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Development and Psychometric Qualities of the SEIPS Survey to Evaluate CPOE/EHR Implementation in ICUs

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Abstract

Health Information Technology (IT) implementation can fail or meet high levels of user resistance for a variety of reasons, including lack of attention to users' needs and the significant workflow changes induced and required by the technology. End-user satisfaction is a critical factor in health IT implementation. In this paper we describe the process of developing and testing a questionnaire to evaluate health IT implementation, in particular Computerized Provider Order Entry (CPOE) and Electronic Health Record (EHR) technologies. Results showed evidence for the validity and reliability of the questionnaire. The Systems Engineering Initiative for Patient Safety (SEIPS) questionnaire is relatively easy to administer and allows researchers to evaluate different aspects of health IT implementation. Results of this research can be used for benchmarking results of future studies evaluating health IT implementation.

Keywords

Health Information Technology; Computerized Provider Order Entry (CPOE); Electronic Health Record (EHR); Implementation process; ICUs; Evaluation; Questionnaire

INTRODUCTION

One of the important applications of information technology (IT) to health care is Electronic Health Record (EHR), which includes the functionalities of computerized provider order entry (CPOE) and electronic medication administration (eMAR) (Lee, Teich, Spurr, & Bates, 1996; Sittig & Stead, 1994; Tierney, Miller, Overhage, & McDonald, 1993). In CPOE, physicians and other providers enter orders directly into the computer instead of using a paper-based system. Through rapid information retrieval and efficient data management, CPOE systems have the potential to improve quality of patient care (Bates, et al., 1998; Bates, et al., 1999; Murff & Kannry, 2001; Overhage, Tierney, Zhou, & McDonald, 1997; Teich, et al., 2000). For reviews of the effects of CPOE on medication safety and quality of care, see Kaushal et al. (2003) and Kuperman et al. (2007). There are four specific areas in which CPOE can deliver specific advantages over traditional paper-based systems: process improvement, resource utilization, clinical decision support and guideline implementation (Kuperman, et al., 2007; Murff & Kannry, 2001; Sittig & Stead, 1994). According to some experts (Bates, Kuperman, & Teich, 1994; Lee, et al., 1996), a major advantage of CPOE and other EHR functionalities such as eMAR is the opportunity to receive online support information at the point of care. Despite the benefits of EHR

(Kaushal et al., 2003), many attempts to implement such systems have failed or met with high levels of user resistance (Bates, 2006; Bates, et al., 1994; Connolly, 2005; Lee, et al., 1996; Massaro, 1993a, 1993b; Sittig & Stead, 1994).

EHR implementation efforts have stumbled for a variety of reasons, including lack of sensitivity to users' needs and the significant changes induced and required by the technology (Massaro, 1993a, 1993b). Only a relatively small percentage of hospitals use EHR. Results of a survey in 2002 (Ash, Gorman, Seshadri, & Hersh, 2004) showed that CPOE was not available to physicians in 84% of the hospitals; completely available in 10% of the hospitals and partially available in 6%. More recent estimates suggest that EHR usage is increasing, but most hospitals are still in the planning stage (Delbanco, 2006; Jha, et al., 2009).

As part of a large study funded by AHRQ (http://cqpi.engr.wisc.edu/cpoe_home), we are evaluating EHR implementation in several intensive care units (ICUs) of a large hospital using a variety of methods, including observational methods, interviews with key personnel, focus groups, a survey questionnaire, assessment of medication errors and adverse drug events, and various quality of care indicators. In this paper we focus on the survey questionnaire. The EHR being evaluated include various functionalities: CPOE, eMAR, physician and nursing documentation, and nursing flowsheets.

When conducting a survey, it is important to use valid and reliable questionnaires, an observation which may be considered all too obvious. A questionnaire needs to meet scientific criteria, as explained by Shortell et al. (1991): "Among the most important criteria of useful measures is that they be theory-based, reliable, valid, relevant to unit of analysis, and relatively easy to administer". However, questionnaires used in health care research are not always reliable or valid. For example, in a study on *patient satisfaction with health care*, Sitzia (1999) evaluated 195 studies and found that in 80% of the studies a new satisfaction assessment instrument was developed. Sixty percent of the studies in which a new instrument was developed did not report any data on validity or reliability of the instrument. Only 6% of the studies used instruments that were tested and met the minimum requirements with regard to reliability and validity. Results of a study examining validity and reliability of instruments measuring nurse-physician collaboration showed that only five questionnaires in 225 studies met the inclusion criteria used by the researchers (Dougherty & Larson, 2005).

In summary, research in health care can benefit by using valid and reliable instruments. In this paper we describe the process of developing a questionnaire to evaluate the implementation of health Information Technology (IT) from a human factors perspective.

