

Employing Modeling and Simulation to Improve Patient Care

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ABSTRACT

In a Labor & Delivery (L&D) environment, new mothers that experience hemorrhages are a medical emergency. How clinicians deal with that emergency is critical for the mother's health. Computer modeling software provides an effective tool to simulate and understand how different treatment processes affects patient care. In order to improve patient safety and quality of care, the department developed a new protocol to request blood and medication supplies for a hemorrhagic mother. This protocol required requesting an additional nurse for the patient and one phone call to the lab for supplies. However, clinicians did not follow the protocol uniformly. This paper describes the data and the model developed at the request of the Medical Director of the Patient Simulation Lab. The model uses data collected from an Electronic Health Record (EHR) system that describes a patient's encounter from admission to discharge. The model compares instances of two patient care scenarios for coping with a hemorrhagic emergency. The first scenario represented the original state, which included multiple phone calls to the lab. The second scenario employed the communication protocol developed to improve the speed of delivering lab and pharmacy supplies. The pharmacy and lab are included as Labor & Delivery informs them of the patient's clinical information collected when the mother-to-be arrives in the Labor & Delivery unit alerting both departments of needed supplies quickly. The simulation clearly demonstrated that following the new protocol decreased time from ordering to administering blood supplies and medication. The model provided Labor & Delivery opportunities to experiment with changing variables within the simulation to deliver better care to new mothers and hemorrhagic emergencies.

ABOUT THE AUTHORS

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INTRODUCTION

Computer simulation modeling provides medical directors, nurse managers, clinicians, and staff an opportunity to consider changes to patient flow and clinician workflow without disrupting the physical environment. For this purpose, simulation software that models discrete events has proven to be a valuable tool. As regulations change in the healthcare environment, a major challenge is compliance while maintaining or improving patient care. Any change that unintentionally decreases the quality of treatment is unwanted. The simulation software allows for testing changes such as staffing levels and the physical environment. After testing different solutions in the virtual environment, management can make an informed decision about changing resources or the layout of the real environment. An advantage of using software is that the modeling design team may highlight the patient movement through the healthcare environment, or focus on clinical staff movements and interaction with patients. This second possibility is the subject of the Labor & Delivery (L&D) simulation. By tracking the time and movement of staff while treating an emergency hemorrhage after childbirth, the computer simulation revealed the advantages of adopting a protocol requesting medication and blood supplies for a patient. One of the challenges in healthcare is changing the culture to reject using treatment options because that is the way it has always been done, and instead accepting new and more efficient techniques. The computer simulation described in this paper shares the results of using technology to train clinical staff on the advantages of adapting new techniques in patient treatment.

DESIGN OF THE SIMULATION

The Labor & Delivery physicians are enthusiastic supporters of simulation as a teaching tool for clinical staff. Patient mannequins are employed in a fully equipped patient room with audio and visual equipment that allows staff to rehearse and test patient treatment scenarios. Maintaining proficiency for rare events in patient care, such as a breech birth, requires ongoing training, and clinical mannequins serve well for this type of learning. The L&D physicians were eager to begin using other simulation techniques to augment existing simulation training.

When developing computer simulations for healthcare environments, the primary metrics are patient movement such as length of stay (LOS) and milestones such as arrival time to seeing a nurse (Door to Nurse) or physician (Door to Doc). In clinical areas such as the Emergency Department these metrics are key indicators for performance and patient satisfaction. In a department such as L&D, Door to Doc and LOS are not key metrics. The most obvious measures of performance are successful deliveries where both the mother and newborn are healthy. Creating a computer simulation of the processes included in the L&D department posed different challenges. The simulation team turned their focus to the movement and interaction of the clinical staff and supporting departments. In a sense this brought the simulation full circle through adding emphasis of staff movement to patient movement and demonstrating improved patient care.

Original Simulation as a Study of Staffing Levels

A computer simulation developed for the Labor & Delivery (L&D) Department focused on the nurse staffing requirements for patients administered Pitocin, which is a medication that facilitates childbirth. Pitocin is a brand name for Oxytocin, “a hormone produced by the hypothalamus and stored in the pituitary gland. It is used to help start or strengthen labor and to reduce bleeding after delivery” (“Oxytocin injection”, 2010).

