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The effects of Computerized Provider Order Entry implementation on communication in Intensive Care Units

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1. Introduction

Successful communication can be defined as the ability to translate information openly, accurately, and in a timely manner (1, 2). The literature shows that direct communication (face-to-face communication or real-time communication) is the preferred mode of communication in Intensive Care Units (ICUs) (3). However, due to the interruptive nature of ICU work, direct communication may contribute to communication breakdowns and medical errors (4, 5). According to the Joint Commission (6), two-thirds of the root causes of sentinel events[1] in the period 1995–2005 were communication-related.

Relatively little is known about the different aspects of communication in ICUs, and how these different aspects of communication vary among healthcare providers. Furthermore, we do not know how health Information Technology (IT) implementation may impact

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[1]A **sentinel event** is defined by the Joint Commission as any unanticipated event in a healthcare setting resulting in death or serious physical or psychological injury to a person or persons, not related to the natural course of the patient's illness.

communication among healthcare providers, and consequently, quality of care and patient safety.

We know that communication is related to quality of care, patient safety and medical errors (7–10), but we know little about what aspects of communication are important. In one of the early thorough studies that examined different aspects of communication in ICUs, Shortell et al. (11) developed and tested a model (see Figure 1) to describe the relation between managerial practices and organizational processes and effective performance defined in terms of quality and efficiency of care provided to patients. They hypothesized that "a team-oriented, achievement oriented culture and leaders who set high standards and provide necessary support provide more open, accurate, and timely communication, effective coordination with other units, and more open collaborative problems solving approaches. These, aspects, in turn, produce greater cohesiveness among team members resulting in the delivery of more effective patient care" (11).

In this study we focus on the core of Shortell and colleagues' model, i.e. the different aspects of communication, and examine how Computerized Provider Order Entry (CPOE) implementation may influence communication patterns. *Communication openness* involves the extent to which nurses and physicians are able to say what they mean when speaking with each other without fear of repercussion or misunderstanding. *Communication accuracy* refers to the degree to which physicians and nurses believe in the accuracy of the information conveyed to them by the other party (12). *Communication timeliness* refers to the degree to which patient information is related promptly to the people who need the information. *Shift/hand-off communication* refers to the effectiveness of nurse/physician communication between shifts (11). Results of the study by Shortell et al. (11) showed that within- and between-group openness, within- and between-group accuracy, timeliness and shift communication are all positively associated with quality of care and negatively with turnover intention of nurses.

Results of the study by Shortell et al. (2) underline how important managerial and organizational factors are. Shortell et al. concluded: "The findings suggest that ICUs that have a team-oriented culture with supportive nursing leadership, timely communication, effective coordination, and with collaborative open problem solving approaches are significantly more efficient in terms of moving patients in and out of the unit. The units also have lower nurse turnover that can result in further cost savings through reduced expenses for recruitment and selection" (2 p. 521).

Apart from the studies by Shortell and colleagues, there are few studies that examine the different aspects of communication and their relation with quality of care in ICUs. Donchin et al. (13) conducted around-the-clock observations to examine human errors in a medical-surgical ICU of a large hospital. Results of the study showed that verbal communication occurred only in 9% of all activities. Most communications were exclusively among physicians or exclusively among nurses. Only in 2% of the recorded activities did physicians communicate verbally with nurses. Interestingly, verbal communications between physicians and nurses were recorded in 37% of the error reports. This percentage is surprisingly high when considering that verbal communications between physicians and nurses were observed only in 2% of activities recorded during the 24-hour observations (13).

In a recent study, Manojlovich et al. (14) examined the relationship between nurses' perceptions of communication between nurses and physicians, characteristics of the work environment and patient outcomes as measured by ventilator-associated pneumonia (VAP), bloodstream infections associated with a central catheter (BSI) and pressure ulcers in 25 ICU units. Manojlovich et al. (14) focused on different aspects of communication: openness;

accuracy; timeliness; and understanding, using the ICU Nurse-Physician Questionnaire (11). Results show that variability in communication understanding was related to VAP and that communication timeliness was inversely related to pressure ulcers. None of the communication aspects was related to BSI.

Carayon et al. (15) assessed the reliability and validity of three of the communication concepts (openness, accuracy and timeliness) developed by Shortell et al. (11) and examined the relationships between these different aspects of communication on the one hand, and unit effectiveness, satisfaction with care provided, job satisfaction, fatigue and tension on the other hand. Results of the study showed that the measures of communication were reliable and valid. Furthermore, openness, accuracy and timeliness were significantly associated with unit effectiveness, satisfaction with care provided, and job satisfaction. Communication openness was also significantly (negatively) correlated with fatigue and tension (15). Using data from the first round of data collection in our study to examine the impact of CPOE, Hoonakker et al. (16) showed that among ICU nurses, communication openness and accuracy were related to perceived quality of care and patient safety.