BACKGROUND: HUMAN FACTORS AND TECHNOLOGY IMPLEMENTATION IN HEALTH CARE

The manner in which a new technology is implemented is as critical to its success as its technological capabilities (see for example Eason (1982), and Smith and Carayon (1995)). End user involvement in the design and implementation of a new technology is a good way to help ensure a successful technological investment. Korunka and his colleagues (Korunka & Carayon, 1999; Korunka, Weiss, & Karetta, 1993; Korunka, Zauchner, & Weiss, 1997) have empirically demonstrated the crucial importance of end user involvement in the implementation of technology for the health and well-being of end users. In this research project, we defined a 'successful' technological implementation from the human factors viewpoint by its 'human' and organizational characteristics: reduced/limited negative impact on people (e.g., stress, dissatisfaction) and on the organization (e.g., delays, costs,

medication errors), and increased positive impact on people (e.g., acceptance of change, job control, enhanced individual performance) and on the organization (e.g., efficient implementation process, safe patient care). Success includes improved patient outcomes such as decreasing medication errors and improving quality of care, which are also part of our study (http://cqpi.engr.wisc.edu/cpoe_home).

The implementation of technology in an organization can have both positive and negative effects on the job characteristics that ultimately affect individual outcomes (quality of working life (QWL), such as job satisfaction and stress; and perceived safety and quality of care) (Carayon & Haims, 2001). This is the basis of the Balance Theory of Job Design developed by Smith and Carayon-Sainfort (1989), and its application to health care, i.e. the Systems Engineering Initiative for Patient Safety (SEIPS) model of work system and patient safety (Carayon et al., 2006c). According to the Balance Theory, the work system includes five elements that interact to produce a stress load and other positive and negative impacts on an individual (Carayon, 2009). The five elements are the individual, the tasks, the technology and tools, the environment and organizational factors (Smith & Carayon-Sainfort, 1989). A change in one element of the work system can have effects on another element; therefore, when a change in one element occurs (e.g., technology-CPOE), the effects on the entire work system need to be considered. Inadequate planning when introducing new technology designed to decrease medication errors in health care, especially inadequate attention to the tasks and worker aspect of the work system model such as workload and system usability, has led to technology falling short of achieving its patient safety goal (Kaushal & Bates, 2001; Patterson, Cook, & Render, 2002). The most common reason for failure of technology implementation is that the implementation process is treated as a technological problem, and the human and organizational issues are ignored or not recognized (Eason, 1988; Berg, 1999). When a technology is implemented, several human and organizational issues are important to consider (Carayon-Sainfort, 1992; Smith & Carayon, 1995).

Another issue related to the success or failure of CPOE implementation is technology usability (Ash, et al., 2002; van der Meijden, Tange, Troost, & Hasmna, 2003). Usability is concerned with how end users can use the various functionalities of a technology (Nielsen, 1993). Usability is a multi-dimensional concept that includes the following dimensions: learnability (technology should be easy to learn), efficiency, memorability (technology should be easy to remember), errors (technology should have a low error rate and facilitate error recovery), and satisfaction (Nielsen, 1993). Performing usability testing before a technology is actually implemented allows the identification of design flaws (which can be fixed before the implementation), as well as training needs (implementation process). Studies of CPOE have emphasized the need for the technology to be ‘efficient’ and usable (Ash, et al., 2002; Lee, et al., 1996).

The Systems Engineering Initiative for Patient Safety (SEIPS) model developed by Carayon and colleagues (2000, 2006c, 2009) serves as the conceptual framework for understanding the impact of CPOE on end users. The SEIPS model has been used to address a number of healthcare quality and patient safety issues, such as EHR implementation in outpatient settings (Hysong et al., 2009). In this study, an adaptation of the SEIPS model to evaluate technology implementation (Carayon and Karsh, 2000) drives the choice of specific human and organizational variables to examine in the context of CPOE technology implementation. This model highlights the importance of the following human factors and organizational variables (see Figure 1):

- Technology characteristics: CPOE technology, user friendliness, usability

- Job (job control and workload) and organizational (communication and coordination) characteristics
- Quality of working life (job satisfaction, stress and turnover intention), and perceived quality and safety of care delivered (self-rated performance)
- Technological change process: employee involvement and participation.

The various elements of the model are addressed in the different sections of the questionnaire.

METHODOLOGY

We used a repeated cross-sectional design with questionnaire data collected 3 months pre-implementation (R1), 3 months-post implementation (R2) and one-year post-implementation (R3).

Sample

The study took place in 4 different ICUs (Adult, Cardiac, Neonatal and Pediatric ICU) of a large hospital in the Eastern part of the USA. The four ICUs employ about 350 physicians and nurses.

