Observing nurse interaction with medication administration technologies

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Abstract

In this paper, we describe the use of observational methods to assess the interaction between nurses and medication administration technologies. The observations were conducted to examine the use of point-of-care bar code technology, and have also occurred pre- and post-implementation of Smart IV pumps with medication delivery software to prevent programming errors. A total of 62 observations were done for the bar code technology, 52 observations were conducted pre-implementation of the Smart IV pumps, and 63 observations post-implementation of the Smart IV pumps. We describe the procedures used to collect data, and present preliminary observation data analysis on the physical environment and the sequence of steps used in the medication administration process under three technological conditions (bar code technology, IV pump technology, and Smart IV pump technology).

Introduction

Human factors engineers use various methods for describing and evaluating interactions between people and their work environment. It is important to recognize that the interactions between people and their work environment can be analyzed at many different levels [1]. From a structural point of view the following levels can be distinguished: (1) political and societal organization of work, (2) industrial relations, market and business conditions, (3) cooperation in groups and human relations, (4) individual work, (5) subtasks and workplaces, (6) specific operations with tools and technologies, and (7) interactions between physiological systems and environment [1-3]. These different structural levels have different impact on the role and actions of people: (1) work-oriented political actions, (2) interaction within an organization and between organizations, (3) group work, (4) motive-related activity, (5) goal-oriented action, and (6) elementary operations and movements [1]. Various methods are used to collect information on the interactions between people and their work environment at these different levels [1, 4]. In this paper, we describe an observational method used to evaluate goal-oriented actions and elementary operations of end users of medication administration technologies. These actions and operations represent subtasks and specific operations performed by nurses when using two types of technologies: bar code technology and IV pump.

According to Stanton and Young [5] observation is a very useful human factors method that provides direct information on the interaction between people and their work environment or tools. The observational method tends to have strong face validity. Human factors experts have also highlighted several concerns regarding observations: intrusiveness of observation, amount of effort required in collecting and analyzing data, the objectivity of the data collection and analysis, lack of information on cognitive processes, and the comprehensiveness of the observational method [5, 6]. It is generally agreed that the quality of the observation data depends heavily on the method of collecting, recording and analyzing data [5].

Drury [6] describes 8 human factors observational methods: (1) raw event/time records, (2) time study, (3) process charts, (4) flow process chart, (5) Gantt charts, (6) multiple activity charts, (7) link charts, and (8) occurrence sampling. Raw event/time records can be useful to analyze the time history of single events, such as in the investigation of accidents or critical incidents. Time studies provide statistical information on the duration of tasks. According to Drury [6], "A process chart is nothing more than a plant (or office, etc.) layout with the materials movement for one or more processes marked on it." (page 50). A flow chart is a process chart in which information on the physical environment has been removed. Gantt charts describe the time relationships among activities, and place those activities on a timeline. Multiple activity chart is a variant of Gantt chart where the activities are grouped into continuous bars placed over a timeline. A link chart is a visual representation of links existing between components or elements, for instance elements of a physical space. Evanoff and his colleagues have used link analysis to evaluate nursing tasks, track motions and physical connections, and identify heavy traffic patterns [7, 8]. In occurrence sampling, the human factors engineer observes the operator or the system at predetermined times. In our study, we used the methods of time study and flow process charting.

The implementation of technologies changes the work of end users in foreseen and unforeseen ways [9-11] and has both positive and negative effects on the job characteristics that ultimately affect individual outcomes (QWL, such as job satisfaction and stress; and perceived safety and quality of care) [12]. This is the basis of the Balance Theory of Job Design, developed by Smith and Carayon [13, 14], which conceptualizes the work system into five elements that interact to produce a stress-load on an individual. The five elements are the individual, the tasks, the technology and tools, the environment and organizational factors [13]. A change in one element of the work system can have effects on another element; therefore, when suggesting a change in one element (e.g., technology), 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 [15, 16]. Technologies can change the way work is being performed and because healthcare work and processes are complex, negative consequences of new technologies are possible [17]. Whenever implementing a technology, one should examine the potential positive AND negative influences of the technology on the other work system elements [18, 19]. In a study of the implementation of an Electronic Medical Record (EMR) system in a small family medicine clinic, a number of issues were examined: impact of the EMR technology on work patterns, employee perceptions related to the EMR technology and its potential/actual effect on work, and the EMR implementation process [20]. Employee questionnaire data showed the following impact of the EMR technology on work. Increased dependence on computers was found, as well as an increase in quantitative workload and a perceived negative influence on performance occurring at least in part from the introduction of the EMR [21]. It is important to examine for what tasks technology can be useful to provide better, safer care [22].

