrijkste beroepsgroepen van artsen, verpleegkundigen en apothekers. In hoofdstuk 5 rapporteer ik over onderzoek naar de mogelijk verschillende effecten van CPOE op chirurgische en niet-chirurgische specialismen. Ten slotte kijk ik in hoofdstuk 6 hoe niet-voorziene werkwijzen in het gebruik van CPOE worden gehanteerd om verstoringen in de praktijk van het medicatieproces te omzeilen.

## RESULTATEN EN CONCLUSIES

Ik vat mijn bevindingen in de volgende vijf punten samen.

- Klinische workflow is een *collectief* gebeuren. Het bestaat uit vele taken en activiteiten die met elkaar verbonden en van elkaar afhankelijk zijn (hoofdstuk 2 en 3 van dit proefschrift).
- Workflow wordt bepaald door *samenwerking* van verschillende professionals van wie de taken sterk van elkaar afhankelijk zijn. Als een CPOE systeem erop gericht is een specifieke taak van een beroepsgroep te automatiseren, dan heeft dat direct invloed op die van de andere. CPOE systemen moeten

dan ook ontworpen worden met het doel coördinatie van verschillende taken en activiteiten mogelijk te maken (hoofdstuk 2, 4 en 6).
- Workflow is nauw verbonden met de *organisatiecontext* van het werk. Iedere betrokkene in de workflow heeft zijn eigen rol en verantwoordelijkheid en de invoering van een CPOE systeem kan daarin soms onbewust en zelfs ongewenst daarin verandering brengen (hoofdstuk 2 en 3).
- Workflow is nauw verbonden met de *klinische* context. Een CPOE systeem dat goed voldoet aan de werkvereisten in een chirurgische afdeling hoeft dat niet noodzakelijkerwijs niet te doen in een afdeling interne geneeskunde (hoofdstuk 5).
- Workflow is in hoge mate *contingent*, dat wil zeggen afhankelijk van ongeplande omstandigheden of onderbrekingen waarop de betrokkenen pragmatisch en improviserend moeten reageren. In het geval dat de invoering van CPOE leidt tot inbreuken op de workflow, kan de gebruiker zijn toevlucht zoeken tot andere werkwijzen om het negatieve effect ervan teniet te doen. Maar zo'n verandering kan de werkbelasting verhogen of zelfs tot ongewenste effecten leiden (hoofdstuk 2 en 6).

Een aantal van de bovenstaande punten wordt fraai geïllustreerd in mijn onderzoek naar de overgang van een op papier gebaseerde toedieningregistratie van medicatie naar Medicatie/EVS. Voor de implementatie van Medicatie/EVS waren in het Erasmus MC twee verschillende papieren toedieningregistraties in gebruik, het Kardex en het TIMED systeem [6]. De verpleegkundigen die het Kardex systeem gebruikten waren meer tevreden met Medicatie/EVS dan de verpleegkundigen die met TIMED werkten. Het bleek dat de veranderingen in de workflow voor Kardex verpleegkundigen beperkt waren, maar voor de TIMED verpleegkundigen juist heel groot. In het TIMED systeem moesten verpleegkundigen het soms moeilijk leesbare handschrift van de arts zelf 'vertalen' naar een leesbare toedieningregistratie. Hierdoor verkeerden zij in de positie om waar nodig aan artsen opheldering te vragen en zelfs vragen te stellen over de voorgeschreven medicatie zelf. Het gaf hun het gevoel dat ze mee konden praten over medicatie. In het Kardex systeem was dat veel minder het geval omdat artsen hun opdrachten schreven op formulieren, waarop gemakkelijk de naam van het medicijn, de dosering, manier en tijd van toediening in vakjes ingevuld konden worden. Het Medicatie/EVS systeem bracht daarin weinig verandering, omdat dezelfde informatie op vergelijkbare manier geprint werd op etiketten. Het was duidelijk dat het verschil in tevredenheid veroorzaakt werd doordat de rol en verantwoordelijkheden van de TIMED verpleegkundigen veranderden en die van de Kardex verpleegkundigen niet.

Mijn proefschrift laat zien hoe complex klinische workflow is. Workflow wordt vormgegeven door vele actoren: zorgprofessionals, beroepsgroepen, organisatie van de zorg en de klinische context laten alle daarin een spoor achter. In het ontwikkelen en implementeren van informatiesystemen zou met al deze facetten rekening gehouden moeten worden. Daarom het belangrijk inzicht te hebben in de gebruikscontext en bij elke implementatie moeite en tijd te investeren in evaluatie. Ontwikkeling en implementatie vraagt vanzelfsprekend om nauwe samenwerking van alle betrokkenen.