To summarize, successful communication is critical in healthcare and is related to outcomes such as quality of care and patient safety, in particular in ICUs. However, we know relatively little about what aspects of communication are important in this process. Further, implementation of CPOE may have negative effects on communication that need to be studied.

1.1 CPOE implementation and its effects on communication

CPOE is a key health IT in healthcare. The orders, based on the physician's decisions with regard to a patient's status, initiate and organize the actions carried out by other healthcare professionals such as nurses, pharmacists, radiologists, and laboratory technicians (17). Research has shown that CPOE may lead to errors (18–20). Errors can occur at each step of the order management process: ordering, transcription, dispensing and execution of orders (17, 21, 22). Specifically, medication ordering has received attention in the literature because medication overuse, misuse, and even underuse can do great harm to the patient (17).

Using a CPOE system, the healthcare decision maker enters orders directly into a computer instead of using paper. Several studies have shown that implementation of CPOE can improve the medication ordering and administration process and reduce medication errors because of the support for information flow and communication between care providers. For example, CPOE implementation has been shown to improve antibiotic ordering patterns (23–27). and significantly decrease non-intercepted medication errors and potential adverse drug events (23). Several functionalities of CPOE such as patient specific dosing suggestions, reminder to monitor drug levels, reminders to choose an appropriate drug, checking for drug-drug and drug-allergy interactions, standardized order sets, increased legibility, automated communication with other departments within a hospital, access to patient data and reference information while ordering, and integration of CPOE with other health IT systems, such as the pharmacy application and the nurses' electronic Medication Administration Record (eMAR) system can improve the medication use process (28).

However, recent studies have shown that implementation of CPOE may undermine the efficiency and safety of the medication process by impeding nurse-physician collaboration and communication (17, 19).

The primary goal of this study is to examine the impact of CPOE implementation on quality of communication in ICUs. We also discuss the results of this study from an international

perspective. We use data from three rounds of data collection: 6-months pre-CPOE-implementation (R1), 3-months post-CPOE implementation (R2), and one-year post-CPOE implementation (R3) to examine the impact of CPOE implementation on communication.

2. Methods

2.1 Setting

The study was performed in four ICUs in a 400-bed rural, tertiary care teaching hospital in the northeast US: the 24-bed adult intensive care unit (AICU), the 18-bed cardiac ICU (CICU), the 38-bed neonatal ICU (NICU) and the 11-bed pediatric ICU (PICU). CPOE was implemented throughout the hospital in October 2007. Related EHR functionalities implemented at the same time included the electronic pharmacy order-management system and electronic medication-administration record (eMAR), along with physician and mid-level documentation (all provided by the same vendor: Epic Systems, Madison, WI). The inpatient psychiatry system had been implemented in 2005 as a pilot. CPOE implementation was delayed by the decision to replace the existing pharmacy order-management system to enable safer, more reliable interactions between the order-entry, pharmacy, and eMAR systems.

2.2 Design

We used a repeated cross-sectional study design with three rounds of data collection: 6 months pre-CPOE implementation (Round 1 or R1), 3 months post-CPOE implementation (R2) and 1-year post-CPOE implementation (R3).

2.3 Sample

Nurses, physicians (attendings, fellows and residents), nurse practitioners, and physician assistants working in all four ICUs were asked to fill out the same survey for all three rounds of data collection. A total of 267 respondents filled out the questionnaire at R1 (response rate (RR): 68%); 177 respondents filled out the survey at R2 (RR: 47%), and 220 respondents filled out the questionnaire at R3 (RR: 68%). Overall response rate was 61%. In the rest of the paper we will make a distinction between nurses and providers (attendings, fellows, physician-assistants (PAs), nurse-practitioners (NPs), and residents). Providers enter orders in the CPOE technology; nurses use CPOE technology to enter verbal orders (although this is uncommon) and to review and verify orders.

2.4 Data collection procedures

Researchers distributed paper questionnaires to nurses and providers in the ICUs. Therefore not all nurses and providers had a chance to fill out the survey if they were not present at any of the times that surveys were distributed. Respondents returned completed surveys in locked mailboxes in each ICU's conference room. The questionnaires were filled out anonymously. Participation was voluntary and the study was approved by the institutional review boards at the University of Wisconsin-Madison and the study hospital.