The protocol requires an additional nurse for patients receiving Oxytocin. The extra RN remains at the patient’s bedside, monitoring the labor phases until delivery. The percentage of patients that received Oxytocin accounted for

38% of the total labor patients from December to May of 2014. L&D management requested a simulation that graphically illustrated this change in nurse assignments.

Both physician and nurse managers reviewed the simulation ensuring that it accurately depicted the L&D environment. The Modeling and Simulation Team validated the simulation against real-world data, and illustrated with experimentation that nurse-staffing requirements would have to change to follow the new guidelines. As this project showed, computer simulation is a tool that allows clinicians the chance to study the effects of changes in process and environment before committing resources to any changes.

Adapting the Simulation to Training Clinical Staff

Building on the success of the original simulation, the physicians in L&D asked if the software could also function as a teaching tool. The physicians were concerned with hemorrhagic patients and the protocol used to request blood and medication supplies. The Modeling and Simulation Team responded by adapting the previous model with changes to patient and staff movements. The model depicted two settings: the first represented the existing process where nurses placed multiple phone calls and successive trips to the lab delivery chute for supplies. The second illustrated the nurse making one phone call and one subsequent trip to the lab for all necessary supplies. The changes for this study were limited to altering the patient tracks, and illustrating a hemorrhagic patient and the staff movements while treating that patient.

As a teaching tool, the simulation graphically illustrated the time difference between placing multiple calls versus one call for medication and blood. When viewed by staff nurses, they immediately understood why the physicians developed the new protocol and the resulting improvements in patient safety and care. As time is critical in treating a new mother hemorrhage, the computer simulation proved to be a valuable instruction technique. The resulting improvements demonstrated that employing computer simulation complemented the current mannequin simulation used by the department.

Model Reuse

The hemorrhagic study presented the team with an opportunity to redesign the existing Pitocin simulation with a different purpose. One of the advantages of the approach of using an existing simulation, similar to code reuse, was time saved in creating a model from scratch. The lessons learned from this exercise led the modeling team to use previously developed patient tracks as the starting point for developing new models on other projects. The team has been able to use this technique because although each environment has specific requirements, patient movements within the healthcare system are similar. By using previous models as a starting point, the team shortens development and simulation delivery times. Clients use the simulations as a decision support system, and faster delivery by the modeling team means faster and more accurate decision making by management.

DESCRIPTION OF THE MODEL

The computer simulation for this study was developed using FlexSim 3D Modeling & Simulation software, and the team began by adapting the previous simulation that addressed Oxytocin and nurse staffing requirements. The team used the initial model's physical layout of the L&D department, including the number of beds, equipment, and staffing levels. Developing this study required changing patient arrival times, and staff movement. This was the first example of the modeling team using staff movement as the primary subject of the model. The L&D physicians wanted to illustrate that making one phone rather than multiple calls for a patient improved patient safety and care.

The clients requested an illustration of the time difference between two treatment scenarios involving a different number of phone calls by the nurse to the lab and pharmacy, so the modeler developed two patient tracks. Each track depicted the arrival of a patient, the onset of the hemorrhage, the movement of the staff to the patient's bed, and the staff member calling the Lab and retrieving the supplies. In the first track the nurse places three phone calls to the Lab and travels to the pickup location, and then returns to the patient room with the supplies. Three calls represent a typical minimum, and in severe emergencies more than three calls were placed. The modeler restricted the number of phone requests to three at the direction of the physicians because the scenario clearly demonstrated how following the one call protocol streamlined the process. Depending on the room inhabited by the patient, the time to retrieve the supplies varied, but not by more than a minute.

