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REDESIGNING THE MEDICATION ORDERING, DISPENSING, AND ADMINISTRATION PROCESS IN AN ACUTE CARE ACADEMIC HEALTH SCIENCES CENTRE

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ABSTRACT

Two simulation models have been built to quantify the advantages of an electronic medication ordering, dispensing and administration process compared with the current manual process at an acute care academic health sciences centre. The first model represents the current manual system, and has been validated against observed data. The second model represents the proposed electronic medication ordering, dispensing and administration system. The results show that there is a potential to significantly reduce the overall turnaround time (from the initiation of the order to the delivery of the medication to the wards) from 256 minutes to less than 123 minutes, a reduction in the pharmacokinetic failures from 16.3% to less than 5.7%, and a reduction in tight failures from 65.5% to less than 14.5%; thus improving the rate of first doses of medications that are delivered in time to be administered.

1 INTRODUCTION

Computer Physician Order Entry (CPOE) has the potential to benefit healthcare organizations. CPOE has been promoted as a technology enabler to increase patient safety and improve health outcomes (Kohn et al. 2000). CPOE can enable automatic IT decision support to check orders for accuracy, completeness, redundancy, and possible contraindications and negative drug-drug, allergy-drug interactions. Studies have demonstrated that CPOE can improve the quality of care (Bates et al. 1999 and Tierney et al. 1993). Furthermore, electronic orders can be sent through the hospital's IT network to the pharmacy IS, minimizing ordering delays.

It is CPOE's potential benefits that initiated this study to be conducted to determine whether CPOE could improve the current paper based method of medication ordering. This study is centered at the Sunnybrook Campus of the Sunnybrook and Women's College Health Sciences Centre (SWCHSC) located in Toronto, Ontario, Canada. Sunnybrook campus has 458 beds and 26000 inpatient visits per year. (Sunnybrook and Women's College Health Sciences Centre, 2003). The hospital possesses both batch/robot and satellite pharmacies to fill in-patient medication orders.

The hospital's process of ordering, dispensing, and administering medications is not able to efficiently service the high volume of daily inpatient drug orders. . Clinical staff report long delays in receiving medications, leading to doses being administered long after the standard administration times determined by hospital policy. These process failures can be attributed to Leape et al's (1995) observation that many health care processes were never formally "designed" to meet the demand for services placed on them, or were designed when the practice of medicine was much simpler. The current method of ordering is driven by the physician writing on a paper chart. The order is then copied to the M.A.R. and the carbon copy is sent to pharmacy. This introduces possible transcription errors and requires end-of-pipe controls to ensure the medication information is complete and accurate.

A study was conducted to examine the timeliness of medication administration under the current process. Baseline data was collected in August-September 1999 from two medical units to determine the time elapsed from when orders were written to when medication was administered to the patient. Criteria were used (as discussed in section 2) to evaluate the performance of the process. The high failure rates found demonstrated the need to change the current process.

Simulation was proposed to evaluate whether CPOE could improve the current process quality. In the literature, simulation has been used to predict how CPOE could reduce the number of physician-initiated medication errors (Anderson 2002). Another simulation model showed how

changing the time of the clinical pharmacist's visit to the ward could affect the mean time delay between the prescription of a non-stock drug and the arrival of that drug on the ward (Dean 1999). To study the effects of CPOE on the timeliness of the entire medication administration process, two simulation models, ("AS-IS" and "TO-BE") have been built that assess the turnaround time from medication ordering to delivery of the medication to the wards. The AS-IS model represents the current manual medication ordering-dispensing-administration process, whereas the TO-BE model represents the proposed CPOE-integrated medication ordering-dispensing-administration process.

2 DESCRIPTION OF PROCESSES AND SUCCESS CRITERIA

2.1 The Medication Ordering-Dispensing-Administration Process

The current medication ordering process consists of the following sequence of events:

1. The physician writes a medication order.
2. The physician finds the patient's chart, inserts the order sheet and indicates a new order is in the chart by raising the chart's flag.
3. The nurse periodically looks for "flagged" charts.
4. The nurse reviews the order, updates the patient's medication administration record (MAR) to include the new order and places the carbon copy of the order in an outbox to be delivered to the pharmacy.
5. At specified intervals in the day, a pharmacy technician picks-up the orders from the wards (and drops off filled orders).
6. The pharmacy technicians drop off the medication orders at the pharmacy.
7. Pharmacists review the order, call for clarification if necessary, then enter the order into the pharmacy computer system or code the order on an order-sheet for the order entry technician to enter. (Discontinued orders must also be entered into the system).
8. If a clarification is required the order is put aside until the other orders have been processed.
9. If the pharmacist does not do the order entry personally, the order entry technicians enter coded orders into the computer system.
10. Labels automatically print from the entered orders if the system determines that the first dose (or more) is to be filled by the satellite pharmacy.
11. Pharmacy technicians attach labels to bags, which are then filled with the medications listed on the label.
12. The pharmacy technicians deliver all dispensed medications to the wards at specified times throughout the day (and pick up new orders).
13. The nurse administers the medications to the patient according to the MAR.

2.2 Proposed Medication Ordering-Dispensing-Administration Process

The proposed CPOE system will change the process to the following:

1. The physician enters a medication order directly into the computer.
2. Pharmacists review the order on-line, call for clarification if necessary, then release or change the orders on-line.
3. Labels are automatically printed based on the entered orders if the system determines that the first dose (or more) is to be filled by the satellite pharmacy.
4. Pharmacy technicians attach labels to bags, which are then filled with the medications listed on the label.
5. The pharmacy technicians deliver all dispensed medications to the wards at specified times throughout the day.
6. The nurse administers the medications to the patient according to the computer display.

2.3 Process Performance Evaluation

Medication delivery failure rates and resource requirements were chosen to compare the process quality of the current and proposed processes. Delivery failure was defined in two ways:

- A *pharmacokinetic delivery failure* is based upon pharmacokinetic principles and drug half-lives. This type of failure occurs when the medication is not delivered to the ward by the requested administration time plus one half of the interval between consecutive administrations of the medication. If the medication is ordered less than two hours prior to the next pharmacokinetic due time, the medication will not be considered to be due until the following pharmacokinetic deadline.
- A *patient focused care ("tight") delivery failure* can occur in two ways. When an order is placed at least one hour prior to the standard administration time (the "standard administration ordering deadline") a failure occurs if it is not delivered by 1 hour after its standard administration time. If the order is placed after this "deadline", a failure occurs if the medication has not been given within 2 hours of the order. Orders written within 2 hours prior to the midpoint of their pharmacokinetic

dosage interval time are treated as belonging to the subsequent administration target. (Geiger G. et al 2003).

3 PROCESS MODELING

3.1 Process Mapping

A process map of the current medication ordering/dispensing system of the pharmacy satellite was developed using the IDEF0 (Integration Definition for Function Modeling) modeling methodology (Figure 1). The IDEF0 process map is composed of a hierarchical series of diagrams that gradually display increasing levels of detail as the map is decomposed into more activities. Inputs, controls, outputs, and mechanisms (ICOMs) are also defined for each activity. The ICOMs represent the information and resource relationships between each activity and also include elements of the external environment that may affect the model.) This served as a basis for the second phase of data collection and the simulation models.

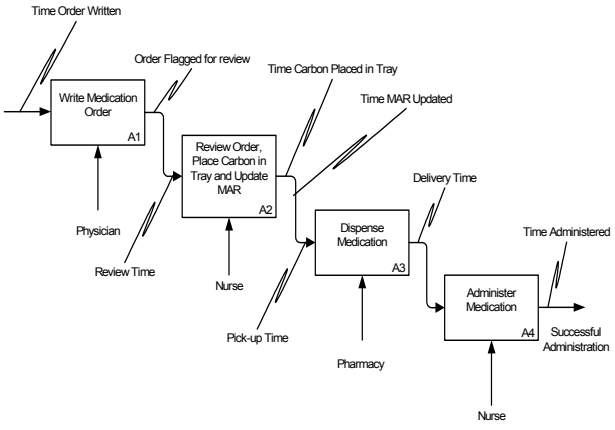

Figure 1: Current Medication Ordering-Dispensing-Administration Process

3.2 Data Collection and Analysis

Highly detailed process data was collected in June 2001 on one medical unit (C4). 249 orders were traced by the observers, of which 173 (69%) were daytime orders and 76 were written at night. The failure criteria were used to determine the process failure rates. The pharmacokinetic and tight failure rates were 14.5% and 57% respectively. The entire process was decomposed into three intervals and the elapsed time within these intervals was calculated (Table 1). Additional data describing activities in the pharmacy were collected to allow a more detailed simulation in the summer of 2002.

