# USING SIMULATION IN THE IMPLEMENTATION OF AN OUTPATIENT PROCEDURE CENTER

Todd R. Huschka

Division of Health Care Policy & Research

Mayo Clinic
Rochester, MN, 55905, U.S.A.

Bradly J Narr, M.D.

Department of Anesthesiology
Mayo Clinic
Rochester, MN, 55905, U.S.A.

Brian T. Denton

Edward P. Fitts Department of
Industrial & Systems Engineering
North Carolina State University
Raleigh, NC, 27695, U.S.A.

Adam C. Thompson

Department of Anesthesiology
Mayo Clinic
Rochester, MN, 55905, U.S.A.

## ABSTRACT

Creation of an Outpatient Procedure Center (OPC) is a complicated endeavor, requiring a detailed understanding of the resources available and the procedures to be performed. Miscalculation of resource allocation or patient flow through the area can result in the waste of expensive resources, patient dissatisfaction, and health care provider inefficiency. The use of discrete event simulation can assist in the design of an OPC with the ultimate goal of reducing resource waste and improving patient flow through the system. In this article we provide a case study of the application of a discrete event simulation model used to support analysis required for moving an existing group (interventional procedures for Pain Medicine) into a new area. This resulted in major changes to the group's practice and modified the new facility utilization.

## 1 INTRODUCTION:

Interventional procedures in Pain Medicine are a high volume procedure practice at Mayo Clinic in Rochester, MN. Prior to 2007 the existing practice consisted of one procedure room housed within an OPC serving several different unique surgical practices. Over time, demand for pain procedures has increased significantly resulting in long patient wait times for these interventions. To provide access for increased demand for pain procedures, a new OPC area was proposed in 2007. The new design increased the number of procedure rooms from one to four to accommodate the higher demand. In addition, the process of patient flow through the system was altered in an effort to improve daily patient throughput.

Because of the complex interaction between resources within the OPC it was not certain that these changes would result in the desired outcome. Simulation of the original single-room pain procedural area had already been performed, where the practice was part of a larger outpatient surgery procedure center (Huschka, Denton, Gul, and Fowler 2007). Using this as a base, a new discrete event simulation model was created to analyze design issues related to implementation of the new proposed pain procedure practice.

Simulation analysis of the new pain procedural area began late in the design of the area and we were not able to significantly affect the physical design of the new OPC. However, it was possible to confirm that the new layout would be able to meet patient throughput expectations, and to make recommendations about the additional supporting resources required for planned procedure rooms. In particular, we examined patient flow through the new process, located possible bottlenecks, and made process recommendations to balance the competing performance measures, patient throughput, and patient wait times.

In this article we discuss the steps taken to answer the most pressing questions regarding the design of the new practice. These included:

- Would four recovery rooms be sufficient to accommodate the anticipated demand and adequately serve the associated four procedure rooms?
- How could patient waiting time for a recovery room be minimized?
- At what time in the overall process should patients be sent to the vitals booths so that they would not experience substantial wait times in the confined vitals booths?

- Could a capacity of 48 patients per day be achieved, and if not what steps were necessary to achieve this capacity?

The remainder of this article is organized as follows. Section 2 provides a brief background on the pain clinic practice. Section 3 is a short review of related literature on simulation modeling of surgery practices. Section 4 describes the original and newly proposed pain practices, and Section 5 describes the discrete event simulation model developed to analyze the proposed practice. Section 6 presents the results of numerical experiments and recommendations that were implemented. Finally, Section 7 summarizes the conclusions of this case study.

## 2 PAIN CLINIC BACKGROUND

The practice of Pain Medicine is multi-disciplinary in approach, incorporating modalities from various specialties to ensure the comprehensive evaluation and treatment of the pain patient (American Association for Pain Medicine, <www.painmed.org>). Most pain disorders are multisystemic and complex. Effective evaluation, diagnosis and treatment of pain disorders necessitate sub-specialty training in Pain Medicine. Pain specialists leverage a variety of modalities, including pharmacologic, rehabilitative, psychological and interventional therapies, to treat pain patients. Pain specialists at Mayo Clinic perform a wide range of interventional pain procedures to include, but not limited to, epidural steroid injections, facet joint injections, neurolytic blocks, radiofrequency lesioning, neurostimulation, and neuraxial infusions. These procedures are performed utilizing fluoroscopic guidance in a full-service OPC where appropriate sedation and nursing care is readily available to optimally serve patients.