A few observational studies have identified human factors deficiencies of healthcare technologies. For instance, Patterson et al. [15] observed medication administration before and after the implementation of bar code medication administration (BCMA) technology. These observations uncovered a variety of negative human factors ‘side effects’ of BCMA implementation, such as worsening coordination between nurses and physicians. Another observational study conducted by Patterson et al. [23] examined human factors barriers to the implementation of computerized clinical reminders for improving adherence to guidelines for HIV care. Observations were performed by two observers and included semi-structured interviews with physicians, pharmacists, nurses, and case managers. Analysis of these qualitative data allowed the identification of several human factors barriers to the implementation of computerized clinical reminders, such as additional workload and additional time necessary to document decisions when the reminder's advice was not followed.

In this paper, we describe the observation methodology used to collect information on nurse interaction with different medication administration technologies. These observations have been conducted to examine the use of point-of-care bar code technology, and have occurred pre- and post-implementation of Smart IV pumps with medication delivery software to prevent programming errors. Based on the work system model of Smith and Carayon [13, 14], the medication administration processes can be described as a series of tasks (or steps), the environment in which the tasks are performed, the policies and regulations governing the work, technologies used to carry out the tasks, communication networks, flow of work, and, most importantly, the complex interactions taking place between all of those factors.

Methods

Study setting

The University of Wisconsin Hospital and Clinics (UWHC) is a 450-bed, university-based, tertiary care center. It serves a broad population of urban and rural patients in south central Wisconsin and northern Illinois with a surrounding four-state referral base. UWHC's clinical areas of excellence include its Level One trauma center, a solid organ transplant service, interventional vascular services and Comprehensive Cancer Center and a 45-bed Children's hospital. UWHC is affiliated with the UW School of Pharmacy and has an accredited Pharmacy residency program. Thru its active Pharmacy program, innovation and early adoption of technology and processes to streamline the medication use process has been the norm with robotics, unit dose dispensing, and decentralized unit and ICU pharmacists. Attention was recently placed on reducing errors in the medication administration process with the systematic implementation of point of care bar code medication administration technology over three years from 2001 thru 2004. This technology uses bar code scanning of the medication, patient and nurse as a double check system to ensure the correct medication and dose is given at the correct time to the correct patient. It also documents administration. To improve IV medication administration and decrease IV pump programming errors, UWHC implemented Smart IV pumps organization-wide in the Fall of 2003. These IV pumps have hospital-specific drug libraries with preprogrammed dosing limits for medications.

With the recognition that the introduction of new technology causes changes in workflow and therefore requires changes to processes already in place, as well as the understanding that new technology may introduce new errors to the system, a prospective risk analysis, or failure mode and effects analysis (FMEA), was undertaken before the introduction of the IV pumps and one year after partial implementation of bar code medication administration technology [24]. Observations of the medication administration process, as described below, were performed to provide data to the FMEA team on nursing practice and interaction with current technology, with an emphasis on variation from accepted procedure and problems with the technology. Observation data were used for flow charting the medication use process, identifying of failure modes, and estimating the likelihood of failure mode occurrence as solution generation.

Observation instruments

The steps taken to develop the observation methodologies have been described elsewhere [25].