Figure 1: The Labor & Delivery Computer Simulation at time zero

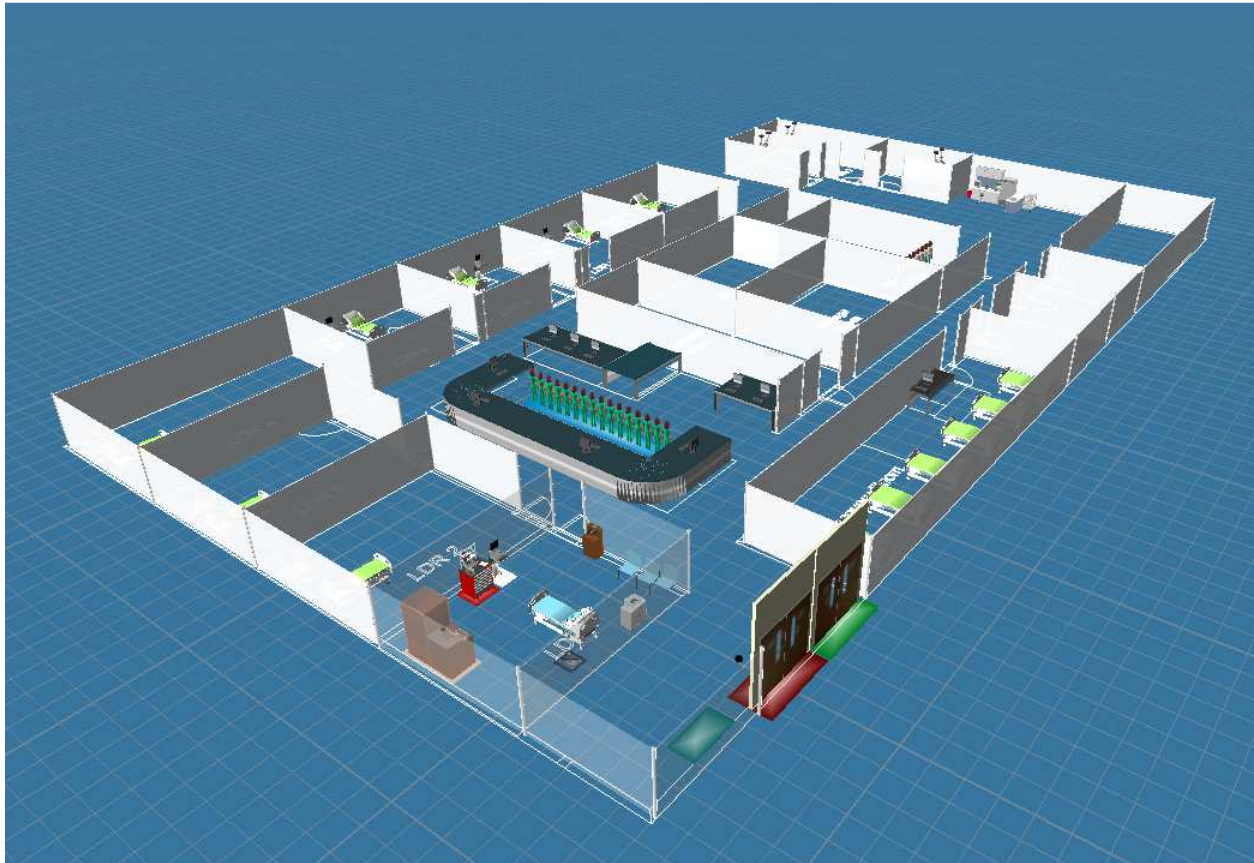


Figure 2: RN administers the blood and medication



PROCESSES

The process for requesting blood supplies and IV medication involves contacting the laboratory and pharmacy. The laboratory and pharmacy deliver medication and laboratory supplies to the appropriate department through a network of air-powered chutes, similar to drive up banking terminals. When a clinician orders supplies for a patient, the lab and pharmacy prepare and place the supplies in the chute for delivery to the correct nursing unit. The process map below illustrates the iterative process of making multiple phone calls and travelling to the delivery chute for blood and medication. One of the drawbacks of this method is that there is a substantial amount of tacit knowledge

used by a Registered Nurse (RN) in their interaction with the other departments. For a relatively new RN, there is a steep learning curve as she gains the type of experience that contributes to her development of personal tacit knowledge. This knowledge contributes to efficient communication between the RNs and other departments. An iterative process consumes time and resources because ordering individual supplies requires more time in the lab and pharmacy for preparation as well as delivery. In an emergency, when an RN must repeatedly leave the bedside for retrieving supplies, the medical staff is down one member, which compromises patient safety and care.