While there are a wide variety of pain procedural interventions, the duration of most procedures is similar. This pattern of procedure lengths has allowed a scheduling system involving five relatively consistent procedure types (I-V) with type I being the simplest and shortest in duration, and type V being the most complex and longest – often requiring multiple techniques and advanced imaging.

The area previously designated for interventional pain procedures at Mayo Clinic in Rochester was an OPC shared by several diverse surgical practices. This area had one dedicated pain procedure suite and four patient preparation and recovery booths. While these *pre/post rooms* were generally reserved for the use of pain patients, they were not explicitly reserved for their use. In addition, nursing resources were shared with other surgical services. In the design phase of the new facility, members from the Pain Medicine group lobbied for an alternative design that more effectively matched the needs of pain patients and facilitated better patient throughput. Simple fluoroscopy-guided pain procedures are typically short in duration and homogenous. Recovery times are closely related to procedure lengths and patient preparation is minimal, normally involving the collection or review of pertinent clinical information and a basic nursing assessment. However, pre/post rooms in the original OPC were comfortable and private patient areas, designed for longer surgical preparation and post-operative recovery and monitoring.

The new facility design abandoned the spacious pre/post room concept and, instead, opted for smaller dedicated vitals booths and separate recovery bays. The new design reduced preparation and recovery space by 25%. However, the vitals booths were sparse, and focused on clinical necessity rather than patient amenities. Thus, excessive patient waiting in the vitals booth prior to entering the procedure room became a chief concern. Additionally, the facility did not allow for extra recovery capacity. As a result, delays in patient recovery – or required extended recovery – had the potential to create a bottleneck in the recovery bays, thus reducing throughput in the procedure rooms.

## 3 LITERATURE REVIEW

Simulation models of surgical suites have been used in many cases to evaluate various performance criteria. Of primary interest in our study was nursing staff allocation, patient flow, and resource utilization. Several examples covering these issues exist in previous studies. For example, Dexter et al. (1999) used simulation to look at block scheduling by surgeon in order to increase operating room (OR) utilization. They focused on the OR only (ignoring intake and recovery processes) and evaluate efficiency of various block scheduling methods.

Dexter and Marcon (2006) studied the impact of several different surgery sequencing heuristics considering both ORs and a post anesthesia care unit (PACU). While surgery sequencing was considered within our simulation, the limited number of pain procedures and similarity in mean and variance in duration for different pain procedures made sequencing less of an issue.

Denton et al. (2006) used a discrete event simulation model for the analysis and design of an endoscopy suite to investigate different endoscopist-to-procedure room allocation scenarios. Huschka et al. (2007) used a discrete event simulation model to evaluate a general OPC housing several surgical practices. They evaluated several patient arrival time scheduling heuristics with respect to competing criteria including overtime for the surgical suites and patient waiting time.

Traditional designs have depended on a one-to-one ratio of recovery to procedure rooms. Sokal et al. (2007) modeled a practice with 3 parallel-processing ORs and a dedicated 3-bed miniature PACU which is similar to our configuration of 4 procedure rooms and 4 recovery rooms. Their model showed that there was sufficient recovery room resource; however the case load was much

lower than that expected in our pain practice. Additionally, pain procedure times were very similar to recovery times suggesting the potential for the recovery area to be a bottleneck.