2.5 Questionnaire

We created 5 scales based on the work of Shortell & Rousseau (11, 29) and our previous research (15, 30). The first scale consists of two items and measures nurse group communication openness. Originally, the scale consisted of 4 items. The second scale also consists of two items and measures provider communication openness. The two items are adapted from a four-item scale on between-group communication openness. The third scale consists of two items and refers to nurse communication accuracy. The fourth scale also consists of two items and refers to physician communication accuracy. The fifth scale

consists of three items and refers to communication timeliness. The last two scales each contain two items and refer to nurse shift communication and physician hand-off communication. See appendix 1 for the items in the different scales. The different scales are combined to create an overall communication construct. All scales are recoded into values between 0 (lowest) and 100 (highest). Results of reliability analysis show that Cronbach-alpha scores of the scales are high (ranging from 0.70 for communication timeliness to 0.92 for physician communication openness). Results of a second order Confirmatory Factor Analysis (CFA) to establish construct validity of the scales showed an adequate fit for the overall communication construct (χ^2=188.9, df=124, p<0.05, GFI=0.88, SRMR=.12 and RSMEA=0.05).

2.6 Analyses

SPSS 18.0 © and NCSS (31) were used to analyze the data. We analyzed missing values in the survey data using Little's test (32). Missing values were completely at random. Analysis of variance allowed us to examine differences between different groups, and a two-level multivariate analysis with repeated measures (33, 34) was used to examine differences in communication between rounds of data collection.

3. Results

Table I describes the study population. A greater proportion of nurses were female as compared to providers. On average, nurses were older and had longer tenure than providers; providers had more years of computer experience and more computer expertise than nurses. Providers in the sample more often work in the AICU. There are no statistically significant changes in the study population's characteristics over time.

3.1 Nurse and provider communication

In our study we make a distinction between nurses and providers because only providers (physicians and physician extenders such as PAs and NPs) can enter orders in the CPOE system. There are significant differences in how the two groups rate the different aspects of communication (see for example Figure 2). Figure 2 shows the results for Round 1 of data collection (6-months pre-CPOE implementation), but the differences between nurses are providers are consistent over all three rounds of data collection. Nurses rate the overall quality of communication consistently lower than providers, especially communication openness and accuracy of providers, communication timeliness and physician hand-off communication.

3.2 Quality of communication, 6-months before, 3-months after and one-year after CPOE implementation

Results of our analyses (see Table II) show that differences in overall quality of communication (all respondents) between the three rounds of data collection are not statistically significant (F=.779, p=0.46). Differences in overall communication for nurses between the three rounds of data collection are not statistically significant different (F=2.72, p=0.07), but the difference between R2 and R3 is statistically significant. Differences in communication for providers between the three rounds of data collection are not statistically significant different (F=.579, p=0.56).

Nurses rate the quality of communication lower as compared to the ratings of providers. Differences between nurses and providers are statistically significant (overall t=−5.69, p<0.001); in R1 (t=−3.69, p<0.001); in R2 (t=−4.38, p<0.001); but in R3 differences are no longer statistically significant (t=−1.81, p=0.71).

Overall, we do not see significant differences in the different aspects of communication for providers. For nurses, overall, the different aspects of communication decrease at R2, but at R3 come back to the same or higher levels at R1. Overall, nurses rate the different aspect of communication lower than providers, especially communication openness of physicians, communication accuracy of physicians, communication timeliness and physician hand-off communication.

4. Discussion

4.1 Effects of CPOE implementation on communication

The primary objective of this study was to examine the effects of CPOE implementation on communication in ICUs. Results of our study show few differences in the quality of communication 6 months before CPOE implementation (R1), 3 months post-CPOE implementation (R2) and one-year post-CPOE implementation (R3). Results show that for nurses, overall, quality of communication decreases 3-months post-CPOE implementation. Especially communication timeliness was significantly lower at R2 than both in R1 and R3. However, at R3 the scores on the different aspects of communication have returned to the same level or higher level as before CPOE implementation. For providers the results are more difficult to interpret, also because some providers had experience with CPOE in outpatient settings before CPOE was implemented in the main hospital. In general, the scores on the different aspects of communication in R3 are lower than at R1 and R2. However, none of the differences is statistically significant. To summarize, we can conclude that CPOE implementation did not have a negative long-term impact on quality of communication in the ICUs.

4.2 Results from an international perspective

An additional objective of this study was to examine the results from an international perspective. Specifically for nurses, most aspects of communication decreased at R2. Especially communication timeliness was significantly lower at R2. Studies in many countries, including Australia (35–37), Denmark (38), France (17), The Netherlands (19, 39–42), and the USA (43–51), have shown that communication is disrupted after CPOE implementation, and that face-to-face communication is replaced by asynchronous communication (for a summary of the studies, see Appendix 2).