Table 1: Average Time Elapsed to Event

Event Interval	Average Elapsed Time (min)
Order Written – Reviewed by Nurse	52
Nurse Deposits in Pharmacy Outbox – Pickup by Pharmacy	75
Pickup – Delivery of Medication	122

3.3 Simulation

Simulation models of both the AS-IS (Figure 2) and TO-BE (Figure 3) processes were constructed using the MedModel simulation package (PROMODEL Corp, 2002). Constructing both models enabled the evaluation of the advantages and disadvantages of each system. In both cases, only the medical unit for which data was collected (C4) was modeled in detail. In order to accurately model the process within the pharmacy the full volume of orders from all wards was modeled. Orders from the other medical units were modeled only from the first to last point of

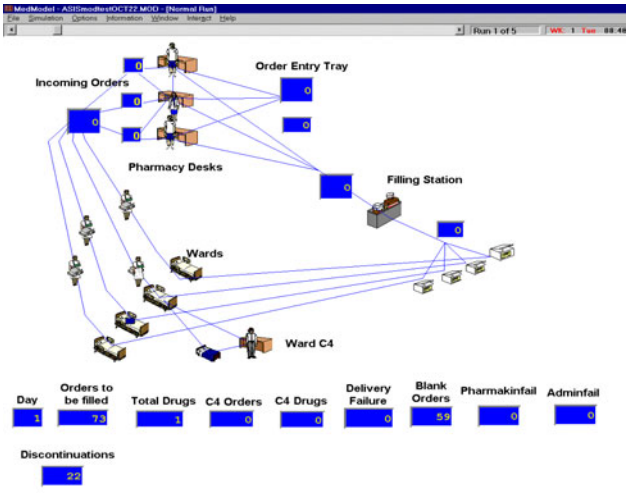

Figure 2: Screenshot of the AS-IS Process

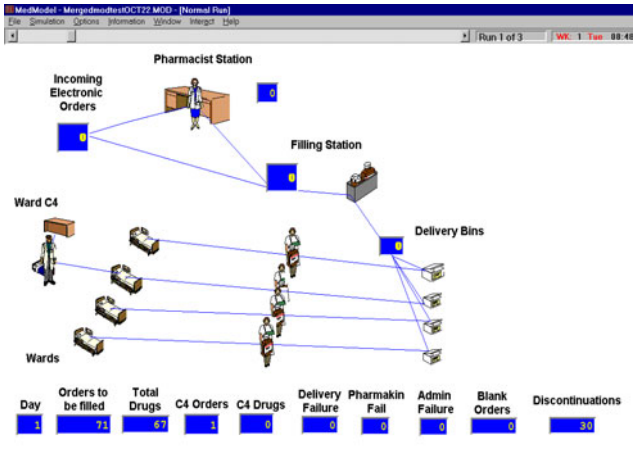

Figure 3: Screenshot of the TO-BE Process

contact with the pharmacy (from order pick-up in the ward to the medication drop off in the ward). As a result, conclusions from the model were based on the effects on the C4 medical unit. These results, however, were then generalized to predict the effect throughout the hospital.

The following sections will outline how each of the processes was modeled in terms of entities, locations, resources, process paths and delay times.

3.3.1 Entities

The entities in both the AS-IS and TO-BE models are:

- Orders – created by the physician.
- Labels – created when orders are entered into the pharmacy computer.
- Drug – created when medication orders are filled.

Each of these entities travel through the medication administration process to various locations where they experience delays and use resources described in the following sections.

3.3.2 Resources

The resources for both the AS-IS and TO-BE models are listed in Table 2. The corresponding boxes in the AS-IS and TO-BE models are check-marked only if that particular resource exists in the respective simulation.

Table 2: Resources in the Simulation Models

Resource	AS-IS Model	TO-BE Model
1. Physician	√	√
2. Nurse	√	√
3. Pharmacist	√	√
4. Pharmacy order-entry technician	√	
5. Pharmacy rounds/dispensing technician	√	√

3.3.3 Process

The processes for the AS-IS and TO-BE models are summarized in Tables 3 and 4. The tables show how the entity moves through the locations, changing form and experiencing delays and actions performed by resources. Details of the queueing process and assumptions that were made are also outlined in this section.