## 4 THE PROPOSED SYSTEM DESIGN

### 4.1 Original Design

The original pain procedural area consisted of four identical pre/post rooms which fed into one procedure room (figure 1). The pre/post rooms acted as a pre-procedure area and a recovery area. It was necessary to have four pre/post rooms to ensure a smooth movement through the procedure room. The short duration and high variability of procedures required ample room for the patient pre-procedure area to guarantee that there were always patients available to enter the high-cost procedure room. In this design the downside of having the procedure room sit idle between patients outweighed that of a patient waiting in a pre/post room for an extended time because the negative effect of waiting was offset by making pre/post rooms relatively comfortable, by including amenities, such as televisions, and comfortable furniture to make the wait tolerable.
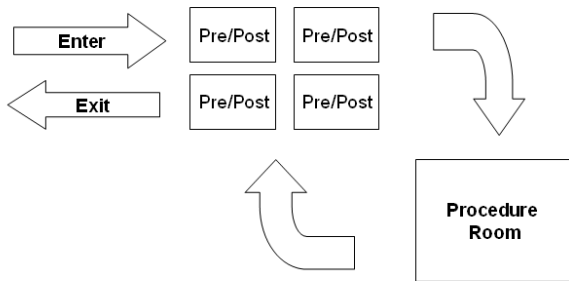


Figure 1: Original Patient Flow. Patients enter and exit a bank of pre/post rooms, usually returning to the same pre/post room after their procedure.

### 4.2 New Design:

The outpatient practice leaders were confident that pre-procedure and recovery times could be reduced through better management of patient flow. Therefore a decision was made to design the vitals booths and recovery rooms to be much smaller. The vitals booths were about one third the size of a traditional pre/post room. To compensate for this it was necessary to reduce waiting in the vitals booth to an absolute minimum. The recovery rooms were about half the size of a traditional pre/post room. Overall this resulted in a much smaller physical space requirement for the clinic freeing space for other uses. Figure 2 shows the flow of the new design.
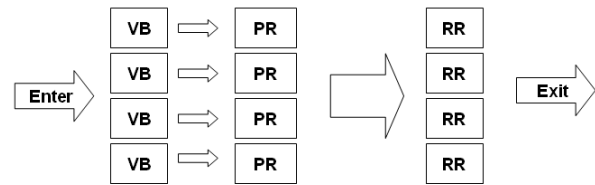


Figure 2: New Patient Flow. Patients enter dedicated vitals booth (VB) replacing pre/post room, then move into attached procedure room (PR), after which they recover in a bank of recovery rooms (RR).

Recovery time is uncertain and has high variance relative to the mean (Huschka, 2007). Long recoveries could cause the entire process to backup, resulting in patients being delayed in a small vitals booth. Furthermore, this would result in decreased patient throughput and therefore lost revenues. Thus, an important question was whether the four recovery rooms would be sufficient to serve the area.

There was also a question of the optimal time to release a new patient from the more spacious and comfortable general waiting area into the more confined vitals booth. In making this decision high utilization of procedure rooms was a consideration, but this had to be traded against patient waiting in the vitals booth. Finally, the question of trying to accommodate 48 patients per day with the new design needed to be tested. In the original practice it was possible to see 12 patients per day with a single procedure room but it was not certain that throughput would scale linearly with respect to an increased number of procedure rooms.

To answer these questions, constraints were added to the simulation model. These constraints dealt with auxiliary resource availability (nurses), and resource limitations (procedure room differences). For instance, nurses were required for the pre-procedure process within the vitals booth, and in recovery rooms to monitor patient and watch for possible complications due to anesthesia or the procedure. The total number of nurses required for the practice was unclear. Additionally, not all procedure rooms were identical. One room would not be able to perform certain procedures, and it was unknown how this might affect the overall flow.

## 5 SIMULATION MODEL

A discrete event simulation model of the new pain procedural area was created using Arena version 10.0. Using existing historical data from the original pain procedural area in the shared OPC compiled over the period of one year, probability distributions were estimated for all processes (Huschka et al, 2007). The original processes included pre-procedure, procedure, and recovery, as well as

the time to move from one area to another. The design of the new area invalidated the pre-procedure times from the original pain practice, in which patients were moved into pre/post rooms as soon as they became available. This resulted in significant waiting times in the pre/post room prior to procedure. Since the pre/post rooms were comfortable this was not a serious issue, but historical data for pre-procedure times included this wait time, making them an unreliable estimate for the new pain clinic. To make new estimates, patients and nurses were observed during pre-procedure to isolate the time for the critical processes and the observations were used to fit a triangular distribution. Recovery times were adjusted to 65 percent of recovery time within the old area based on the expectations of facility managers of the original area. As in the original design, patients were scheduled to a specific procedure room, and in the case of the new design the specific vitals booth associated with each procedure room. A patient arriving early would not enter a vitals booth to which they were not scheduled. Recovery rooms were on a first come first serve basis, with the exception of procedure type V patients, which automatically went to a secondary recovery area regardless of primary recovery availability. Turnover times for the vitals booth, procedure room, and recovery rooms between patients were based on triangular distributions. Hours of operations were 8am – 4pm.