Instrument for observing the use of point-of-care bar coding technology

The point-of-care bar coding technology observation tool is a modified version of the tool developed for IV Pump observations (see Appendix A for a copy of the observation instrument). Across the top of the tool is an area to document the patient care unit where the observation took place, the shift the observation took place, the begin and end times of the observation, and the initials of the observers and the date the observation took place. The remainder of the top area provides an area to document the number of medications being administered based on dose form. Immediately below is where the bulk of observation data are collected. Moving from left to right, the first two columns – *technology use* and *loc'n* – are used to document the sequence of actions performed by the nurse relative to the correct sequence defined by procedure and the location the nurse performed the action (hallway, the medication room, patient room, or other). The sequence in which the medication administration and documentation steps were performed was recorded and compared with the ideal technological sequence as defined by both hospital policy and software programming; the *technology use* column listed this correct sequence. The location of occurrence of each step in the process was recorded with a letter abbreviation describing the location. Both of these were recorded in the *loc'n* column. The column titled *Automation surprises* was used to document unusual actions observed by the technology that surprised the user or the observer. *Staff comments* and *Patient comments* were used to record comments about the technology provided by those individuals, whether made directly to the observer or overheard when talking with another user. *Interruptions* allowed documentation of activities that appeared to disrupt the normal sequence of events of the user. The observer utilized the area titled

Comments to record notes about the observation and the names of the medications administered to the patient. The area to the far right of the tool was used to document the lighting, noise level, and state of the physical environment in which the observation took place. Below that is an area to record particular practices that were considered deviations that could contribute to administration errors.

Instrument for observing the use of IV pump technology (pre-implementation)

The instruments used for the pre-implementation IV pump observations consisted of an observation sheet, time study board, and writing instrument. See appendix B for a copy of the observation tool. The observation recording sheet was modified several times based on input from a series of observations and discussion in research meetings [25]. The observation recording sheet was designed to record the steps (tasks) of the medication administration process in the order in which they were performed. Information about the work environment, interruptions in the process, patient and nurse comments, nurse interaction with technology, technology failures or surprises, and alarms were also recorded. The environmental factors of light, noise, and overall physical environmental (i.e. messiness, crowdedness, organization) were noted. The number of keystrokes was also documented, along with the method used to calculate the rate of administration for a medication (i.e. dose rate calculator on the pump, hand-held calculator, manually). Observers also noted if tubing was already present, if and when the error alarm sounded, and if the nurse washed his hands. An area for written comments was also included. The shift (i.e. 1st, 2nd, and 3rd), nursing unit and medication name were also recorded. The entire observation from the moment the nurse secured the IV bag to pushing the “start” button on the pump was timed using a time-study board. To respect confidentiality and to uphold anonymity, no personally identifiable information about the nurse or the patient was included on the observation sheet.

Instrument for observing the use of IV pump technology (post-implementation)

The post implementation observation instrument consisted of a two-page observation sheet, an interview form, a NASA TLX question form to measure time pressure and mental workload [26], a note card listing the visual and audio signals and a time study board. In a later phase of observation, a Tablet PC was used to record data.

The pre implementation observation sheet was used as the starting point and re-designed for post implementation observations due to significant differences between the Smart IV Pumps and previous pumps in terms of programming. A pump programming process flow diagram was designed detailing the three types of pump programming: 1. basic infusion, 2. secondary infusion, and 3. Guardrails® infusion using the pre-programmed drug library or dose-rate calculator. This classification aided in data collection to follow and record the pump programming steps and alarms/alerts heard closely. While conducting observations, the main focus was on the steps during programming and visual or audio signals noting an advisory, alarm, error or prompt.

The first page of the sheet contained the flow diagram mentioned above, fields to note the date or week number when the data were collected, the unit where the data were collected, name of medication administered, the label on the pump related to just administered medication, other pumps attached to patient, number of bags attached to the patient just before observed medication administration started, duration of the observation and automation surprises/technology failures as well as the nurse's reaction to these automation surprises and technology failures. The labels, sequence of the pumps in relation to the programming module and number of pumps, were also recorded. Audits were included in the observation to note if a double-check was performed, if the tubing was properly loaded and if the top fitment was placed appropriately. There was also room to record notes. The second page was used to note environmental factors such as light, noise, and others present in patient's room.

An interview sheet was designed to ask to the users their perception of the pumps. The interview sheets were changed slightly after preliminary observations. In the preliminary observations, nurses were asked to describe their current shift in terms of "busyness". Then NASA TLX questions on mental and temporal workload replaced this question. Nurses responded to the interview questions with relative ease.