Questionnaire development

We identified items and scales in the literature that have been proven to be reliable and valid in previous research and used them to draft the pre-implementation and post-implementation versions of the questionnaire. The pre-implementation version of the questionnaire consists of 4 sections (sections A, B, D and E, see Figure 1), whereas the post-implementation questionnaires consist of 5 sections (sections A through E). Section A (About your job) includes 9 questions and asks participants about their job title, their tenure at the hospital, the unit they work on, the number of hours they work per week, and the shift they work on. Section B (About communication and coordination in the ICU) consists of 25 questions about communication openness, communication accuracy, communication timeliness, shift and hand-off communication, within and between unit coordination and shift and hand-off coordination. Section C (About the EHR in general, CPOE, eMAR and the nursing flow sheet, POST-implementation only) asks 58 questions about the technology implementation process, usability and acceptance of the EHR, CPOE, eMAR and the nursing flow sheet, and specific questions about CPOE (e.g., use of order sets, allergy and drug-interaction warnings, and drug alerts). Section D (About your quality of working life) asks 21 questions about quality of care and patients safety, job characteristics (e.g. workload, job control), job satisfaction, burnout and turnover intention. Section E (About you) asks 9 questions about gender, racial background; age, education level, and computer experience and computer availability (see Table 1). The different versions of the questionnaire were tested in pilot studies. The questionnaires were then revised based on the feedback we received. The questionnaire development process is summarized in Figure 2. The different versions of the questionnaire are available at: http://cqpi.engr.wisc.edu/cpoe_tools.

Pilot Study Pre-Implementation—Four nurses, two physician attendings, one fellow and three residents took part in the pilot study. The purpose of the pilot study was to test the questionnaire, determine how long it would take respondents to fill out the questionnaire, and make it specific for health care (content validity). Results of the pilot study showed that it took nurses an average of 8 minutes and physicians an average of 10 minutes to fill out the pre-implementation questionnaire. Most respondents were satisfied with the length and format (the use of scales and relatively few open-ended questions) of the questionnaire,

although a few respondents wished that the questionnaire be shorter. Feedback we received during the pilot study resulted in changes to the list of job positions, specific questions for residents who rotate through the units, the list of possible shifts, and abbreviations used in the questionnaire (for example, not all respondents were familiar with the terms of EHR (Electronic Health Records before implementation), eMAR, etc…). We also received useful feedback on the questionnaire distribution and collection process. Based on the feedback we made minor changes to the questionnaire that primarily involved changes in the wording of some questions.

Pre-Implementation round of data collection (Round 1)—During the pre-implementation round of data collection (R1) both a paper & pencil version and a web-based survey version of the questionnaire were used. Paper & pencil versions of the questionnaire were personally distributed to ICU staff by the research team. ICU nurses and providers (i.e. attendings, fellows, residents, physician assistants (PAs) and nurse practitioners (NPs)) were asked to fill out the survey and put the filled-out survey in a locked mailbox, which was left in the unit's conference room. Response rates were high: 95% for nurses and 84% for physicians (including NPs and PAs, but excluding residents).

One particular problem was our inability to get enough responses from residents. In general, residents are very busy and work long hours. In addition, as part of their training they rotate on a monthly basis through the different units of the hospital. Therefore we decided to use a web-based survey (WBS) for the residents. All hospital employees have access to an e-mail account. In this hospital physicians have actually two e-mail-accounts: one e-mail account for day-to-day operations as part of the hospital internal system, and one general e-mail account. For security reasons, the hospital's internal network does not allow users to access Internet links (URLs) outside of the network; in order to conduct the WBS we needed an external link. Therefore, we had to send the invitations to participate in the survey to the residents' GroupWise account. However, residents use their GroupWise account only sporadically; in addition, the list names and e-mail addresses that we were provided had some mistakes. This led to a very low response rate for the WBS (19%).

Data Analyses Round 1—Results of R1 questionnaire data analysis showed that most of the scales are reliable (see Tables 2–10). Results also showed that two items were unacceptably skewed: "Errors occur frequently when a medication is ordered" and "If an error occurs when a medication is ordered, it is likely to be detected before it could lead to an adverse event" (respective means of 2.05 and 3.87 on a scale from 1 Strongly disagree – 2 Disagree – 3 Neither agree, nor disagree – 4 Agree – 5 Strongly Agree). Therefore we changed the wording and the response categories of the items to: "How often does an error occur when a medication is ordered?" and "If an error occurs when a medication is ordered, how often is it detected before it can lead to an adverse event?" with the following scale: 1 Never – 2 A few times a year- 3 Once a month – 4 A few times a month – 5 Once a week – 6 –A few times a week- 7 – Every day.

