Safety of the Antibiotic Medication Use Process in the Intensive Care Unit

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Understanding the antibiotic medication use process in the intensive care unit (ICU) is important for patient care outcomes. A system view of the medication use process facilitates understanding the role of communication between various disciplines in ensuring the timely administration of antibiotics. Antibiotic-related medication safety events (N=312) were collected in two adult ICUs. We describe the information and communication flow in the medication use process and show the complexity of the process. An in-depth analysis of 101 (32%) events for late first-dose antibiotic identifies multiple factors contributing to the events.

INTRODUCTION

Intensive Care Unit (ICU) patients are critically ill, and the life-saving interventions in the ICU include the administration of numerous medications such as antibiotics. However, errors in the medication use process may result in harm to the patient. Cullen et al (1997) showed that the large number of medication errors and adverse drug events (ADEs) in the ICU are directly related to the large number of medications used. For example, delays in the initiation of antibiotic therapy in patients with conditions such as meningitis and sepsis can result in increased mortality (Kumar et al, 2006). As a result, the guidelines for management of sepsis state that antibiotics should be administered within one hour of diagnosis (Dellinger et al, 2007). A better understanding of the antibiotic medication use process in the ICU is a precursor to improving timeliness and thereby reducing ICU patient mortality through increased effectiveness and safety of antibiotic medication use.

Medication safety

Medication administration is the last opportunity to detect and correct upstream errors in the medication use process. There is limited opportunity and time to detect and correct errors made during this step, especially in a high-paced complex environment such as the ICU. When errors are not caught, attention is usually focused on people involved, e.g. the nurse performing the administration, rather than on the care system as a whole. Leveson (1995) refers to an oversimplification of causation, stating that "an operator who does not prevent accidents caused by design deficiencies or lack of proper design controls is more likely to be blamed than the designer." As a result, the focus for improvement is not shifted to the system from which problems originate; thus the upstream errors and system-safety issues may continue to lead to patient harm. Some system errors may go unreported because latent errors, such as communication failures, are not thought of as errors by healthcare providers (Henneman, 2007). Weick (2002) discusses the importance of communication and mindful interdependence in reducing errors, observing that "people tend to see what they are able to deal with." In its 2007 report, "Preventing Medication Errors," the Institute of Medicine (IOM) found that latent communication failures, such as providing incomplete drug information or ordering a drug in a nonstandard way, contribute to errors resulting in serious patient harm and even death. Therefore, the IOM (2007) has called upon the healthcare community to "look beyond blaming individuals and focus on the multiple underlying system failures that shape individual behavior and create the conditions under which medication errors occur."

Medication use process

The medication use process is complex and often situation- and patient-dependent, involving coordination of the efforts of people in different disciplines and job categories. The medication use process is often described as a linear progression from ordering, transcription, preparation, dispensing, administration, and monitoring. However, a linear view of the medication use process provides an insufficient basis for a system view and does not represent the actual process. The actual medication order process observed by Cheng et al (2003) and Hazlehurst et al (2003) in ICU settings involves multiple communication feedback loops which are not captured in the common linear model of medication use. In addition, the steps of the process are often performed in parallel and are highly iterative and interactive.

Communication within and between steps in the medication use process is complex and varies according to multiple factors, including the medication involved. For example, pharmacists may be involved in monitoring the use of certain medications and communicating with the physician and nurse. Communication and coordination of providers within the ICU, as well as with other healthcare staff outside of the ICU, are strong contributors to patient and staff outcomes (Beauscart-Zéphir et al, 2005; Shortell et al, 1994).

METHODS

The purpose of this study is to understand the relationship between information flow and medication events at different stages of the medication use process. These data on ICU antibiotic medication safety events were collected as part of a larger study to evaluate the impact of computerized provider order entry (CPOE) implementation in ICUs (http://cpoe.engr.wisc.edu/). The study used multiple evaluation methods and a pre-post design. Medication safety event data (errors and ADEs) were collected by four trained nurse data collectors using a protocol adapted from research by Bates and colleagues (1995). The protocol involved the review of medication orders through the medication use process by reviewing the written orders, transcribed orders, documentation of medication administrations, and use of various triggers potentially associated with ADEs such as administration of an antidote to treatment symptoms. All medication-related incident reports sent by the ICU staff to the hospital event reporting system were also reviewed, and ICU staff could also directly report events to the nurse data collectors. Additional data on contributing and causal factors were collected from the patient record for all medication safety events identified by the nurse data collectors. The research team reviewed all medication safety events to adjudicate the occurrence of a medication error or ADE.