3.3.3.1 Queueing Processes

There are four queues listed in the tables below. The queueing process at each is described in this section. Other delays in the simulation are either a delay until a certain time of day when pick-ups and deliveries occur or an observed delay during data collection that is entered into the simulation using a theoretical or empirical distribution.

3.3.3.1.1 The Pharmacist Queue

In the AS-IS model, orders arrive at the pharmacy in batches with each pick-up (occurring every 1-2 hours). The queue functions slightly differently depending on the number of pharmacists processing orders.

When there are three pharmacists processing (in the morning and evening) there are specific wards assigned to each pharmacist. The group is divided into three queues based on these assignments and orders are organized within each queue by ward. The orders from a randomly chosen ward are then drawn from the queue one by one.

Table 3: AS-IS Process

Entity	Location	Action (Resource)/Delays
Order	1. Ward C4 patient bed	Writes Order (Doctor)
Order	2. Ward C4 nursing station	Drops off order (Doctor) Delay time before order found Reviews order (Nurse)
Order	3. Order pick-up/drop-off location	Drop off order (Nurse), Delay until set pick-up times Pick-up order (Rnds/Disp. Rx Tech.)
Order	4. Three queues for pharmacist (pharmacy order entry trays)	Drop-off Orders (Rnds/Disp.Tech.) Queueing Delay
Order	5. Three pharmacy workstations	Code and/or Enter Orders (Pharmacist)
Order	6. Queue for clarification orders (if required)	Queueing Delay
Order	7. Three pharmacy workstations (if clarification was required)	Clarify and Code and/or Enter Orders (Pharmacist)
Order	8. Queue for Order Entry Technicians (if required)	Queueing Delay
Order	9. Three pharmacy workstations (if required)	Enter Coded Orders (Order-Entry Tech)
Label	10. Filling Queue	Queueing Delay, Pick-up labels (Rnds/Disp. Tech.)
Label	11. Filling Station	Fill order (Rnds/Disp. Tech.)
Drug	12. Pharmacy Bins	Drop off medication (Rnds/Disp.Tech.) Delay until set delivery time
Drug	13. Order Drop-off location	Drop off (Rnds/Disp.Tech.), Pick-up (Nurse)
Drug	14. Ward C4 patient bed	Drop-off (Nurse)

Table 4: TO-BE Process

Entity	Location	Action (Resource)/Delays
E-Order	1. Ward C4 patient bed	Electronically Enters Order (Doctor)
E-Order	2. Queues for pharmacist	Queueing Delay
E-Order	3. Three pharmacy workstations	Review and Release Orders not requiring clarification (Pharmacist)
E-Order	4. Queue for Clarification orders (if required)	Queueing Delay
E-Order	5. Three pharmacy workstations (if clarification was required)	Clarify and Release Orders (Pharmacist)
Label	6. Filling Queue	Queueing Delay, Pick-up labels (Rnds/Disp. Tech.)
Label	7. Filling Station	Fill order (Rnds/Disp. Tech.)
Drug	8. Pharmacy Bins	Drop off medication (Rnds/Disp.Tech.) Delay until set delivery time
Drug	9. Order Drop-off location	Drop off (Rnds/Disp.Tech.), Pick-up (Nurse)
Drug	10. Ward C4 patient bed	Drop-off (Nurse)
Drug	11. Pharmacy Bins	Drop off medication (Rnds/Disp.Tech.) Delay until set delivery time
Drug	12. Order Drop-off location	Drop off (Rnds/Disp.Tech.), Pick-up (Nurse)

When a pharmacist has processed all the orders from the chosen ward the next ward is randomly selected.

In the afternoon, there is only one pharmacist and two order entry technicians processing orders. The orders are again grouped by ward and processed one ward at a time by the pharmacist (this time drawing from just one queue). When the pharmacist has coded the orders from an entire ward all the orders from that ward are passed on to the order-entry technician to be entered. The next ward is then randomly chosen for processing.

For the TO-BE model, orders are drawn from the queue on a FIFO basis.