Changes to the questionnaire—In preparation for the post-implementation survey, the minor changes described above were made to the questionnaire and the post-implementation part (Section C) was added to the questionnaire. We also added a question about the experience respondents had with the EHR technology system in outpatient settings in Section E.

Pilot study 3-months post-implementation—Four nurses, two attendings and two residents filled out sections C and D of the questionnaire. The total time needed to fill out sections C and D was on average 14 minutes. Respondents made comments about the wording of some items and instructions. Changes were then made to several items and the

instructions (e.g., some people did not understand “custom orders”; so we changed it to “predefined orders”).

Three-months post implementation round of data collection (Round 2)—In Round 2 we used only the paper & pencil version of the questionnaire. In a manner similar to round 1, questionnaires were personally distributed to ICU staff by the research team and questionnaires were collected through locked mailboxes that were left in the units’ conference rooms. Response rates for R2 were 51% for nurses and 41% for providers (including attendings, fellows, residents, NPs and PAs). The lower response rate was probably due to the length of the R2 questionnaire (see Table 1) and to questionnaire ‘fatigue’; response rates in second rounds of data collection are typically lower than in first rounds of data collection.

Data Analysis Round 2—Results of R2 questionnaire data analysis showed that most of the scales are reliable (see Tables 2–10). Results also showed that two items that were changed after R1 had a better distribution, even though this made it impossible for us to compare results before and after implementation. Results of the data analysis also showed that many nurses answered questions about CPOE with “not applicable” or “do not know”. Data were analyzed to reduce the number of items in the one-year-post-implementation (R3) questionnaire. Reliability data, factor analysis and correlation analysis were used to identify the items that best fitted in the scales (construct validity) and showed high correlations with the variables of interest, i.e. perceptions of quality of care and patient safety. Responses to the question about computer availability (“A computer is available on the unit when I want to use it”) were completely skewed: only 7% of respondents indicated that sometimes a computer was not available to them; therefore, this question was eliminated in the R3 questionnaire.

Changes to the questionnaire—Given the high number of nurses who did not respond to several questions in the R2 survey (in particular, questions about CPOE and order sets), for the one-year-post-implementation questionnaire, we decided to develop two different versions of the questionnaire: one for nurses and one for providers. The length of the questionnaire was reduced from a total of 122 questions in the 3-months-post implementation version of the questionnaire to 86 questions for nurses and 99 questions for physicians for the R3 questionnaire (see Table 1). The question about computer availability was deleted from the questionnaire. The question about highest level of education achieved was deleted from the physician version of the questionnaire because all physicians have a graduate degree.

One-year-post-implementation round of data collection (Round 3)—Response rates in the third round of data collection were 72% for nurses and 56% for providers.

RESULTS

Section B: Communication and coordination in the ICU

Table 2 shows results for communication and coordination in the ICU. The original ICU nurse-physician questionnaire was developed by Shortell et al. (1989;1991;1995) and was adapted to measure communication with pharmacists.

Section C: About Epic: EHR, eMAR, Nursing Flow sheet and CPOE implementation and specific parts of CPOE

Table 3 shows the results for the questions about the technology change process that were originally developed by Carayon et al. (2005b).

Table 4 shows the results for the questions on health IT evaluation; these questions were developed by Carayon et al. (2005),Chin et al. (1998) and Lee et al. (1996).

Order Entry Providers Only (Table 5-6-7)—Table 5 shows the results for the questions about specific features of CPOE, such as the use of order sets. The original questionnaire was developed by Lee et al. (1996).

Table 6 shows the results for the questions on medication error detection and recovery that were developed by the researchers.

Table 7 shows the results for the questions on drug alerts: drug alerts overrides, usefulness of drug alerts and barriers against the use of drug alerts. The question on drug alert overrides was developed by the researchers; the other questions on drug alerts were taken from a study by Glassman et al. (2006).

Section D: Perceived quality and safety of care and Quality of working life

Table 8 shows the results for the questions on perceived quality and safety of care. The questions are adapted from Bertram et al. (1990),Singer et al., (2003) and Sorra & Nieva (2004), and were used in previous research by Carayon et al. (2006 2005).

Table 9 shows the results for the questions on workload and job control. The questionnaire on workload (NASA TLX) was developed by Hart & Staveland (1988) and the question on job control was adapted from McLaney & Hurrell (1988).

Table 10 shows the results for the quality of working life questions. The job satisfaction item was adapted from Quinn et al. (1971), the questions and scale on emotional exhaustion are taken from Schaufeli et al. (1996), and the question on turnover intention was developed by the authors in previous research (Carayon, Schoepke, Hoonakker, Haims, & Brunette, 2006).