Results of *observational* studies show that the time spent on communication is actually reduced after CPOE implementation (47, 51). Results of an observational study by Shu et al. (51) in a large hospital in Massachusetts showed that after the implementation of a CPOE system, physicians spent significantly less time talking, less time with other physicians or in educational activities, and significantly more time alone than before CPOE implementation. Cheng et al. (47) observed 50 clinicians (physicians, nursing staff, and pharmacists) to study the impact of CPOE two months after implementation on workflow processes in a 15-bed medical/surgical ICU in California. Results of this observation study show that CPOE changed workflows and led to new forms of communications, such as adding ad hoc verification tasks to check for an order's existence and correctness.

Results of other, mostly qualitative studies support the observational studies. For example, Fields et al. (49) interviewed nurses to examine the impact of CPOE on nurses and nurses' work in a tertiary care community hospital in California. Results of the study showed that nurses were spending more time checking for orders and many nurses felt the need to seek the physician to better understand the care plan, and needed additional information with regard to medication because physicians had entered orders off-floor. Beuscart-Zephir et al. (17) examined CPOE implementation in 3 hospitals in France using observations,

interviews, and documentation review. Results showed that, after CPOE implementation, doctors and nurses had less time to interact and discuss medications. Synchronous communication had been replaced with asynchronous communication. Pirnejad et al. (19, 40) examined the effects of CPOE implementation on nurse-physician collaboration in 6 internal medicine wards of a Medical Center (1200 beds) in the Netherlands. The researchers used questionnaires and interviews in a pre-post (5 months after CPOE implementation) design. Results of the study showed that synchronization and feedback mechanisms in nurse-physician collaboration had been impaired after the CPOE system was implemented. Many of the feedback loops that existed in the paper-based system were negatively affected after CPOE implementation. For example, nurses complained that they were not sure why a doctor had stopped or changed a medication, and they were not notified when an order had been placed by the physician off the floor. Physicians on the other hand complained about the fact that they did not know whether nurses had picked up medications. Pirnejad and colleagues concluded that: "… the CPOE system has a physician-advantaged design that promotes asynchronous communication and separates the work of physicians from that of nurses" (19). Results of secondary qualitative data analysis on data from 5 different hospitals that implemented CPOE in the US (48) showed that CPOE can have a negative impact on the communication between all actors in the care process: physician-nurse communication, physician-patient communication, and physician-pharmacist communication. For example, CPOE allows care providers to write orders off the floor, and the nurse does not always know that a new order has been placed. The latter is especially a problem in ICUs where medication orders need to be carried out as soon as possible. Other studies that used secondary analysis and expert panels confirmed these results (44, 46). To summarize, based on the results in these different countries, we can conclude that in general CPOE implementation disrupts communication patterns, and especially communication between nurses and physicians.

Interestingly, many of the problems caused by CPOE implementation such as change in established workflow patterns and communication have been known for quite a while. Massaro (43) in 1993 described the effects of CPOE implementation at the University of Virginia (UVA) Medical Center. CPOE implementation at UVA was difficult: the implementation experienced considerable delays, and its cost was higher than originally estimated. Among the causes of the problems with CPOE implementation at UVA were the alteration of established workflow patterns and a change in the way the medical center's professional groups related to each other (43). Using CPOE, orders were placed by clinicians from anywhere in the hospital and no direct communication with other caregivers was required.

The results of the international studies have shown that several underlying mechanisms are causing disruption in physician-nurse communication after CPOE implementation. First, the amount of time for nurse-physician communication is reduced. Second, direct or synchronous communication in which the physician gives a verbal order or writes a paper order (including change orders), which is acknowledged by the nurse, who then takes care of the ordering process, is replaced by *asynchronous* communication: the physician puts the order in the system, assumes that the "system" will take care of the ordering process (sometimes called an "illusion of communication" (48)), but it can take time for the nurse to find out about the order. For example, the nurse may have to log in the system to find about the order. In other words: there is a delay between the physician "sending" the order and the nurse "receiving" the order (44, 46, 48). Third, some of the feedback mechanisms that are present in verbal or paper ordering are missing. In a synchronous paper ordering system, the physician gives the verbal order or writes the paper order and the nurse receives the order. If there are any questions about the order, at that moment the nurse can ask questions to the physician. In addition to this verbal exchange of information and the opportunity to get

direct feedback and resolve possible issues with the order, non-verbal communication takes place. Face-to-face communication between the physician and nurse is multi-dimensional: the face-to-face communication does not only convey information about patient care, but also meta-communication messages that are important to create and maintain interpersonal relationships, evaluate one other's knowledge, and establish trust (52).