In practice, a patient scheduled for a procedure would be seen on that day even if they entered the area after the scheduled close of the procedure room. In the simulation model, if a patient was unable to enter a procedure room before the scheduled end of day, they would be removed from the system and counted as unable to be served within the scheduled day. This would happen even if they were already in a vitals booth awaiting their procedure. The reason was that the stakeholders involved in decision making wanted to focus on the number of patients that could be served within the scheduled hours of operation.

Design and analysis of the simulation model took place in several stages and included many meetings with administrators responsible for design of the new pain clinic. Validation of model outputs was carried out by soliciting expert opinions from administrators familiar with the operation of the original practice. Twenty-five replications of 107 days were simulated in all cases with the exception of the final graph, in which case fifty random days were simulated over each hedge value of 0 to 31. Those values were then smoothed. Half-widths for simulation runs were less than 1% of the mean values reported with the exception of patients moved to a secondary recovery room, which were less than 10% of the reported mean values.

## 6 SIMULATION RESULTS

Simulation analysis provided valuable results. First, one of the primary questions to be answered was whether the four recovery rooms would be able to serve the four procedures rooms. Additionally, it was not clear what the optimal time, or *trigger* for moving a patient into a vitals booth should be. By trigger we mean a natural point within the daily process to place the patient retrieval activity. We evaluated two easy to implement triggers. The first, moving a patient into the procedure room as soon as it became available, and the second, moving the patient into the room at completion of the pre-procedure process (the process that prepares the patient for administration of the pain procedure itself) for the prior patient.

Table 1 shows our initial results, and demonstrates that several benchmarks would not be met by the proposed design. Not only would the new design be unable to serve the expected 48 patients per day, but patients would be waiting for a recovery room, decreasing procedure room utilization. However, the results did show that movement into the vitals booth after the prior patient completed the pain procedure appeared to be the optimal trigger; movement of the patient earlier would result in excessive waiting times. With these results it is clear that an additional recovery area would be needed occasionally.

Table 1: Initial simulation results using same schedule from original area in order to determine trigger to move into procedure room and find bottlenecks. Half-widths were less than 1% of reported means.

| Trigger to Move into Vitals Booth | Immediate | After Pre-Incision | After Surgery |
|---|---|---|---|
| Wait in Vitals Booth | 14.55 Min | 10.26 Min | 1.56 Min |
| Wait for Recovery | 3.42 Min | 3.41 Min | 3.34 Min |
| Average # of Patients per day | 43.6 | 43.6 | 43.5 |

Our initial analysis assumed patients were available at the beginning of the day. In practice a patient arrival schedule that considered total patient waiting time needed to be designed. Previous work in surgery scheduling has looked at applying a *hedge*, i.e., adding planned time beyond the mean time for a procedure (Huschka et al 2007). Hedging is motivated by variance in procedure times. When patients exceed the mean duration for the bottleneck within the process, waiting times accumulate, causing the waiting room to back-up over the course of a day. In order to minimize patient waiting we looked at adding 5, 10, and 15 minute hedges to the mean duration.

Combining our patient throughput results, and our analysis of hedged arrival schedules, a decision was made to adjust the process to accommodate routing Type V patients (which had the longest duration and the longest re-

covery) to a secondary recovery area available to the pain clinic. While not preferred this was the best recourse option available given the need for additional recover room capacity. Table 2 illustrates improvements in most areas (with the exception of the recovery area) resulting from use of the secondary recovery area. Additionally, it is evident that hedging reduces waiting time without greatly affecting patient throughput. Hedging up to 10 minutes does not cause a significant reduction in procedure room utilization or patient throughput.