DISCUSSION

When conducting a questionnaire survey, it is very important to use valid and reliable questionnaires. A questionnaire needs to meet scientific criteria of reliability and validity. Unfortunately, too often questionnaires are developed and used without regard to these criteria. Several reviews have shown that many of the questionnaires used in health care are neither reliable nor valid (Dougherty & Larson, 2005; Sitzia, 1999).

In this paper we described the questionnaire development process used to evaluate the implementation of EHR technology implementation in four ICUs in a repeated cross-sectional design (see Figure 2). The different steps used to develop the questionnaire take a lot of time and effort. This process is easier when researchers use scales and items that have proven to be reliable and valid in previous research. The process to select existing, valid and reliable items and scales is described in Dougherty and Larson (2005) and Hoonakker et al. (2010). When researchers use existing items and scales, less time and effort are required in the questionnaire development process; in addition, results are available for benchmarking (comparing the results of different studies).

Results of our analysis show that the reliabilities of various scales ranged from 0.60 to 0.96 and are adequate. However, reliabilities of two scales are rather low: time pressure affecting patient safety (0.66 in R1 and 0.60 in R2) and shift coordination (0.66 in R1 and 0.56 in R2). For future use these two scales should be revised, replaced with other scales and items or removed. Furthermore, reliabilities of the scales are stable over time: the differences in

reliabilities between the different rounds of data collection are minimal and in general the reliabilities are close to the originally reported reliabilities.

Validity of most of the scales used in our questionnaire was established in previous research. For example, the communication items and scales were adapted from the ICU Nurse – Physician Questionnaire developed by Shortell et al. (1991). The ICU Nurse-Physician Questionnaire is one of the 5 questionnaires identified in a review of valid and reliable instruments measuring nurse-physician collaboration (Dougherty and Larson, 2005). Reliability, content and construct validity of the scales have been confirmed in recent research (Hoonakker, Carayon, Douglas, et al., 2008; Hoonakker, Carayon, Walker, & Wetterneck, 2008).

Most of the scales in section C on health IT evaluation were proven to be valid in previous research. For example, Hoonakker et al. (2010) identified both the QUIS (Chin, et al., 1998) and the POESUS (Lee, et al., 1996) as valid and reliable instruments to measure end-user satisfaction with health IT. Other scales used in section C, for example the scales about usefulness of and barriers to using drug alerts, have been used in previous research (Glassman, et al., 2006; Glassman, Simon, Belperio, & Lanto, 2002). Relatively little is known about the validity and reliability of the scales, but results of our analysis show that the scales are reliable (Cronbach alpha scores of 0.96 and 0.83). Results of confirmatory factor analysis (CFA) show adequate goodness-of-fit measures (χ^2=18.3, *df*=5, p<0.01, GFI=.96, CFI=.98, AGFI=.88, SRMR=0.02, RSMEA=0.12) for the usefulness of drug alerts scale and (χ^2=85.2, *df*=20, p<0.01, GFI=.90, CFI=.85, AGFI=.82, SRMR=0.07, RSMEA=0.14). Reliability and construct validity of the last scale can be improved by removing item “System problems (e.g., too slow, shuts down at inconvenient times)”.

Validity and reliability of the scales used in section D on quality of working life have also been demonstrated in previous research in health care research (e.g. quality of care and patient safety (Carayon, Alvarado, et al., 2006; Carayon, et al., 2005; Hoonakker, Carayon, Douglas, et al., 2008), workload (Battiste & Bortolussi, 1988; Hill, et al., 1992; Rubio, Díaz, Martín, & Puente, 2004), and burnout (Schaufeli, Keijsers, & Reis Miranda, 1995; Schaufeli, et al., 1996). Reliability of the workload scale (the NASA TLX) is low in our study (0.61, 063, and 0.64 in R1, R2, and R3 respectively). However, some authors argue that NASA TLX is a *multidimensional* scale, and therefore Cronbach’s alpha is not the appropriate measure of reliability. Test-retest reliability should be used to evaluate reliability of a multidimensional scale. Results of a study by Batisse and Bortolussi (1988) showed that test-reliability of NASA TLX is 0.77.

To keep the questionnaire as short as possible, some concepts (e.g. job satisfaction, job control, and turnover intention) are measured with single items. Although using more items is preferred to capture the different dimensions of concepts, we have chosen for these aspects of quality of working life to be represented by a single item in order to keep the questionnaire short. There is some support in the literature for using single items, especially in the case of job satisfaction (Dolbier, Webster, McCalister, Mallon, & Steinhardt, 2005).