These underlying mechanisms can at least partly explain the results of our study. Nurse-physician communication openness and timeliness decreased between pre-CPOE implementation and 3-months post-CPOE implementation, but nurse-physician communication accuracy did not change. Studies in several countries have shown that CPOE does improve accuracy (53–57). However, at R3, one-year after CPOE implementation, communication openness and timeliness are back at the same level as pre-CPOE implementation. We assume that nurses and physicians have adapted to the disruptive effects of CPOE on communication by changing the way they communicate, and using workarounds and new ways of communicating. For example, several studies have shown that there is an increase in calls made by nurses to physicians to get additional information about the orders (42, 47, 49). The study by Khajouei et al., (41) in the Netherlands, 10 years after CPOE implementation, shows that both nurses and physicians have found new ways to communicate, and restored the feedback loops by using paper artifacts. The CPOE that was implemented provides the possibility to print out labels that indicate to nurses that a new order, or change or discontinuation of previous orders has occurred. Nurses mentioned that they use these print-outs to coordinate ordering activities with physicians and other nurses.

4.3 Conclusion

Communication in healthcare is of crucial importance. According to the Joint Commission, many errors in medical settings are related to communication (6, 58). Several international studies have shown that CPOE can disrupt communication. However, there are few studies that have studied long-term effects of communication.

Results of this study show that CPOE implementation has a negative effect on the quality of communication in the short time, but that in the long-term quality of communication reverts to pre-CPOE implementation levels. Results of this study show that implementation of health IT, such as CPOE, causes basically the same problems in different countries, despite differences in health IT implementation approach (bottom-up, middle-out, or top-down). This means that the problems are caused by the technology and not so much the implementation process. Technology implementation has an impact on work processes, workflow, and communication. Interestingly, even in countries with a bottom-up approach, such as the USA, where one would expect more competition between vendors and therefore more attention to customer demands, these problems persist, and will not be resolved until either vendors pay more attention to usefulness and usability of health IT, or employees have found ways to work around the problems caused by technology implementation.

4.4 Study limitations

In this study we used a repeated cross-sectional design (trend study); therefore, there may be some dependency between the samples in the different rounds of data collection (R1, R2, and R3). For the providers the dependency is limited because residents are a large part of the sample (48% in R1, 39% in R2 and 30% in R3, see Table I). Residents rotate through the units, thus the chance that the same resident filled out the questionnaire in an ICU in the three rounds of data collection is rather small. There were no statistical differences between the nurses' samples in the different rounds of data collection with regard to gender, age, education, tenure at the hospital and unit they work in, and average years of computer experience. This means that there must be some dependency between the nurses' samples at

R1, R2, and R3. The question is how important that dependency is. It is possible that the manner in which nurses filled out the questionnaire at R1 may have some effect on how they filled out the questionnaire at R2, nine months later, and R3 (18 months later than R1 and 9 months later than R2). A second limitation of this study is that the samples of providers at R1-R3 were rather small, and consist of different job positions (residents, fellows, attendings, nurse practitioners, and physician assistants). However, results of a power analysis, conducted before we started the study, showed that at the provider-level, an optimal sample size configuration to maintain statistical power at .80, with alpha = .05, would be 50. The sample size of the prescribing providers is small, but should be large and sensitive enough to detect statistically significant differences.

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Appendix

Appendix 1

Communication in the ICU (Adapted from the ICU Nurse-Physician Questionnaire ([1, 2]))

If you are a resident, when answering the questions in this section, please think about the ICU that you worked on most recently.

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
1. Communication with nurses on this ICU is very open.	☐1	☐2	☐3	☐4	☐5
2. It is easy to ask advice from nurses on this ICU.	☐1	☐2	☐3	☐4	☐5
3. Communication with physicians/PAs/NPs on this ICU is very open.	☐1	☐2	☐3	☐4	☐5
4. It is easy to ask advice from physicians/PAs/NPs on this ICU.	☐1	☐2	☐3	☐4	☐5
5. Communication with pharmacists on this ICU is very open.	☐1	☐2	☐3	☐4	☐5
6. It is easy to ask advice from pharmacists on this ICU.	☐1	☐2	☐3	☐4	☐5
7. I can think of a number of times when I received incorrect information regarding patient care from nurses on this ICU.	☐1	☐2	☐3	☐4	☐5
8. It is often necessary for me to go back and check the accuracy of information regarding patient care I have received from nurses on this ICU.	☐1	☐2	☐3	☐4	☐5
9. I can think of a number of times when I received incorrect information regarding patient care from physicians/PAs/NPs on this ICU.	☐1	☐2	☐3	☐4	☐5
10. 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.	☐1	☐2	☐3	☐4	☐5
11. I can think of a number of times when I received incorrect information regarding patient care from pharmacists on this ICU.	☐1	☐2	☐3	☐4	☐5
12. It is often necessary for me to go back and check the accuracy of information regarding patient care I have received from pharmacists on this ICU.	☐1	☐2	☐3	☐4	☐5
13. I get information on the status of patients when I need it.	☐1	☐2	☐3	☐4	☐5
14. When a patient's status changes, I get relevant information quickly.	☐1	☐2	☐3	☐4	☐5

If you are a resident, when answering the questions in this section, please think about the ICU that you worked on most recently.