Ik doe twee aanbevelingen om de onderliggende modellen van klinische workflow voor het ontwikkelen en implementeren van informatiesystemen te veranderen. Op de eerste plaats zou het modelleren van *individuele* taken en activiteiten van *individuele* zorgprofessionals moeten verschuiven naar het *geheel* van taken en activiteiten over een langere periode. Op de tweede plaats zou het modelleren moeten verschuiven van het werk van het individu naar dat van het collectief. Zo hoeven we niet meer te wachten op Godot om een optimale fit tussen workflow en systeem te realiseren.

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Zahra Niazkhani

October 10, 2009

Rotterdam, The Netherlands

# CURRICULUM VITAE

Zahra Niazkhani was born on September 12, 1973 in Naghadeh, West Azarbaijan province, Iran.

In June 1991, she graduated from Hefdahe-Shahrivar High School in Naghadeh. In January 1992, she started studying Medicine at Urmia Medical Sciences University. In June 1999, she graduated in Medicine with the title of the best medical student of the Urmia Medical Sciences University among the medical graduates (so-called in Iran, one percent medical student). She worked as a General Practitioner in public and private sectors for four years. In 2003, she was awarded a scholarship from the Iranian Ministry of Health and Medical Education to pursue her study abroad in Medical Informatics. She was the chief physician of the main campus clinic of Urmia University when she left Iran in November 2003.

Zahra joined the International Master course of Health Information Management at Erasmus University Rotterdam in March 2004. She graduated from the Master program in July 2006 and worked on her PhD project reported in this thesis at the Institute of Health Policy and Management (iBMG), Erasmus Medical Center. She is planning to continue her work on “making a fit between clinical workflow and health care information systems”.

Zahra married to Habibollah Pirnejad in 1998 and they have two daughters, Samin (born on June 2, 2001) and Yasmin (born on March 25, 2009).

# LIST OF PUBLICATIONS

- **Niazkhani, Z**. Evaluating the impact of CPOE systems on medical workflow: a mixed method study. Studies in health technology and informatics. 2008;136:881-2.

- **Niazkhani, Z**, Pirnejad, H, de Bont, A, Aarts, J. Evaluating inter-professional work support by a computerized physician order entry (CPOE) system. Studies in health technology and informatics. 2008;136:321-6.

- Pirnejad, H, **Niazkhani, Z**, Berg, M, Bal, R. Intra-organizational communication in healthcare--considerations for standardization and ICT application. Methods of information in medicine. 2008;47(4):336-45.

- Pirnejad, H, **Niazkhani, Z**, van der Sijs, H, Berg, M, Bal, R. Impact of a computerized physician order entry system on nurse-physician collaboration in the medication process. International journal of medical informatics. 2008 Nov;77(11):735-44.

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- **Niazkhani, Z**, van der Sijs, H, Pirnejad, H, Redekop, WK, Aarts, J. Same system, different outcomes: comparing the transitions from two paper-based systems to the same computerized physician order entry system. International journal of medical informatics. 2009 Mar;78(3):170-81.

- Pirnejad, H, **Niazkhani, Z**, van der Sijs, H, Berg, M, Bal, R. Evaluation of the impact of a CPOE system on nurse-physician communication--a mixed method study. Methods of information in medicine. 2009;48(4):350-60.

- **Niazkhani, Z**, Pirnejad, H, de Bont, A, Aarts, J. CPOE in Non-surgical versus Surgical Specialties: A Qualitative Comparison of Clinical Contexts in the

PUBLICATIONS

Medication Process. Open Medical Informatics Journal; the supplement on "Socio-technical approaches to the evaluation and design of health ICT applications". 2009. *Accepted.*

# PHD PORTFOLIO SUMMARY

| Activity (*location*) | Year | Workload (ECTS/ hours) |
|---|---|---|
| Master of Health Information Management (Erasmus University Rotterdam) | 2004-2006 | 60 ECTS |
| English course (Erasmus University Rotterdam) | 2004 | 63 hours |
| English academic writing (Erasmus University Rotterdam) | 2005 | 40 hours |
| English course for staff (Erasmus University Rotterdam) | 2004 | 16 hours |
| English refresher courses for staff (Erasmus University Rotterdam) | 2004-2006 | 32 hours |
| EIMHIM summer course (Rotterdam) | 2005 | 16 hours |
| Promovendidagen Medisch Informatica (Berg en Dal) | 2007 | 12 hours |
| Paper presentation at Promovendidagen Medisch Informatica (Berg en Dal) | 2007 | 8 hours |
| Paper presentation at Healthcare Governance meetings (iBMG) | 2007 | 8 hours |
| Biomedical English Writing and Communication (Erasmus Medical Center) | 2007 | 3 ECTS |
| Paper presentation at Healthcare Governance meetings (iBMG) | 2008 | 8 hours |
| Paper presentation at MIE2008 (Sweden) | 2008 | 12 hours |
| Paper presentation in doctoral consortium of MIE2008 (Sweden) | 2008 | 12 hours |
| Poster presentation at MIE2008 (Sweden) | 2008 | 12 hours |
| Drug safety symposium (Erasmus University Medical Center) | 2008 | 4 hours |