3.3.3.1.2 The Clarification Queue

In both models, orders arrive at the clarification queue in two ways. If the pharmacist encounters an order that needs clarification it is put aside in the clarification queue until all the incoming orders have been processed. Orders are then drawn from the clarification queue in FIFO sequence. The pharmacist then attempts to clarify the order. If unsuccessful the order returns to the clarification queue and waits a randomly generated amount of time before returning to the pharmacist (regardless of what is in the queue). This second time in the queue represents the specific time before the pharmacist receives a return call to clarify the order. Orders therefore leave the queue when the prescribed time has elapsed.

3.3.3.1.3 The Order-Entry Technician Queue

In the AS-IS model, the sequence in which orders arrive from the order entry queue to be processed by the order-entry technician depends on the sequence in which they were processed by the pharmacist. Once the pharmacist has completed an entire ward the orders for that ward are processed in a FIFO sequence. In other words, the sequence is the same as that followed by the pharmacist but there may be an additional delay waiting for the pharmacist to complete all the orders in the ward.

In the TO-BE model, this queue is not required, since the order has already entered into the computer system by the physician.

3.3.3.2 The Filling Queue

In both models, Orders are drawn in FIFO sequence from the Filling Queue whenever a Rounds/Dispensing Technician is available to process it.

3.3.3.3 Simulation Assumptions and Limitations

The following assumptions have been built into the simulations:

- The medication ordering process is the same on weekends as during the week.
- The pharmacy is open from 8 am to 8 pm seven days a week.
- Daily volume and distribution of orders throughout the day is based on the average volumes and distributions from one month of data collected in the pharmacy. We ignored variations by weekday or season.
- All clinician and pharmacy resources are assumed to be available 100% of the time while on-shift.
- It is assumed that the nurse puts the order in the pick-up tray as soon as (s)he has finished reviewing it. In reality (s)he may get distracted by another task along the way.
- In the AS-IS model if there are a few orders left from the last pick-up at 6:45 pm that did not make it out on the last delivery at 7:45 pm, there will be an additional delivery at 8:45. This usually occurs in practice.
- In the AS-IS model the actual pharmacy staffing varies slightly (number of pharmacists vs. order-

entry technicians) according to staff scheduling, but a fixed schedule was assumed that is representative of the average staffing level (3 pharmacists in the morning and evening and 1 pharmacist and 2 order entry technicians in the afternoon). So on average there are ~2.5 pharmacist working on order processing each day.

- Although the amount of time required to complete a pick-up/drop-off round varies, an average rounding time of 15 minutes is assigned in the AS-IS model in order to aid in validation of the model.
- Clarifications are put aside initially until all other orders are cleared; a phone call is then placed to the ward. The order is either clarified as a result of the call or is put aside until a return call is received at which point it is resolved. In fact, there is no defined process, but our approximation appears reasonable.
- In the wards, non-medication orders (e.g. lab tests) are written on the same order sheets as medication orders. Nurses routinely remove the carbon copy of the order sheet used by the pharmacy and deposit it in the pick-up tray regardless of whether or not there is a medication order on the sheet. These orders, referred to as "blanks", require the pharmacist's attention, at least briefly to ensure that there are no medication orders. These are included in the AS-IS model but excluded from the TO-BE model since they are a function of the paper system.
- Discontinuation orders are orders to stop sending medication previously ordered. In the AS-IS model, these are entered into the computer in the pharmacy but not processed further (since no medication needs to be delivered). In the TO-BE model the orders exit prior to the pharmacy since they do not need to be reviewed by pharmacists.

Due to the complexity of the underlying process, the following limitations are encountered in the models:

- In reality some of the poor performance issues of the current system are overcome by working around the process. Some of these include: a) the orders being taken to the pharmacy between n pick-up cycles; b) drugs being returned to the ward between cycles; c) delaying the delivery cycle in order to process a few remaining orders; d) pharmacists prioritizing orders as the delivery cycle approaches; e) nurses double checking for orders as the pick-up time approaches; and f) physicians/nurses calling an order down to the pharmacy. It is likely that there are also others we have not yet encountered. Since these workarounds are inconsistent and rather complicated to model, they were excluded.
- The simulation does not model failures that would occur if the drug was delivered on time but was not administered by the nurse on time (e.g. she was not aware the drug had arrived). The simulations are modeled on the premise that the nurse gives the drug to the patient if it arrives on time to be given.