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
15. In matters pertaining to patient care, nurses call physicians in a timely manner.	☐1	☐2	☐3	☐4	☐5
16. There is effective communication between nurses across shifts.	☐1	☐2	☐3	☐4	☐5
17. Nurses associated with the unit are well informed regarding events occurring on other shifts.	☐1	☐2	☐3	☐4	☐5
18. There is effective communication between physicians/ PAs/NPs across shifts.	☐1	☐2	☐3	☐4	☐5
19. Physicians/PAs/NPs associated with the unit are well informed regarding events occurring on other shifts.	☐1	☐2	☐3	☐4	☐5

[1]Shortell SM, Rousseau DM. The Organization and Management of Intensive Care Units. University of California-Berkeley, 1989.

[2]Shortell SM, Rousseau DM, Gillies RR, Devers KJ, Simons TL. Organizational assessment in intensive care units (ICUs): construct development, reliability, and validity of the ICU nurse-physician questionnaire. Medical Care. 1991;29(8): 709-26.

Bullets

What was already known about the topic

- Communication patient safety
- Computerized Provider Order Entry (CPOE) can improve the medication ordering and administration process and reduce medication errors because they support better data communication between care providers
- Recent studies have shown that implementation of CPOE may undermine the efficiency and safety of the medication process by impeding nurse-physician collaboration and communication

What this study added to our knowledge

- Few studies have examined the long term effects of CPOE implementation on communication
- In addition, few studies have examined what aspects of communication are affected by CPOE implementation
- Results of this study show that CPOE implementation has a short-term, negative effect on communication timeliness and openness, but in the long term these effects revert to the same or higher levels as pre-CPOE implementation

Highlights

- Few studies have examined long term effects of CPOE implementation on communication
- Few studies have examined what aspects of communication are affected by CPOE
- CPOE implementation has a short-term, negative effect on communication
- In the long term the effects revert to the same levels as pre-CPOE implementation