Since there are 36 different kinds of visual or audio signals that Smart IV pump and programming module can produce, it was almost impossible to differentiate various visual and audio signals while conducting observations. To make sense of the sound and visual signals a small "cheat" sheet in size of 3x5 inch was used (See appendix C).

Observation procedures

In our observation methodology, the observer is a 'complete observer' that does not participate in any way in the process being observed [27].

Observing use of point-of-care bar coding technology

Observation periods were conducted at times when medications were most likely to be passed, which we determined to be in the morning (0800) and then in the evening (2200). Observations were performed on nine inpatient units ranging from general medicine and surgical to intensive care units. The observers reached the floor 30 minutes to 60 minutes before the medication pass was scheduled to begin. Hospital policy allows nurses to begin passing medications one hour before they are due to be administered to help with workload associated with administering medications and being responsible for up to four patients. The observers entered the medication room on the patient care unit. The observational period began at the point the nurse logged into the bar code technology software. At this point we explained to the nurse that we were involved in a hospital quality improvement project studying the effect of the bar code technology on nurses and that we wanted to watch her complete this medication administration and record what she did. If the nurse consented, we then observed the nurse accessing the patient medication profile, taking the medication from the patient-specific medication drawer, scan the medication, enter the patient room and administer the medication. If any action performed by the nurse or the software occurred that appeared out of the ordinary interaction, we asked the nurse what had happened and whether they could explain why. We also benefited from the audible alerts the scanner made when an error had occurred. This provided a convenient time to interrupt the nurse and inquire.

Interaction with the patient was limited. Upon entering the room the nurse would usually identify the observers as people who were watching her give the medication. If this exchange did not occur we indicated that we were watching her administer medications for a research project. For both the nurse and the patient, a form clearly stating the purpose of the observation was provided.

A total of 62 observations were conducted during the first (28 observations or 45%) and second (34 observations or 55%) shifts. Observations were conducted on nine different units and were performed by a team comprised of a human factors engineer and a pharmacist. The average duration of observation was about 8 minutes (minimum: 2 minutes; maximum: 29 minutes).

Observing use of IV pump technology (pre-implementation)

Observations were conducted by a team of two observers. The observers were human factors engineers who had received basic information about the bar code technology and the medication administration process. Each team concentrated on specific areas of the hospital to gain familiarity with the staff, processes and cultures. Observers arrived to units and proceeded to the pharmacy area where the research study was explained to staff present, primarily nurses. While explaining the study to the entire staff together would have been more efficient, other nurses were usually occupied with patient care duties and asking them to delay their tasks was clearly not a possibility. Therefore many nurses were told about the study during one-on-one conversation with observers. The study was approved by the medical school IRB and a waiver of consent was granted, eliminating the need for a signed consent. Patients were also asked before the observations began if they would verbally consent to observers entering the room to conduct research.

After each observation, observers met to discuss and compare aspects of their observations. Initial observations were quite slow; some observers could only collect three observations over a three-hour period. With increased familiarity came increased efficiency, allowing observers to nearly double their rate of observation. To improve efficiency and decrease the amount of time standing in the pharmacy area waiting for nurses to administer IVs, the physician member of the research team assisted observers by retrieving scheduled administration times from the pharmacy database. This information was passed on to the observers.

A total of 52 observations were performed. Sixty percent of the observations were conducted during the first shift, 28% during the second shift, and 125 observations during the third shift.

Observing use of IV pump technology (post-implementation)

Initial observations were conducted by a two-person team (one person with an industrial engineering background and one clinical person). Later, to avoid medical judgments and to observe instances only from a human factors engineering standpoint, a single industrial engineer observed. Patient names, nurse name, or any other information/data that can be used to identify the nurse or patient were never recorded. An instruction form was developed to help observers in completing the observation sheet. The observation rate for each observation period ranged from one observation during a two-and-one-half-hour period to four observations over a 45-minute observation period. A total of 63 observations were performed over about 50 hours during twenty observation periods. On average, we performed about 2 observations over a 1.7 hour period. Twenty-one observations were conducted during the first shift, 35 observations during the second shift, and 7 observations during the third shift.

Sample

Observations were performed on a variety of hospital units as indicated in Table 1. Observations were conducted during all three shifts.