4 RESULTS AND VALIDATION

Each model was simulated for 10 replications of 5 weeks (35 consecutive simulated days). Because there were very few orders that wait overnight in the pharmacy (i.e. the system was empty each morning), there was no initialization period. Summary statistics were collected on the time delays experienced during the three event intervals, as well as the overall process times and failure rates. To calculate failures, the simulation tabulates whether each order placed during the day passes or fails the criteria outlined in Section 2.

4.1 Summary of Results

Table 5 shows the averaged results of each simulation (10 replications) as well as the results drawn directly from the data collection. Note that the TO-BE results assume just two pharmacists are used as opposed to the ~2.5 pharmacists used in the AS-IS model.

Table 5: Summary of Results

	Data	AS-IS	TO-BE
Average Total Turnaround Time (minutes)	257	256.1	122.6
% Average Pharmacokinetic Failures	14.5	16.3	5.7
% Average "Tight" Failures	57	65.5	14.5

Orders that are included in the pharmacokinetic evaluation include all daytime orders except PRN orders (to be given as needed), discontinuations or holds and STAT orders (to be given immediately). Orders that are included in the "tight" evaluation include all daytime orders except PRN orders and discontinuations or holds.

4.2 Validation of AS-IS Results

The AS-IS model was validated by comparing the outputs generated by the simulation (Table 6), to the actual data (Table 1) that was collected from the medical unit. A 95% confidence interval (based on 10 replications) was generated for each of the simulation outputs.

The table shows that the AS-IS model represents the current system well. The time from the nurse reviewing the order to the order being picked-up falls slightly outside the 95% interval. It was felt that this small variation was attributable to the inconsistency surrounding pickup times in

Table 6: Validation of AS-IS Model Results

	Data (average)	AS-IS (95% interval)	
		Low	High
Total Turnaround Time (minutes)	257	253.1	259.0
Order written – Reviewed by Nurse	52	51.8	53.9
Nurse Deposits in Pharmacy Outbox – Pickup by Pharmacy	75	70.5	74.7
Pickup – Delivery of Medication	122	127.8	133.1

the actual system, whereas these times were strictly adhered to in the simulation. The elapsed time between the order pick-up and medication delivery also falls outside the 95% interval. According to the data collected, waiting for a return call on clarifications can take a very long time in some cases (from 1.5 to 7.5 hours). This distribution was used to model waiting time for return calls on clarifications. The problem is that all but one of the clarifications observed were resolved within the same day. In other words the long clarifications observed usually started early enough in the day to be resolved before the pharmacy closed. However, in the model, this delay may begin at any time, making it possible for some delays to wait overnight. As a result, the model produces some clarification delays of 13.5 to 19.5 hours (1.5-7.5 hours plus the 12 hours for waiting overnight). Although few of these were observed in the data, it did occur on one occasion so it can not be assumed all clarifications are resolved by the end of the day. As a result, the model is considered valid despite this discrepancy.

In addition, the model's face validity was confirmed by a pharmacist who has been involved with the process for many years.

4.3 Results Comparison for the Two Models

A comparison of the results is given in Table 7. The AS-IS model utilized ~2.5 pharmacists, so results for the TO-BE model, using 2 pharmacists and 3 pharmacists, are given.

The results look very encouraging. The improvements shown in these results make it clear that there is significant potential for the CPOE system, if well implemented, to drastically improve the current situation. However, there is a need to further refine the TO-BE model as more detail on the new system becomes available through pilot studies.

5 SOURCES OF ERROR

A simulation model will never be an exact representation of an existing or a proposed model of any degree of complexity. In this section, some sources of error for both models are discussed.

Table 7: Comparison of AS-IS to TO-BE Results

	AS-IS	TO-BE (2 phrmcst)	TO-BE (3 phrmcst)
Average Total Turnaround Time	256.1	122.6	97.3
% Pharmacokinetic Failures	16.3	5.7	3.8
% "Tight" Failures	65.5	14.5	9.8