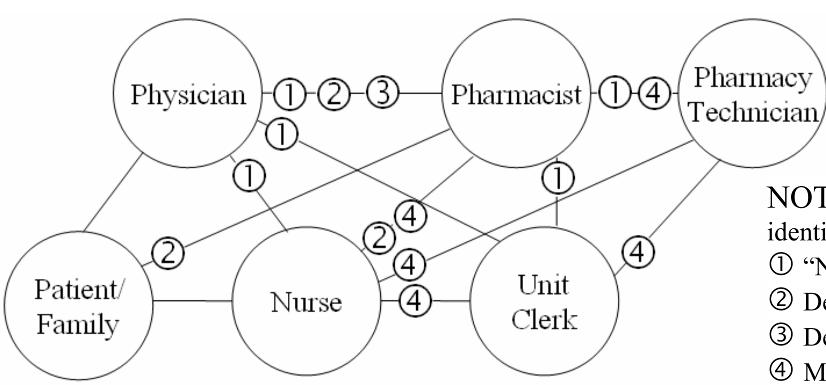
Two ICUs in a tertiary care teaching hospital in the Northeast region of the US participated in the study: (1) a 24-bed adult medical/surgical ICU and (2) an 18-bed cardiac ICU. Antibiotic pre-printed order sets with drug names and suggested doses were mandatory for all antibiotic ordering. Data were collected on 630 consecutively enrolled subjects in both ICUs over a five month period. From these data, a subset of 312 antibiotic-related events were identified as medication safety events for which the category of the medication involved was "antimicrobial." The data presented here includes only data collected prior to the implementation of CPOE, while the paper ordering process was still in place.

Late first dose antibiotic administration events were reviewed to identify contributing factors, based on event descriptions and related or causal factors recorded by the nurse data collectors. An antibiotic administration was considered to be late if the first dose of the antibiotic was administered greater than 1 hour after the order was written or if a scheduled dose of antibiotic was administered greater than 2 hours after the scheduled administration time. Antibiotic events were excluded from this analysis if they were not administered via the intravenous (IV) or oral route, if the antibiotic was administered for prophylaxis before surgery, or if the antibiotic order represented a change in antibiotic regimen in which administration within one hour of the order would not be clinically indicated. Each event was reviewed by a physician and an industrial engineer for inclusion, and they determined factors which may have contributed to late antibiotic administration in a given event. Differences in classification were discussed until a consensus was reached.

RESULTS

Information flow and communication in the medication use process

The medication use process activities and information flow vary based on the type of medication and patient situation. Figure 1 shows the lines of communication in the medication use process by role in the ICUs studied. The physician, pharmacist, and nurse each act as hubs of information, interacting closely with each other through structured written and verbal communication. Pharmacy technicians and unit clerks also play a role in the information flow. For example, the unit clerk is responsible for taking the carbon copy of a new medication order off the chart and faxing it to the pharmacy. The pharmacist then reviews the order and oversees the pharmacy technician who completes preparation and dispensing of the medication. The nurse and physician are the primary points of contact for the patient and patient family on medication use information. Information also flows within a role, such as when nurses update each other on patient status during report at shift change.



NOTE: The factors contributing to late administration are identified as follows:
① "NOW" not indicated in order for 1^{st} dose antibiotic
② Delay in pharmacist processing and clarification of order
③ Delay in pharmacist consult on antibiotic dose
④ Medication missing/not found at time of administration

Figure 1: Medication use process and information flow with factors contributing to late administration

Table 1: Roles, activities and information flow in the medication use process

Role	Activity	Information flow methods
Physician, physician assistant	Assesses need for therapy and writes orders	Written order (chart), verbal in-person, verbal by phone (written by nurse), verbal communication with patient/family about drugs prescribed.
Pharmacist	Transcribes order into computer system, assesses order appropriateness	Written order (chart/pharmacy system), verbal in-person, verbal by phone.
Nurse	Administers medication & documents administration	Written missed dose report to pharmacy, verbal in-person, verbal by phone, written documentation (MAR in chart), verbal communication with patient/family about drugs given.
Pharmacy Technician	Facilitates order movement & information flow	Routes phone calls to pharmacist, brings written orders (faxed or sent by pneumatic tube from chart copy) and missed dose reports to pharmacist, preparation and dispensing of medication and MAR label.
Unit Clerk	Facilitates order movement & information flow	Sends orders and missed dose reports to pharmacy by fax or pneumatic tube.
Patient and Family	Provides information (i.e. known allergies) & receives medication	Verbal communication with physician & nurse about current meds and known allergies, discuss meds with nurse at time of administration.

Various mechanisms are used to pass information from one person to another. Table 1 describes the roles, activities, and information flow methods in the medication use process at this hospital. Information is often communicated in written form only or by telephone, and there is an expectation that written communication in the chart will be read by the relevant care provider(s). Visual cues are used to assist in managing this information. For example, the physician will move the chart to the nursing station and turn the chart dial to red, indicating a new order.

Data on the 312 antibiotic medication safety events were categorized by the medication use process stage at which the event occurred. Ordering errors subsequently corrected by a pharmacist through the process of reviewing and clarifying an order accounted for 93 (30%) of events. Dispensing events, such as the medication missing or not found at the time of administration, accounted for 97 (31%) of events. A total of 105 of the 312 (34%) events observed were late antibiotic administration, of which 101 were for a first dose of an antibiotic. The rest of the analyses focus on these late first dose administration events because delay in antibiotic administration has a major impact on ICU patient mortality (Kumar et al, 2006).