The impetus for developing a new process stemmed from the L&D physicians goal of illustrating the result of using one phone call for supplies and its affect on patient care. This new process was published to the department as a change in the protocol for treating hemorrhages. Initially the acceptance rate of the new process was lower than the physicians had hoped. Nurses seemed to rely on their experience, and the new process required them to change their behavior.

While the processes are similar, the main difference is that by avoiding multiple phone calls, the RN is able to assist the patient at bedside. Because the length of time and extent of hemorrhages varies, a patient may need more than one round of supplies. Even in the cases where additional supplies are needed, following the one phone call protocol benefitted both the RN and patients as it increased the number of resources available to the patient. If a hemorrhage continues, additional requests may be placed, or the patient more likely becomes a candidate for surgery to stop the hemorrhage.

Figure 3: Existing process flow requiring multiple requests for laboratory supplies and IV medication

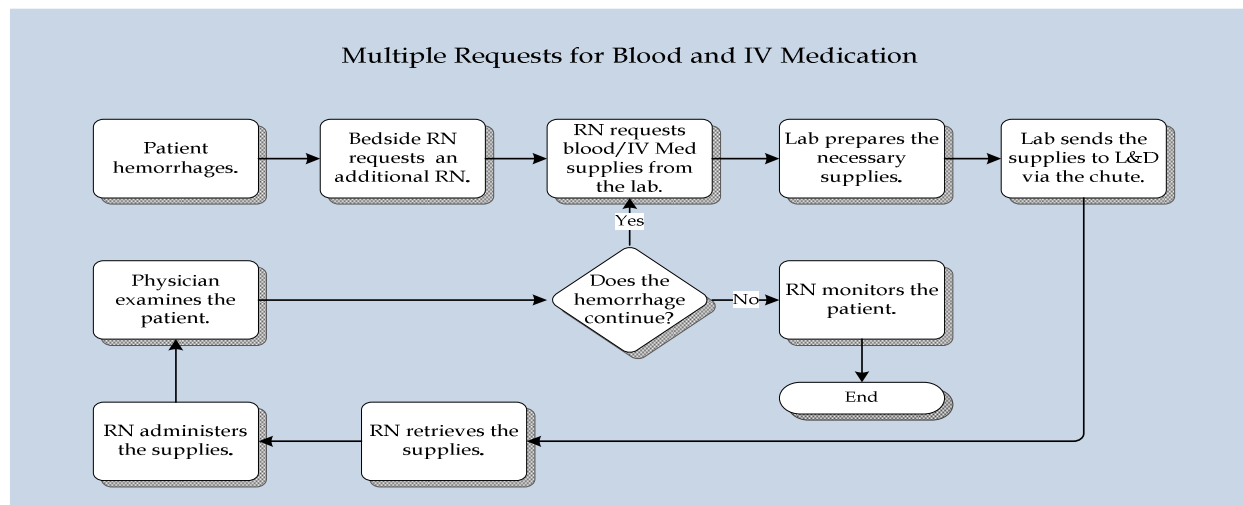
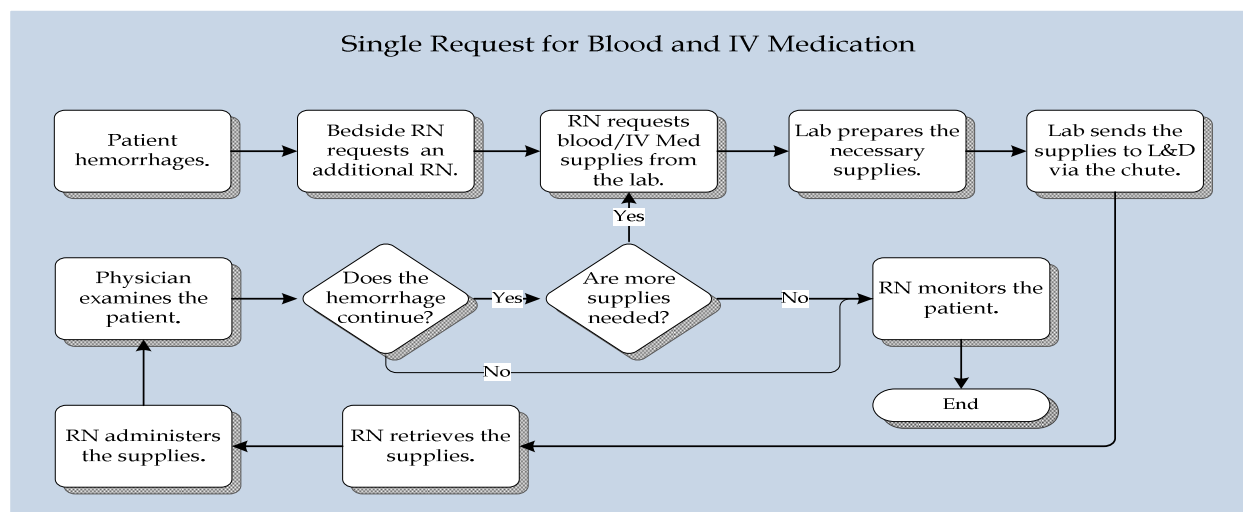