Table 2: Simulation results looking at how different hedging heuristics affect performance. Half-widths were less than 1% of reported means.

|  | Mean | Plus 5 Min | Plus 10 Min | Plus 15 Min |
|---|---|---|---|---|
| Wait in Vitals Booth | 1.54 Min | 1.50 Min | 1.29 Min | 0.52 Min |
| Wait for Recovery | 3.34 Min | 3.32 Min | 3.24 Min | 2.78 Min |
| Procedure Room Utilization | 70.2% | 70.1% | 69.0% | 63.0% |
| Avg # of Pats per Day | 52.1 | 52.2 | 51.4 | 47.8 |

Table 3 shows the results combining use of the secondary recover area with the best arrival schedule options (10 and 15 minute hedge). By utilizing the secondary recovery area the patient throughput goal could be met.

Additionally, we found that utilization of the secondary recovery area was expected to be low. Management in the area was concerned that use of the secondary recovery would cause problems for other areas of the OPC; however the results from the simulation helped the decision process by showing that it should be a minor issue.

Table 3: Simulation comparison of 10 minute and 15 minute hedging heuristics. Half-widths were less than 1% of reported means with the exception of patients in secondary recovery, which is less than 10%.

|  | Plus 10 Min | Plus 15 Min |
|---|---|---|
| Wait in Vitals Booth | 0.39 Min | 0.18 Min |
| Wait for Recovery | 0.00 Min | 0.00 Min |
| Procedure Room Utilization | 67.2% | 61.3% |
| Avg # of Pats per Day | 52.8 | 48.3 |
| Pats in Secondary Recovery per Day | 1.93 | 1.12 |

Based on our findings, both a 10 minute and 15 minute hedge satisfy the basic criteria of 48 patients per day. Neither of these options dominates the other with respect to all of the criteria considered. However, Figure 3 illustrates this tradeoff, showing how utilization and patients seen per day drop off as the hedge is increased past 10 minutes. As a result we can be reasonably confident that a 10 minute hedge on scheduling will perform best in practice and meet the criteria required by area managers.
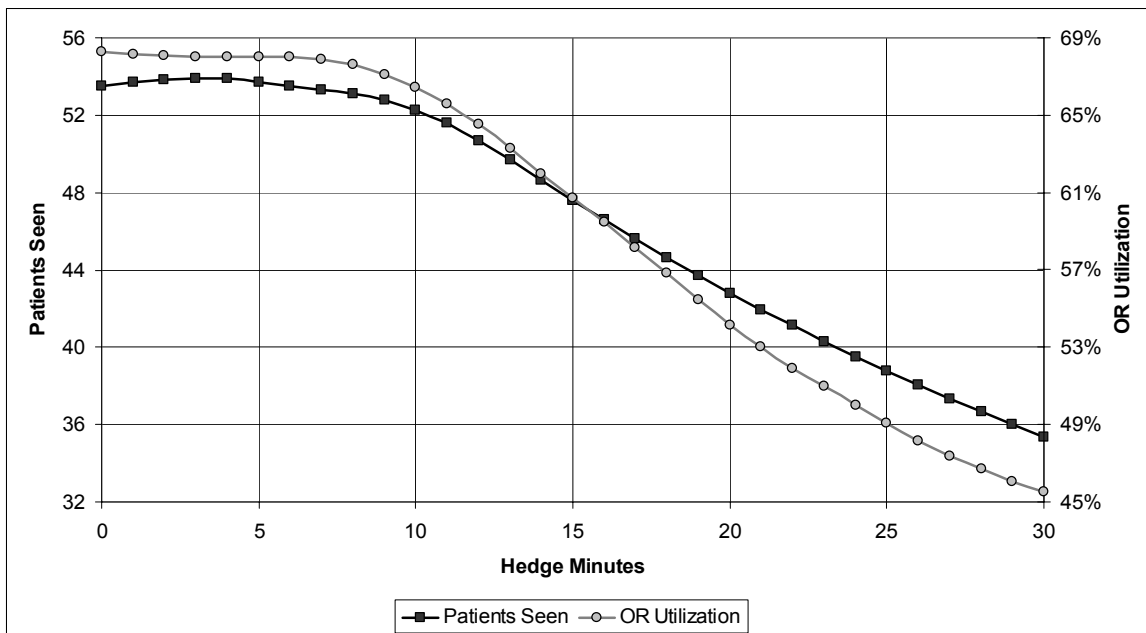


Figure 3: Graph showing decrease in OR utilization and number of patients seen in a day as the hedge in the patient arrival schedule is increased.