Results

In this paper, we report preliminary analysis of the observation data. The results focus on the physical environment and the sequence of steps (tasks) used to complete the medication administration process using three different technologies, i.e. point-of-care bar code technology, IV pump, and Smart IV pump. Additional data analysis is being conducted and will be reported in future publications.

Observation of nursing interaction with point-of-care bar coding technology

Table 2 shows data on the physical environment as it was observed in patients' room and in the medication room. For each location, the following environmental factors were observed: lighting, noise, and overall physical environment. Lighting in the medication room was observed as full, whereas lighting in patients' rooms was either primarily full or dimmed. Patients' rooms were observed to be more often quiet than the medication room. In 3 observations, the medication room was observed to be loud. In 12 observations, the medication room was found to be messy and disorganized.

The analysis of sequence of steps for the medication administration process with the bar code technology shows a total of 18 different types of sequence. The two most frequent types of sequence are:

- scan self / obtain medication / check medication / scan medication / enter patient's room / scan patient ID band / give medication / document administration (24 observations)
- scan self / obtain medication / check medication / scan medication / enter patient's room / scan patient ID band / document administration / give medication (17 observations)

Observation of nursing interaction with IV pump technology-Pre-implementation

Table 2 shows data on the physical environment for the patient's room and the medication room. Lighting was full in the medication room, and either full or dimmed in patients' rooms. Patients' rooms tended to be more quiet than the medication room. The medication room was actually observed to be loud in 2 instances. Patients' rooms and the medication room were observed to be messy and disorganized in 10 and 8 instances respectively.

Only 45 out of 54 observations were used in analyzing the task sequence in the medication administration process. Other observations did not provide sufficient data on the task sequence. We identified a total of 13 different task sequences performed by nurses when performing an IV medication administration. These task sequences are displayed in Figure 1. The two most frequently observed task sequences were: (1) Hanging IV, Turn on pump, program, push start (11 out of 45 times); and (2) Hanging IV, program, push start (9 out of 45 times).

Observation of nursing interaction with IV pump technology-Post-implementation

According to table 2, lighting was often full in patients' rooms. Patients' rooms were found to be loud in five instances. In the post-implementation observations, we split the question on the general physical environment into two separate questions: one question on level of organization in the space, and one question on crowdedness. In 12 of the observations, the space was found to be disorganized, and in 17 observations, the patient's room was found to be crowded.

A total of 39 observations were conducted while a basic infusion was set up, whereas 14 Guardrail observations were performed. One observation combined a basic infusion and the use of Guardrail. An example of the sequence of steps used for a basic infusion is shown in Figure 2.

Discussion

A major strength of the observational methodology is to collect data on the task actually carried out. Leplat [28] distinguishes between five representations of task: (1) the prescribed task (e.g., task instructions, procedures), (2) the implied prescribed task (i.e. representation of the person of his/her task), (3) the task the operator sets him/herself, (4) the task actually carried out, and (5) the representation of the performed task. Our observational methodology produced a representation of the performed tasks when administering medications that we assume represent the tasks actually carried out by the nurses. The data on sequence of steps (tasks) demonstrates a rather large diversity for each of the three types of medication administration technologies. There does not seem to be only ONE way of administering medication with any of the technologies.

The observational methodology provides rich detailed information on the tasks performed by nurses when administering medication and using various technologies. This descriptive data does not provide any information on the appropriateness of the tasks or the usability and usefulness of the medication administration technologies. Additional methods and procedures can be used to obtain an evaluation of the observation data. For instance, the observation data can be presented to a group of ‘experts’ (e.g., workers, managers) who can evaluate whether the tasks and sequence of tasks performed are appropriate. Another evaluative method involves a Failure Mode and Effects Analysis (FMEA) of the medication administration process using the observation data as input into the assessment process [29].

One usage of the observation methodology is to provide information on what is actually being done when administering medication. In our study, the observation data of the point-of-care bar code technology was provided to an FMEA team assessing the failure modes associated with this technology. The observation data was invaluable to the FMEA team in many ways. First, it allowed for an unbiased and non-judgmental look at the actual nursing processes in place as opposed to outlined procedure in the nursing policy and procedure manuals. Because the observations were performed by researchers, data observed and recorded were not affected by cultural and organizational factors. Second, observers brought the experiences of dozens of nurses from different care settings to the FMEA team which would not have otherwise been possible due to nursing schedules and team size but was critical to team success. Next, observations were used to confirm the occurrence of failure modes on a day-to-day basis. Observers also identified variations in practice that were evaluated as potential failure modes by the team. Lastly, the human factors approach to the observations led to potential solutions for failure modes thru changes in technology and the user-technology interface.