Figure 4: New process flow that uses one request for laboratory supplies and IV medication



DEPARTMENT COORDINATION

Since a hemorrhage may continue for an extended time, and present at different levels, it is critical that the correct supplies are available quickly. As with any other medication or blood for transfusion, administering follows the five rights: the right patient, blood/medication, dosage, pathway, and time. In the case of a hemorrhage, time is of the essence, and delivering all medication and blood supplies at once decreases the time from physician order to administration. This new protocol, developed by the physicians, leveraged information contained in the EMR such as blood type and allergies. Since the collection and inclusion of patient data in the EMR is routine, it is available to any department that has approved access to the data. When a patient enters the L&D unit, the lab has all of the patient information to prepare the packet of supplies that are ready for delivery on the physician's order. The revised protocol is able to take advantage of this data to streamline procuring supplies from the lab.

The new protocol required that the pharmacy and lab change their processes accordingly by delivering the package of supplies at once. The set up time increased, however, it is important to recognize that by including all of the supplies in one package, the repeated calls freed up the respective department's staff to perform other tasks. The efficiencies gained were evident in the L&D unit as well as the pharmacy and lab. The simulation demonstrated the advantages of departmental coordination and following the new protocol.

One advantage of computer simulation is experimentation. While experimenting with the number of staff available and the traveling distance to retrieve supplies could reinforce the importance of using the single request process, the simulation team did not conduct the experiments for the staff when presenting the model because the advantage of collecting all of the supplies in one trip and keeping more RNs at the bedside was evident. There was no need to increase the number of staff, access other resources, or change other variables of the actors to test the protocol. Instead, the simulation used the software default values for the speed of staff movement. Although these values may be changed, in this case there was no benefit to the outcome from making changes. In fact, keeping the nurses' speed constant and equal in both model tracks was valuable in showing the advantage of the new protocol.

DATA

The modeling team collected the data of RN movement for this simulation through interview and observation. Typically, there are no milestones registered within the Electronic Medical Record (EMR) that informs us of the time necessary for completing tasks such as making phone calls or traveling to an area to retrieve supplies. In the case of a hemorrhage, movements speed up, including travelling to and from the delivery chute. At the physicians' request, the modeling team did not change the speed of the actors in the computer simulation because this simulation primarily functions as a teaching tool.

The data in the table reflects the average times, but there is some variability for each activity. This variability was represented in the model as a triangular distribution that included the maximum, minimum, and mode times. As the summary table shows, multiple phone calls increase the time necessary to order, retrieve, and administer the supplies by three times.