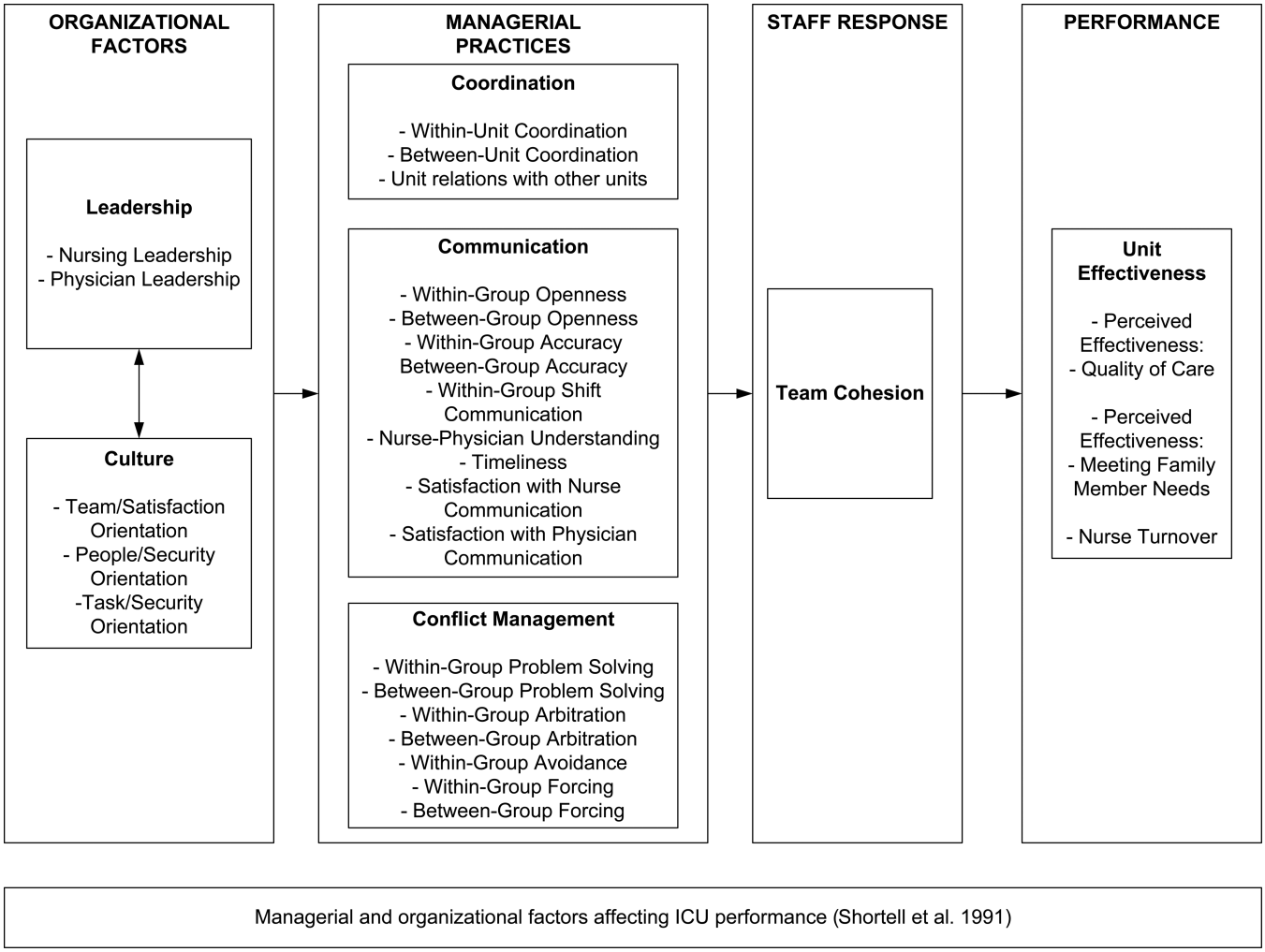

Figure 1.
Managerial and organizational factors affecting ICU performance (Shortell et al., 1991)