Conclusion

A key principle of human factors engineering is to assess the interaction between people and their work environment. An important distinction made by human factors engineers concerns that of ‘prescribed task’ versus ‘task actually carried out’. Human factors engineers are keen to evaluate the actual tasks performed by workers. In our study, we are striving to evaluate nursing interaction with various medication administration technologies. This paper has presented three observation instruments used to assess nurse interaction with point-of-care bar code technology, IV pump technology and Smart IV pump technology. These observational tools collect information at the level of interaction between the nurse and specific technologies. It is important to realize that, even though data is collected on the environment and context of work (e.g., physical environment) and on the organization of tasks (e.g., sequence of tasks), the observation focuses on only one element of the nursing job. It does not consider the whole job of nurses, only the medication administration activity.

Acknowledgments

This research is funded by AHRQ Grant # 1 UC1 HS014253-01 (PI: Pascale Carayon; co-PI: Tosha Wetterneck).

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APPENDIX A – OBSERVATION TOOL – POINT-OF-CARE BAR CODING TECHNOLOGY

APPENDIX B – OBSERVATION TOOL – PRE-IMPLEMENTATION IV PUMP TECHNOLOGY

Unit ________ Shift ____ Medication ______________________ # pumps ____ # bags ____ begin time = **0**, end time = ____'____"

* (Loc'n abbreviations key: **h** = hallway, **m** = medication room, **p** = patient room, **o** = other (ex: supply room))

	Pump use	*Loc'n	*Interruptions (who/why)*	*Automation surprises*	*Tech dysfunc/delay*	*Patient statements*	*Staff statements*
	_obtain bag						
	_√ bag vs MAR or Accuscan						
	_scan self (Accuscan only)						
	_select tubing						
	_select pump						
	_scan IV bag (visual or Accuscan)						
	_enter pt rm						
_____ (time)	_hang IV						
	_prime tubing						
	_scan/√ pt ID band						
	_connect IV to pt.						
_____ (time)	_turn on pump						
	_program pump option->dose->wgt->drug amt->volume						
_____ (time)	_dbl √ by 2nd RN *independent* vs *joint*						
_____ (time)	_push start						

Lighting	*full*	*dimmed*	*none*
Patient room			
Medication room			

Noise level	*quiet*		*loud*
Patient room			
Medication room			

Physical environment	*neat organized uncrowded*		*messy disorganized crowded*
Patient room			
Medication room			

	Yes	*No*
Is tubing already present?		
Did error alarm sound?		
Did provider wash hands?		

keystrokes for pump programming:

Did nurse use dose rate calculator on pump? Y N

If no: manual vs calculator

Comments:

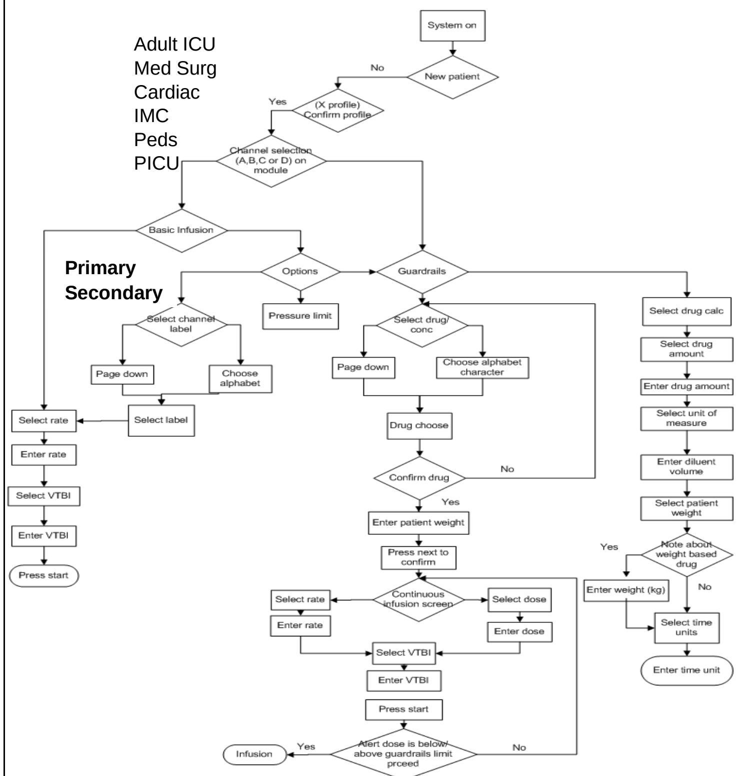
APPENDIX C – OBSERVATION TOOL – POST-IMPLEMENTATION IV PUMP TECHNOLOGY

Wk#:______ Unit: __________ Shift: __________ Med: ____________________________ Label: ______________

Other pumps: ____ # bags: ______ Begin time: 0 End time: __________

Adult ICU
Med Surg
Cardiac
IMC
Peds
PICU

Primary
Secondary



Modules / Labels

Modules		Labels
	Left	______________
		______________
		______________
		______________
	Right	______________

Modules / Labels

Modules		Labels
	Left	______________
		______________
		______________
		______________
	Right	______________

Prime tubing?: Y N Double check by RN?: Y N

Load tubing?: Y N ☐ bottom to top ☐ top to bottom ☐ front-in

Top fitment ☐ already in place Proper? Y N

Automation surprises or technology failure	Reaction of Nurse

Lighting	Effects and Reactions
☐ full overheadlight on ☐ dimmed overheadlights ☐ dimmed spotlights ☐ none, no overlights	

Noise Level			Effects and Reactions
quiet		loud	

Physical environment			Effects and Reactions
organised		disorganised	
uncrowded	crowded		

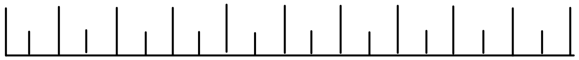
People in patient's room :	Effects and Reactions
visitor: ________ nurse: ________ MD: ________ Other: ________	

Type	Sound	Code
Advisory	One short beep every two seconds	AD
Alarm	Choice of three alarm audio profiles	A#
Error	(for HW&SW) Pairs of long beeps	E
Illegal key press	Two short beeps	I
prompt	One short beep every two seconds	P
switchover	Six short beeps	S

A1: Accumulated Air-in-Line
A2: Air-in-Line
A3: Channel Disconnected
A4: Check IV Set
A5: Close Door
A6: Open Close Door
A7: Occluded-Fluid Side/Empty Container
A8: Occluded Patient Side
A9: Partial Conclusion Patient Side
A10: Restart Channel

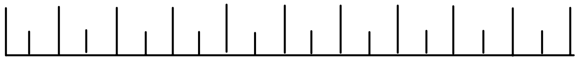
***Please put an "X" on the following scales at the point that matches your experience while you just administered the patient's medication*.**

How much **mental activity** was required during this medication administration?



Low High

How much **time pressure** did you feel during this medication administration?



Low High

Table 1 – Number of observations by technology and unit type

Unit	Bar coding technology	IV pump (pre-implementation)	IV pump (post-implementation)
Medical	26	24	2
Surgical	9	7	6
Critical care	18	21	35
Other	9	–	13

Table 2 – Observed physical environment

	Bar coding technology		IV pump (pre-implementation)		IV pump (post-implementation)
	Patient room	Medication room	Patient room	Medication room	Patient room
LIGHTING					
• full • dimmed • none-minimal	23 32 6	61 0 0	30 21 1	51 0 0	41 12 1
NOISE					
• quiet • normal • loud	35 26 0	16 42 3	24 28 0	6 44 2	28 15 5
GENERAL PHYSICAL ENVIRONMENT					
• neat/organized • normal • messy/disorganized	13 34 15	9 40 12	12 29 10	19 25 8	
• organized • normal • disorganized					26 6 12
• non-crowded • normal • crowded					18 11 17

Figure 1 – Sequence of tasks in IV medication administration (pre-implementation)

Note: The frequency for each sequence is given in the last box of each sequence ('End' box).