## 7 CONCLUSIONS

The design of the new pain procedural area at Mayo Clinic serves as an example of how discrete event simulation can play a valuable role in designing a new health care practice. Although simulation was not used early in process, which would have shown the need for an additional recovery room before construction was completed, it supported a number of important decisions prior to opening the area, leading to a more efficient practice from the patient and provider's perspective. In addition to identifying the recovery area bottleneck our model was used to make process design decisions and construct a patient arrival schedule with a good trade off between competing criteria from a administrative and patient perspective. Future work will involve direct comparison of the new practice to the original practice to evaluate the differences between the two designs. Additionally, expansion of the model to include the other medical specialty areas using the new OPC will be performed to see how global process changes could improve overall operations.

## ACKNOWLEDGEMENTS

## REFERENCES

Dexter, F., A. Macario, R. Traub, M. Hopwood, and D. Lubarsky. 1999. An operating room scheduling strategy to maximize the use of operating room block time: Computer simulation of patient scheduling and survey of patients' preferences for surgical waiting time. *Anesthesia and Analgesia* 89:7-20.

Dexter, F. and E. Marcon. 2006. Impact of surgical sequencing on post anesthesia care unit staffing. *Health Care Management Science* 9:87-98.

Denton, B., A. Rahman, H. Nelson, and A. Bailey. 2006. Simulation of a multiple operating room surgical suite. In Proceedings of the 2006 Winter Simulation Conference, ed. L. Perrone, F. Weiland, J. Liu, B. Lawson, D. M. Nicol, and R. Fujimoto, 414-424. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Huschka, T., B. Denton, S. Gul, and J. Fowler. 2007. Bi-criteria evaluation of an outpatient procedure center via simulation. In Proceedings of the 2007 Winter Simulation Conference, ed. S. G. Henderson, B. Biller, M.-H Hsieh, J. Shortle, J. D. Tew, and R. R. Barton, 1510-1518. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Sokal, S., Y. Chang, D. Craft, W. Sandberg, P. Dunn, and D. Berger. 2007. Surgeon Profiling: A Key to Optimum Operating Room Use. *Archives of Surgery* 142:371-380.

## AUTHOR BIOGRAPHIES

**TODD R. HUSCHKA** is a Master Health Systems Analyst II at Mayo Clinic in the Health Care Policy and Research department of Health Sciences Research. His primary interests are simulation modeling, optimization and statistical analysis relating to improvements in health care systems. He completed his MS in Industrial Engineering Decision Science/Operations Research at the University of Wisconsin in Madison, Wisconsin. His email address is <todd.huschka@mayo.edu>.

**BRIAN T. DENTON** is an Assistant Professor in the Edward P. Fitts Department of Industrial & Systems Engineering at North Carolina State University. His primary research interests are in the development and application of operations research methods to health care delivery, and his work relating to surgical scheduling won the IIE Transactions outstanding publication award in 2005. He completed his Ph.D. in Management Science at McMaster University in Hamilton, Ontario, Canada. His email address is <bdenton@nscu.edu>.

**BRADLY J. NARR** is the Chair of the Department of Anesthesiology, Mayo Clinic Rochester. He completed his undergraduate and medical studies at the University of Minnesota in Minneapolis, Minnesota. His e-mail address is <narr.bradly@mayo.edu>.

**ADAM C. THOMPSON** is an Operations Manager in the Department of Anesthesiology at Mayo Clinic in Rochester, MN. He is a West Point graduate and former healthcare administrator in the US Army. He completed a Masters of Human Relations degree from the University of Oklahoma in Norman, Oklahoma. His email address is <thompson.adam@mayo.edu>.