The SEIPS questionnaire uses a total of 29 different types of response categories. Using so many different response categories was not our choice, but the result of using existing scales. In order to compare the results of our study with results of earlier studies, we had to use the same response categories. Respondents did not seem to be bothered by the different response categories: some respondents in the pilot-studies even made the remark that they liked the fact that so many different response categories were used.

Study limitations include the relatively small sample size (N=264 in R1; N=177 in R2, and N=220 in R3) and the relatively low response, especially among physicians in R2. Survey

response rates are in general low among physicians (Asch, Jedrziewski, & Christakis, 1997; VanGeest, Johnson, & Welch, 2007) and it is very difficult to ask ICU physicians to fill out a questionnaire survey because of the acuity of the patients and the fact that physicians are not always present in the ICUs. The overall response rate for the study was 61%, and therefore acceptable.

Conclusion

User perceptions and attitudes are essential when implementing health IT. Furthermore, health IT implementation can have a major impact on the way work is organized (workflow) and how people experience their work. We developed a reliable and valid survey questionnaire that can be used to evaluate health IT implementation. The SEIPS questionnaire is easy to administer and allows researchers to evaluate different aspects of the health IT implementation, such as the implementation process, satisfaction with the user interface, usefulness of and user satisfaction with health IT. Results of this research can be used for benchmarking results of future studies on implementation and evaluation of health IT implementation.

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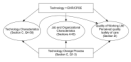

Figure 1.
Conceptual framework of the impact of technology on end users

Figure 2.
Questionnaire development and administration process

Table 1

Number of items in the different versions of the questionnaire

	Pre-implementation	Three-months post-implementation	One-year post implementation Nurses	One-year post implementation Physicians
Section A	9	9	7	9
Section B	25	25	17	17
Section C	-	58	29	47
Section D	21	21	21	21
Section E	8	9	8	7
Total	57	122	82	101

Table 2

Communication and coordination in the ICU (Pre-and Post-implementation)

Scale	Source	# Items	RC*	α (R1) α (R2) α (R3) α [original]	M (SD) R1	M (SD) R2	M (SD) R3	Example question
Communication Openness Nurses	Shortell et al. (1991)	2	A	(.82) (.74) (.85) [.83]	77.5 (17.9)	78.0 (16.1)	80.0 (15.5)	Communication with *nurses* on this ICU is very open.
Communication Openness Physicians	Idem	2	A	.91 (.94) (.93) [.88]	77.3 (18.6)	75.2 (20.0)	75.7 (19.6)	It is easy to ask advice from *physicians/PAs/NPs* on this ICU.
Communication Openness Pharmacists	Idem	2	A	.93 (.95) - -	77.7 (20.5)	74.5 (21.5)	-	Communication with *pharmacists* on this ICU is very open.
Communication Accuracy Nurses	Idem	2	A	.83 (.76) .76 [.78]	32.4 (23.2)	33.6 (21.0)	34.3 (22.1)	I can think of a number of times when I received incorrect information regarding patient care from *nurses* on this ICU.
Communication Accuracy Physicians	Idem	2	A	.88 (.88) .87 [.74]	28.6 (20.9)	29.9 (20.8)	30.4 (20.7)	It is often necessary for me to go back and check the accuracy of information regarding patient care I have received from *physicians/PAs/NPs* on this ICU.
Communication Accuracy Pharmacists	Idem	2	A	.91 (.91) - -	25.1 (18.8)	24.8 (18.6)	-	I can think of a number of times when I received incorrect information regarding patient care from *pharmacists* on this ICU.
Communication Timeliness	Idem	3	A	.71 (.71) .66 [.64]	78.1 (12.6)	75.2 (13.9)	78.2 (11.1)	I get information on the status of patients when I need it.
Nurse Shift Communication	Idem	2	A	.82 (.82) .82 [.68]	68.6 (18.4)	68.4 (17.7)	70.3 (17.7)	There is effective communication between *nurses* across shifts.
Physician Hand-off Communication	Idem	2	A	.87 .88 .90 -	67.6 (18.2)	66.8 (17.9)	68.9 (17.3)	*Physicians/PAs/NPs* associated with the unit are well informed regarding events occurring on other shifts.

Scale	Source	# Items	RC*	α (R1) α (R2) α (R3) α [original]	M (SD) R1	M (SD) R2	M (SD) R3	Example question
Within Unit Coordination	Idem	2	B	.74 (.70) .75 [.80]	73.9 (18.4)	73.0 (18.8)	74.1 (17.7)	To what extent does *one-to-one communication* between staff contribute to the coordination of staff activities *within your ICU*?
Between Unit Coordination	Idem	2	B	.84 (.87) - [.81]	52.4 (24.3)	53.7 (25.7)	-	To what extent do *daily staff rounds* contribute to the coordination of your unit's activities *with other hospital units?*
Shift Coordination	Akl et al. (2006)	2	B	.66 (.56) - NA	70.4 (16.3)	68.8 (15.3)	-	In your ICU, how effective are *nurses' shift changes* in passing on the adequate information about patients' cases and management plans?