5.1 The AS-IS Model

- As mentioned above, the model does not account for medical staff finding ways to improve results by working around the system. There is a lot of value in evaluating how the system works as designed since system workarounds are often a source of error. However, it makes it difficult to validate such a model against real observed data. Therefore, data-points that were clearly a result of workarounds were removed from the data set when comparing results. For example, a data-point indicating that the order was turned around by pharmacy in 2 minutes is clearly a workaround since there is at least 1 hour between consecutive pick-up and delivery cycles.
- Only 82 of 173 data sets have a drug delivery time but failure rates and turnaround times produced by the model are based on distributions drawn from all 173 data points (for modeling the ward). As a result pharmacy turnaround times, total turnaround times and failure rates from the simulation may not match the results obtained from the subset to which they must be compared. In addition, 6 of the 82 data sets were excluded for having process exceptions. It is difficult to determine conclusively if the remaining 76 data sets are representative of the 173 data sets or if they are biased in some way. For example, it is possible that some of the missing data points are missing because of a very long turnaround time in the pharmacy.
- It was difficult to verify the level of clarifications against initial data collection results since the rate or length of clarifications that took place during the data collection period was not observed (only order pick-up and medication delivery times are known since the pharmacy was originally assumed to be a black box).

Since the variation is likely to be large from one day to the next (pharmacists say they vary from 2-25% of orders per day), it would be difficult to reconstruct the clarifica-

tion times for the original observation period without spending a large amount of time collecting sufficient data. All other tasks in the pharmacy have consistently short durations relative to the total drug turnaround time, so they can be added to the model and be expected to produce outcomes consistent with the pharmacy turnaround time observed from the ward. In the simulation, it was assumed that 20% of orders must be clarified. With this rate the turnaround times matched the observed data quite well. The higher the clarification rate the smaller the difference between the AS-IS and TO-BE model; therefore, 20% provides a conservative comparison between the two models. More detailed analysis of the effects of various clarification rates and durations will be carried out in the next phase of this study.

5.2 The TO-BE Model

Factors that may cause results to be better than predicted include:

- The drop-off times for the drugs may now be set at different times since the frequency with which orders must be picked-up from the ward is no longer a consideration.
- The rate of clarification, which has a reasonably significant impact on the results (particularly in the TO-BE model) may also improve as clarifications based on drug and allergy interactions and those due to handwriting should be eliminated with the use of the electronic information system and decision support tool. Also, with the new system, pharmacists will be able to access order requests from any workstation. As a result they are not likely to stay in the pharmacy itself but may spend more time on the wards processing orders from there as required instead of waiting in the pharmacy for requests to come in. This proximity to the physicians and nurses and patients on the ward will likely speed up clarifications considerably.

Factors that may cause results to be worse than predicted include:

- The rate of clarifications may increase as the new system is implemented and new issues arise. One such issue currently under consideration is the difference between what physicians and the pharmacists consider important information (e.g. number of dose/day vs. time of dose). This will only be a problem if the physician is unable (or unwilling) to find the desired drug stored in the information system and must "write-in" the order. This effect should decrease with time.
- Since the pharmacists are likely to spend more time on the wards processing orders the timing of the orders being reviewed may not be consistent with the model. The model assumes that it will be reviewed upon arrival by a few dedicated pharmacists. Instead they may be reviewed less frequently. However the pharmacist will be able to see which orders need to be processed right away.

Because the cascading effects of the implementation of automated physician order entry is unclear, it is assumed in the model that no changes will occur except for the method of communicating orders from the physician to the pharmacy. This is very likely to produce variations when compared to the final results but it is expected that the model is providing conservative estimates. As more detail becomes available the model will be revised.

6 FURTHER RESEARCH

Further areas to be explored using these models include:

- Refining the TO-BE model as more information becomes available though piloting.
- The impact of a varied clarification rate and duration. (The model is based on the observed data over a short period. Clarifications are believed to vary greatly from day to day and may also vary from ward to ward).
- The impact of changing the drop-off times of medication in the TO-BE model.
- The impact of having some pre-selected medication orders that are not deemed to pose any risk, bypass review by the pharmacist and go straight to dispensing.
- Varying the number of pharmacists reviewing orders.
- An evaluation of the impact on resource utilization.

7 SUMMARY

A simulation model of an acute care hospital's current medication ordering-dispensing-administration process was built after performing a detailed analysis of the existing system. This model has been validated against observed data. The model of the current system was then used for comparison against a simulated medication ordering-dispensing-administration process incorporating CPOE. The proposed system requires fewer steps, thus simplifying the system. The comparison between the two models shows that there is the potential to reduce the overall turnaround time by 50%-60%, and a reduction in pharmacokinetic and tight failures by 65%-77% and 75%-85% respectively.

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