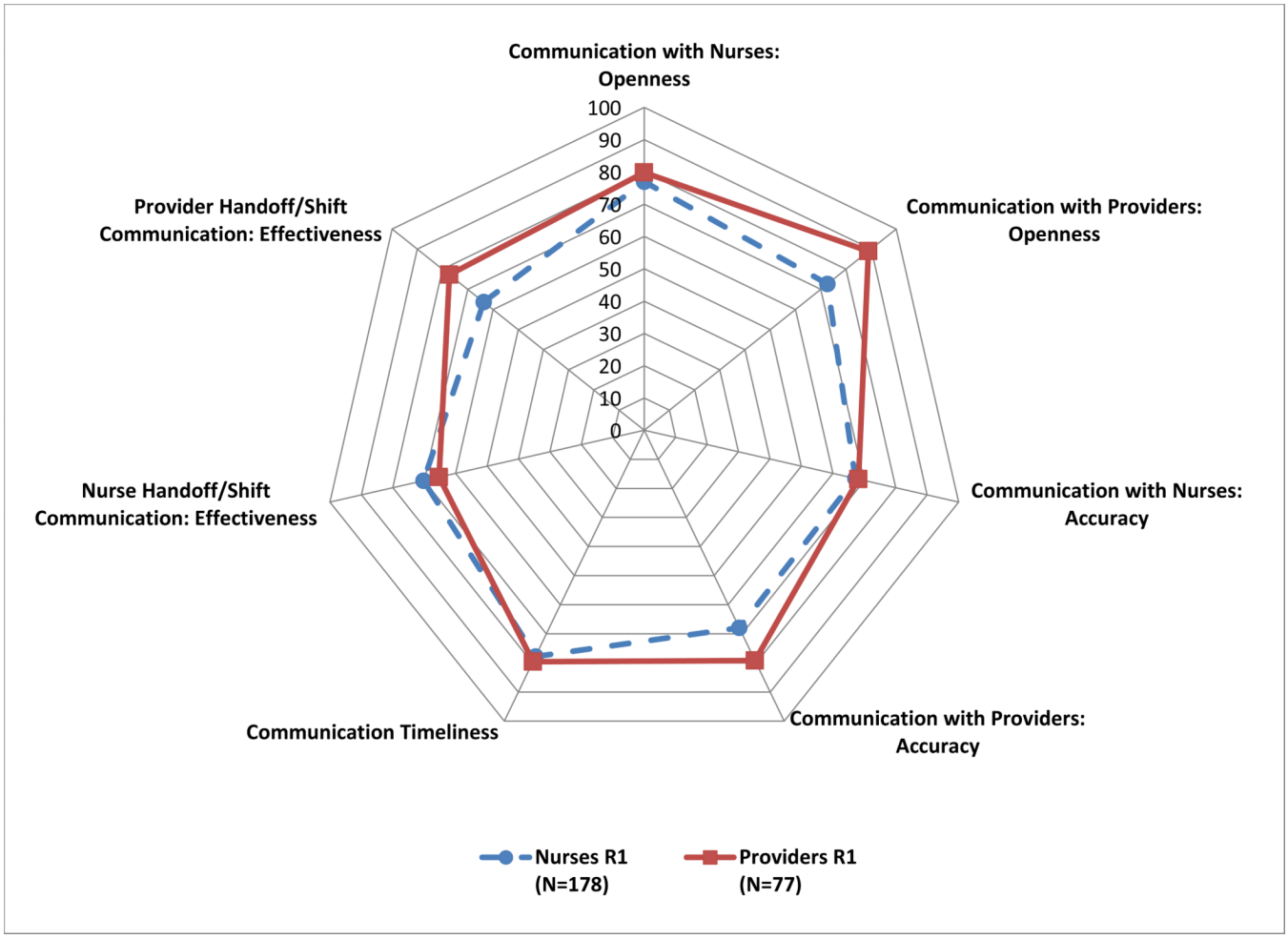

Figure 2.
Differences in communication between nurses and providers

Table I

Summary table descriptive statistics nurses and providers, Round 1, percentages, means and [standard deviations]

	Nurses (N=178)	Providers[1] (N=79)	Significance
Age			
/< 34	33.7%	53.8%	χ^2 = 10.6, *df*=3,
35–44	27.4%	21.3%	p<0.05
45–54	32.0%	17.5%	
>/ 55	6.9%	7.5%	
Gender			
Male	12.4%	60.8%	χ^2 =64.7, *df*=1,
Female	87.6%	39.2%	P<0.001
Education			
Some college or technical training	40.3%	1.3%	χ^2 =195.3, *df*=3,
Graduated from college	46.6%	7.5%	p<0.001
Some graduate school	10.2%	2.5%	
Graduate degree	2.8%	88.8%	
Years of computer experience	9.9 [6.1]	13.5 [6.4]	t=−4.3, p<0.001
Computer expertise (1 = never use it; 7 = regular and expert user)			χ^2=18.9, *df*=5, p<0.01
Tenure at hospital (Years)	11.5 [10.3]	6.5 [8.4]	t=3.9, p<0.001
Tenure at ICU (Years)	10 [9.2]	3.5 [6.8]	t=5.8, p<0.001
ICU			
Adult ICU	28.3%	45.8%	χ^2=10.3, *df*=3, p<0.05
Cardiac ICU	27.2%	24.1%	
Neonatal ICU	30.6%	14.5%	
Pediatric ICU	13.9%	15.7%	

[1] R1: 9 Physician Assistants (PAs), 9 Nurse Practitioners (NPs), 22 attendings, 4 fellows, 40 residents and interns, R2: 3 PAs, 3 NPs, 15 attendings, 10 fellows, 22 residents and interns, 1 unknown; R3: 7 PAs, 4 NPs, 21 attendings, 8 fellows, 17 residents and interns

Table II

Communication by job type and round of data collection 6-months pre-implementation (R1), 3-months post implementation (R2) and one-year post implementation (R3), means and [standard deviations]

	Nurses R1 (N=178)	Nurses R2 (N=120)	Nurses R3 (N=162)	Providers R1 (N=77)	Providers R2 (N=52)	Providers R3 (N=55)
Communication with nurses: openness	77.0 [15.8]	75.2 * [16.0]	79.8 * [13.9]	79.9 [20.3]	84.6 [14.8]	80.7 [19.5]
Communication with physicians: *1,2,3*	72.7 [17.6]	70.1 [20.3]	72.8 [19.0]	89.0 [13.3]	87.0 [13.3]	84.3 [18.8]
Communication with nurses: accuracy	67.2 [23.1]	64.7 [21.8]	65.9 [21.5]	68.2 [23.3]	70.1 [19.2]	65.2 [23.9]
Communication with physicians: accuracy *1,2*	67.9 [20.6]	66.9 [21.7]	68.4 [20.0]	79.2 [19.5]	77.9 [16.5]	73.0 [22.4]
Communication: timeliness *1,2,3*	77.8 ** [10.5]	73.4 ** [12.9]	77.8 ** [11.7]	79.5 [13.8]	79.6 [15.4]	79.7 [13.2]
Nurses Handoff/ Shift Communication	70.2 [16.0]	68.3 [17.3]	71.7 [16.4]	65.3 [21.4]	68.9 [18.9]	66.4 [20.7]
Physician Handoff/ Shift Communication *1,2,3*	63.7 [16.5]	63.0 [17.6]	66.2 [16.8]	77.3 [16.4]	75.2 [15.9]	76.8 [16.6]
Communication Total *1,2*	71.4 [10.7]	69.0 [12.1]	72.2 [11.0]	77.1 [12.4]	77.9 [12.6]	75.4 [12.3]

* Differences between rounds of data collection are statistically significant at $p<0.005$, and

** $p<0.001$

1,2,3 Differences between providers and nurses are statistically significant in respectively R1, R2, and R3