*RC= Response categories:

A: 1: Strongly disagree – 2: Disagree – 3: neither disagree nor agree – 4: agree – 5: Strongly disagree

B: 1: Not at all effective – 2: Slightly effective – 3: Moderately effective – 4: Effective – 5: Very effective

Table 3

Information and inputs in decisions regarding EHR implementation

	Source	# Items	RC*	α (R2)	Mean (SD)	Example question
Information	Carayon et al., 2006	5	C, D, E, F, G	.94	61.3 (24.0)	What do you think about the *information* you received about the EHR implementation?
Inputs in decision	Carayon et al., 2006	6	C, E, G, H, I, J,	.99	47.9 (30.2)	What do you think about your *inputs in decisions* regarding the implementation of the HER?

* RC= Response categories:

C: 1: Insufficient – 7: Sufficient

D: 1: Incomplete – 7: Complete

E: 1: Non-timely – 7: Timely

F: 1: Vague – 7: Precise

G: 1: Useless – 7: Useful

H: 1: Meaningless – 7: Meaningful

I: 1: Bad/poor – 7: Good

J: 1: Non-productive – 7: Productive

Table 4

Healthcare Information Technology Evaluation

Scale	Source	# items	RC*	α (R2), α (R3), α original	Mean (SD) R2	Mean (SD) R3	Example question
EHR acceptance	Carayon et al. (2005a)	1 (1)	K	NA	63.65 (24.4)	65.7 (23.9)	Please check the box that best reflects your acceptance of the EHR:
User satisfaction with CPOE functionalities	Chin et al. (1998)	3 (6)	L, M, N	.91 .94	51.9 (24.4)	55.7 (24.5)	What are your overall reactions to order entry (CPOE)?
User satisfaction with eMAR functionalities	Idem	3 (6)	L, M, N	.95 .96	64.4 (24.8)	68.0 (24.0)	The electronic medication administration record (eMAR) functions as I expect.
User satisfaction with nursing flow sheet functionalities	Idem	2 (6)	L, M	.92 .90	66.0 (23.4)	66.9 (24.4)	What are your overall reactions to the nursing flow sheet?
QUIS EHR Usability	Idem	7 (21)	O, P, Q, R	.93 .93 .93 [.94]	51.7 (21.1)	54.3 (21.8)	Exploring new features by trial and error
CPOE User Satisfaction	Lee et al., (1996)	16 (16)	S	.90 .90 [.85]	51.3 (15.2)	57.5 (15.7)	Order entry improves my productivity.

*RC= Response categories:

K: 1: Dislike very much and don't want to use – 10: Like very much and want to use

L: 0: Difficult – 9: Easy

M: 0: Frustrating – 9: Satisfying

N: 0: Never – 9: Always

O: 1: Difficult – 10: Easy

P: 1: Never – 10: Always

Q: 1: Unhelpful – 10: Helpful

R: 1: Confusing – 10: Clear

S: 1: Never – 4: It varies – 7: Always

Table 5

Usefulness of specific features of CPOE

	Source	# Items	RC*	α R2 R3	Mean (SD) R2	Mean (SD) R2	Example question
Usefulness of specific features of order entry	Lee et al. (1996)	3	T	.68 .64	76.5 (16.3)	80.4 (16.6)	Usefulness of specific features in order entry (CPOE): Order sets

*RC= Response categories: T: 1: Not useful at all – 4: It varies – 7: Extremely useful – 8: Never use this feature

Table 6

Usefulness of features for error detection and recovery, new questions

	Source	# Items	RC*	α R2 R3	Mean (SD) R2	Mean (SD) R3	Example question
Error detection	New	3	U	.82 .83	54.2 (24.6)	58.5 (24.9)	How useful are the following features in identifying a problem with a medication order: Allergy warnings?
Error recovery	New	3	U	.82 .88	50.8 (22.5)	54.1 (25.9)	How useful are the following features in correcting a problem with a medication order: Drug-drug interaction warning?