Analysis of late antibiotic administration events

Contributing factors for late dose administration were identified by reviewing the 101 late dose administration events. There were 42 events for which a contributing factor was not identified from the chart review, but review of the other 59 late first-dose antibiotic events provided information on potential causal factors. Some events had multiple contributing factors. Figure 1 shows 4 types of contributing factors and their role in the information flow of the medication use process.

In this hospital, first-dose antibiotics are to be treated differently than other medications: they are to be given within one hour of the order unless otherwise specified by the ordering provider. One contributing factor identified is that the usual process to request a medication to be given within an hour is to write the word "NOW" in the medication order (see contributing factor #1 in Figure 1). New antibiotic orders that do not have "NOW" written in the order may be viewed as a routine medication order by other healthcare providers. Failure to indicate "NOW" on the medication order for a first dose antibiotic is an omission in communication from the physician to the unit clerk, pharmacist, and nurse. This may have a cascading effect on communication between the pharmacist and the unit clerk and pharmacy technician (see Figure 1).

In some cases, the pharmacist processed the antibiotic order after the one-hour late administration time, leading to a subsequent assignment of an administration time more than 1 hour after order written. A medication is not prepared until the order is verified by the pharmacist, so delay at these steps directly delays administration time. Pharmacist clarification of an ordering error and pharmacist consults on the dose to be administered were identified as contributing factors because of the time delay sometimes incurred by these steps (see contributing factors #2 and #3 in Figure 1). A pharmacist clarification occurs when the pharmacist identifies and corrects an incomplete or potentially inappropriate medication order. Clarification often involves contacting the ordering physician and may involve gathering additional information about the patient (see Figure 1). A pharmacist consult occurs when the physician writes the order for the pharmacist to determine the appropriate dose of the medication, for example, for antibiotics in which pharmacokinetic monitoring is important like gentamicin, or for patients with renal dysfunction. The number of pharmacists and their availability to review orders varies by time of day and may have an impact on the time an order waits for clarification or a consult to be performed.

Another contributing factor is when the medication to be given is not available for administration (see contributing factor #4 in Figure 1). When a nurse is unable to locate the medication to be given, a missing dose request form may be sent to the pharmacy. The nurse, pharmacist, technician, and unit clerk all may become involved in remedying the situation.

Other contributing factors such as workload of the nurse and patient condition are indirectly related to communication between care givers. When the nurse is busy with other patient care activities, s/he may perceive those activities as taking priority over antibiotic administration (e.g. administering fluids and pressors for low blood pressure). Also, the patient state may preclude the medication from being given at the indicated time of administration, e.g. IV access is not available or the patient is gone for a test. Multiple factors may be present in any given antibiotic event and influence administration. In one case, a first dose antibiotic was given 4 hours late, potentially related to the medication order not indicating to administer "NOW," a delay in pharmacist processing and clarification of the dose, the patient being out of the ICU for a test, and the patient needing to receive 3 other antibiotics at the same time. These contributing factors give insight into the medication use process, in particular the complex communication lines between the different providers (see Figure 1).

DISCUSSION

Communication within the ICU is important to medication safety (Beuscart-Zéphir et al, 2005; Shortell et al, 1994). We identified multiple factors related to information flow and communication which may contribute to the late administration of an antibiotic. These communication factors contribute to the complexity of the medication use process: medication not ordered "NOW," pharmacists not processing orders promptly resulting in a scheduled time later than 1 hour from the ordering time, the time involved with pharmacist clarification of an antibiotic order or consulting about the dose to be administered. Tools such as CPOE and electronic health record (EHR) systems have been suggested as ways to improve medication safety. However, their impact on information flow and provider communication is not well-known. It is important to understand the impact of these tools, or any other change, on the steps of the medication use process, information flow and communication (Beuscart-Zéphir et al, 2005).

Passive forms of communication, such as documenting in the patient chart, need to be complemented by active forms of communication such as verbal communication in person or on the phone. Physical and visual cues can also be used to assist in managing workflow, providing information about what is to be worked on next.

The medication use process has many characteristics of a complex work system (Carayon, 2006), such as distributed and dynamic system. The analysis of information flow in the antibiotic medication use process in two ICUs shows the need for many different roles to be involved in active communication.

CONCLUSION

Understanding communication and information flow in the complex medication use process and their impact on medication safety will aid in planning system improvement efforts. Timeliness, effectiveness, and safety of antibiotic use are related, and team communication plays a role in the outcomes of the medication use process (see Figure 1 and Table 1). Improvement efforts must focus on the entire work system (Carayon et al, 2006), and understanding the various contributing factors in different environments will assist in eliminating barriers to providing safe, timely, effective care.

Future work on the changes in the medication use process and information flows related to the implementation of information technology is recommended. It is also necessary to understand other contextual factors such as the expertise and number of staff on-site and on-call, which varies by time of day. This study examines the medication use process and medication events on two ICUs at one hospital, therefore limiting the generalizability of our results. Further study to understand the similarities and differences at other hospitals is warranted.

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