Table 1: Existing protocol with multiple requests and retrieval trips for blood supplies and medications (time in minutes)

	<i>Request lab and pharmacy supplies</i>	<i>Lab and pharmacy prepare packet</i>	<i>Lab sends packet through chute</i>	<i>RN retrieves packet</i>	<i>RN administers meds</i>	<i>Total time in minutes</i>
Call 1	.5	3	1	1	1.5	7
Call 2	.5	3	1	1	1.5	7
Call 3	.5	3	1	1	1.5	7
One call	.5	3	1	1	1.5	7

Table 2: Summary Data

<i>Total time for one request</i>	<i>Total time for three requests</i>	<i>Net time saved</i>
7 minutes	21 minutes	14

The modeling team collected patient milestone data for the simulation from the EMR software used in L&D and the Neonatal Intensive Care Unit (NICU). The EMR software allows clinicians to chart patient's information as well as use data uploaded from medical monitoring equipment. The efficiencies that this type of functionality represents include clinician's no longer manually entering data such as respiratory rate, blood pressure, and pulse. Clinicians upload the data by polling the monitoring equipment, and the information populates the corresponding fields in the EMR. At Baptist Hospital of Miami (BHM), only the NICU and L&D departments currently use this type of software that allows polling vital signs from medical monitoring equipment.

The data set included six months of data for pregnant patients admitted to the department. Multiple admissions are possible for a patient, as each admission does not always result in labor. Although the number of multiple admissions is less than 1%, it is imperative for data integrity to account for the possibility. The data included such attributes as admission date and time, the beginning time of the first, second, and third stages of labor, time of birth, type of delivery, and infant status. Due to the nature of the simulation, collecting demographic data such as patient names was unnecessary. The modeling team collected patient identifier data including the unique patient identification and visit numbers. In the EMR software, each patient receives a unique visit number that identifies individual encounters with the healthcare system. When concatenated to the patient identifier, the two numbers identify both the patient and visit, which is essential for identifying patients admitted more than once for the same pregnancy.

RESULTS

The computer simulation in this example graphically illustrated what seemed obvious to the L&D physicians. It reaffirmed that reducing the number of requests for hemorrhage supplies increased the quality of patient care and safety. Developing the simulation and presenting it to the staff drove home the point that making a seemingly small change in patient care process would yield benefits beyond the small time saved. Hemorrhaging patients require a higher level of care, and by keeping resources at the bedside contributes to raising the level of care. During the physician interviews for this project, Maria Lopez-Beecham, MD Obstetrics & Gynecology, stressed that the goal of introducing the new protocol maintained nurses and other resources at the bedside. The simulation proved successful as the time difference between the two retrieval methods was evident both visually and statistically.

This simulation illustrated a process change and the improvements resulting from that change. It is not a stretch to imagine that the same techniques could transfer to other areas of our organization. As an example, we are engaged in a project of redesigning processes and building a computer simulation for our Risk Management Department with a goal of increasing the privacy of collecting, recording, and storing patient demographic information. Modeling and Simulation fit perfectly as a tool for us in process re-engineering projects because process flows, interdepartmental interaction, and staff movement occur in every department of our organization. We believe that the technology is adaptable to any environment where there exists a focus on movement of people, assets, and improving process flows.

CONCLUSION

Simulation software represents a new opportunity for healthcare organizations to review and re-engineer processes. When applied to clinical environments, discrete event software provides a tool that informs management, improves patient care, and increases clinician efficiency. While any simulation is a learning tool, experimentation reveals how changes produce benefits and drawbacks. Computer simulation functions well as a tool for management to develop a better understanding of process, and how changing processes affects patient care. This model-building instance provided the Modeling & Simulation Team an opportunity to build a model with the primary goal of educating the clinical staff of the L&D Department; aligning the outcomes with other simulation teaching techniques. Shifting the concern from the time and movement of patients to the movement of staff treating a single patient changed the focus of the model and the effect on the audience. This exercise also revealed that models created for one purpose are

applicable to another domain, thereby increasing the value of the team's expertise and the investment in the simulation software. Simulation is now a first choice for projects aimed at improving workflow processes along with our current toolkit of process flows and use cases.

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