* RC= Response categories: U: 1: Not useful at all – 4: It varies – 7: Extremely useful

Table 7

Usefulness of and barriers to drug alerts

	Source	# Items	RC*	α (R2) R3	Mean (SD) R2	Mean (SD) R3	Example question
Drug alerts override	New	1	V	-	47.2 (36.5)	78.1 (18.5)	How often do you override the drug alerts in the EHR?
Drug alerts: usefulness	Glassman et al., (2006)	3	W	.93. 90	63.8 (24.7)	52.9 (27.1)	Drug alerts help me prescribe safely.
Drug alerts: Limitations	Glassman et al., (2006)	8/3	X	.79 .77	59.9 (47.9)	47.9 (22.2)	Too many non-relevant alerts

*RC= Response categories:

V: 1: Never – 7: Always

W: 1: Strongly Disagree – 2: Moderately Disagree – 3: Neither Disagree Nor Agree – 4: Moderately Agree – 5: Strongly Agree – 6: Not Sure/Not Applicable

X: 1: A great deal – 2: Moderately – 3: Somewhat – 4: A little – 5: Not at all – 6: Not sure

Table 8

Perceived quality of care and patient safety

	Source	# Items	RC*	α R1 R2 R3	Mean (SD) R1	Mean (SD) R2	Mean (SD) R3	Example question
Satisfaction with quality of care provided	Bertram et al. (1990)	1	A	-	82.9 (14.6)	75.7 (18.9)	79.6 (13.4)	In general, I am satisfied with the quality of care that I provide.
Time pressure affecting patient safety	Singer et al. (2003), Carayon et al. (2005a)	2	A	.66 .57 .61	72.1 (16.5)	65.6 (17.6)	68.3 (17.3)	I have enough time to complete patient care tasks safely.
Overall perception of patient safety	Sorra & Nieva (2004), Carayon et al. (2005)	2	A	.80 .82 .83	38.3 (23.7)	42.7 (24.1)	36.3 (24.8)	We have patient safety problems in our unit.

*RC= Response categories:

A: 1: Strongly disagree – 2: Disagree – 3: neither disagree nor agree – 4: agree – 5: Strongly disagree

Table 9

Perceived workload and job control

	Source	# Items	RC*	α (R1) α (R2) α (R3) α [original]	Mean (SD) R1	Mean (SD) R2	Mean (SD) R3	Example question
Workload	Hart & Staveland (1988)	6	Y	(.61) (.63) (.64) [.77]**				
Mental demand		1	Y	-	87.9 (10.6)	87.2 (12.9)	87.5 (13.2)	**Mental demand.** How much mental activity is required to perform your job?
Physical demand		1	Y	-	62.8 (27.2)	64.4 (29.4)	69.3 (26.4)	**Physical demand.** How much physical activity is required to perform your job?
Temporal demand		1	Y	-	73.8 (18.1)	77.0 (18.5)	76.7 (17.2)	**Temporal demand.** How much time pressure do you feel due to the rate or pace at which the tasks or task elements-occurred?
Effort		1	Y	-	80.3 (13.5)	79.9 (15.8)	81.1 (14.4)	**Effort.** How hard do you have to work?
Performance		1	Y	-	79.7 (13.0)	77.4 (16.0)	80.1 (13.7)	**Performance.** How satisfied are you with your performance at your job?
Frustration level		1	Y	-	55.1 (26.4)	56.9 (25.5)	56.2 (27.6)	**Frustration level.** How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent do you feel about your job?
Job Control	McLaney and Hurrell, (1988)	1	Z	-	39.7 (26.1)	39.1 (27.3)	46.4 (26.9)	In general, how much influence do you have over work and work-related factors?

* RC= Response categories:

Z: 1: Very little – 2: A little – 3: Moderate amount – 4: Much – 5: Very much

** Test-retest reliability

Table 10

Quality of Working Life

	Source	# Items	RC*	α R1 R2 R3	Mean (SD) R1	Mean (SD) R2	Mean (SD) R3	Example question
Job Satisfaction	Quinn et al. (1971)	1	AA	-	75.2 (21.8)	76.5 (21.6)	78.4 (20.6)	All in all, how satisfied would you say you are with your job?
Emotional Exhaustion	Schaufeli et al. (1996)	5	AB	.92 .93 .94	49.2 (23.0)	52.1 (22.9)	47.2 (24.9)	I feel emotionally drained from my work.
Turnover intention	Seashore et al. (1983)	1	AC	-	27.7 (33.2)	28.7 (32.1)	36.0 (29.2)	How likely is it that you will actively look for a new job in the next year?

* RC= Response categories:

AA 1: Not at all satisfied – 2: Not too satisfied – 3: Somewhat satisfied – 4: Very satisfied

AB 1: Never – 2: A few times a year or less, almost never – 3: Once a month or less, rarely – 4: A few times a month, some-times – 5: Once a week, rather often – 6: A few times a week, nearly all the time – 7: Every day

AC 1: Not at all likely – 2 – 3: Somewhat likely – 4 – 5: Quite likely – 6 – 7: Extremely likely