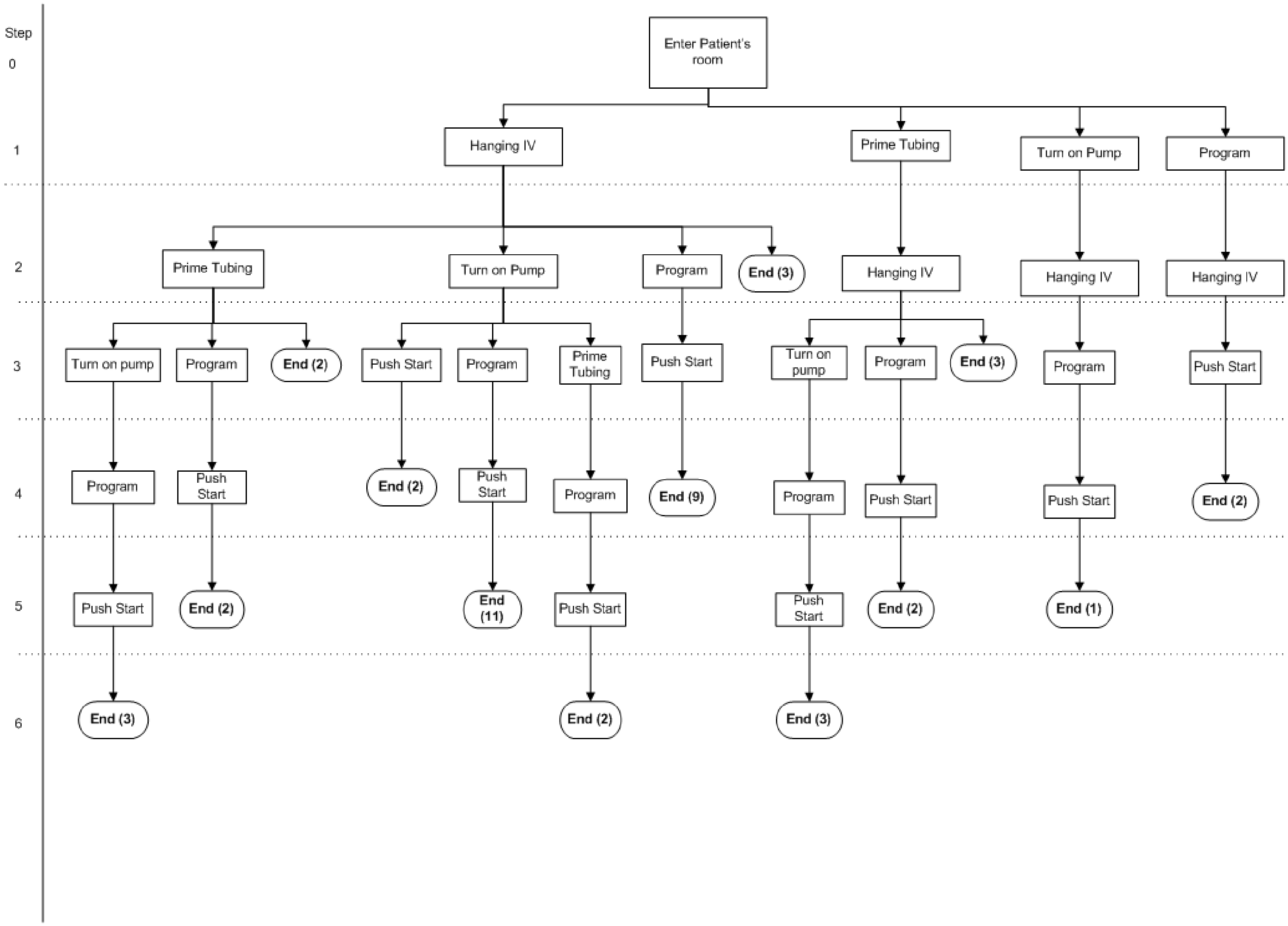


Figure 2 – Example of sequence of tasks in IV medication administration for basic infusion (post-implementation)