The Impact of Propofol on Patient Throughput in an Outpatient Endoscopy Suite

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ABSTRACT

Background: The clinical effects of propofol are well documented, but the effect on financial performance is not well studied.

Objective: To estimate the increase in number of colonoscopies per day that can be completed in an outpatient endoscopy practice as a result of changing sedation agents.

Design: A discrete event simulation model was used to compare performance measures for the base case of existing sedation agents (midazolam and fentanyl), and a hypothetical case of propofol.

Methods: Major steps in the simulation model included patient arrival, check-in, intake, procedure, recovery, and discharge from the unit. Major resources included intake and recovery bays, procedure rooms, and gastroenterologists. Probability distributions for steps in the process were based on historical data and data collected through a time study.

Setting: Outpatient endoscopy practice.

Intervention: Colonoscopy

Main Outcome Measurements: Average daily patient throughput, patient waiting time, overtime, and provider utilization.

Results: For the baseline case with 4 procedure rooms and 4 recovery bays, 9.1% more patients could be served per day if the sedation agent were switched to propofol. Other performance measures such as average end of day, resource utilization, and patient wait times were not sensitive to the change in sedation agent.

Limitations: Results are based on a single medical center; factors such as cost and availability of an anesthesia provider were not considered.

Conclusion: Changing sedation agents to propofol could increase the number of patients served during a day without adversely affecting resource utilization and patient wait times.

INTRODUCTION[1]

Endoscopy suites are composed of expensive human and physical resources that present a high fixed cost for daily operation. As a result, opportunities to increase the number of cases per day can have a significant financial impact on the viability of a practice. Improved efficiency could result in improved access to the resources necessary to screen for colorectal cancer.

Recovery is a lengthy part of the overall process for a colonoscopy. It is also a resource intensive activity, requiring sufficient nurse coverage, as well as available physical resources such as recovery bays. Recovery times are highly unpredictable; as a result, recovery can, at times, be a bottleneck in the overall process. A congested recovery area can cause blocking of patients who back up into procedure rooms, which subsequently causes congestion in the intake area, and the check-in area. Ultimately this reduces patient throughput or leads to high overtime. Increased patient waiting time also results in increased anxiety, and ultimately dissatisfaction with the overall process.

Propofol is a fast-acting sedation agent that has both sedative and amnesic properties[1]. In the United States this sedation agent can only be administered by a trained anesthetist who monitors the patient continually. There is potential benefit from the patient's perspective since recovery is rapid with almost no hangover effect[1]. There is also potential benefit from the operational perspective from reducing the bottlenecks in recovery.

We used a discrete event simulation model for an outpatient endoscopy practice to evaluate the hypothetical operational impact of changing sedation agents from the current mix of midazolam and fentanyl to the use of propofol. We studied the consequence of the change on patient throughput as a result of reductions in mean recovery time. We also evaluated the impact on resource utilization and the end of day time. Sensitivity analysis was used to determine how the benefits are affected by the available capacity in the recovery area.

METHODS

We developed a discrete event simulation model for an outpatient endoscopy suite affiliated with a large academic medical center. The base model was designed by a group of systems engineers working in conjunction with several subject matter experts from UNC Hospitals, Chapel Hill, NC. Basic process flow was developed through e-mail, weekly conference calls, and on-site visits. Periodic review of the model was performed as part of the validation process.

The off campus facility has four procedure rooms, two gastroenterologists, four prep bays, four recovery bays, one prep nurse, four procedure nurses, two float nurses, one recovery nurse, and four endotechs. The model was based on three major process areas: an intake (prep) process that involved the patient changing and being prepared for the endoscopy, a procedure process that involved sedation and procedure, and a recovery process. The general process flow and major activities are described below.

Prep. Patients begin with check-in and wait in a lobby until they are called back by the prep nurse or one of the endotechs. The patient changes in one of the three changing rooms and goes to one of the four prep bays. Once in the prep bay, the prep nurse reviews the medical history with the patient and checks the patient's vital signs. There is one nurse designated for prep, and two float nurses who may help with prep. Endotechs can perform part of prep if they are not busy, but registered nurses are required to perform certain aspects of prep.

Procedure. Once prep is completed, the patient is transferred to a procedure room. Next, the patient's medical history is reviewed, and sedation begins. There are four procedure rooms, each requiring one endotech, one registered nurse, and one provider to perform the endoscopy. Two providers service the four procedure rooms, and four procedure nurses and endotechs. Following the colonoscopy, room turnover time takes place.

Recovery. After completing the procedure, the patient is transferred to one of four recovery bays, provided a bay is available. There is one recovery nurse designated to cover four patients. Once the patient is awake and recovered, the physician reviews the case with the patient. The patient is then discharged.

To simplify the analysis of recovery time reduction on patient throughput it was assumed the only procedure performed is colonoscopy. Two gastroenterologists shared the four procedure rooms. This is consistent with the current practice and also reported to be an efficient configuration[2]. The patient arrival schedule was based on current practice, with a patient scheduled to arrive every hour for each procedure room (one arrival every 15 minutes for four rooms).

Data

Historical data was used to develop and validate the discrete event simulation model. Data was extracted from a vendor software package, Provation RN, which included time stamps for major steps in the process. Data was used for the time period of July, 1, 2009 to September 11, 2009. This yielded a total of 1184 samples. Prep and procedure room turnover times were collected by a time study based on samples collected on two different days. Procedures were performed by attending gastroenterologists.

Simulation Model

The discrete event simulation model was built using Arena 12.0. Consistent with scheduling policy at the endoscopy suite, colonoscopy patients were scheduled to arrive every 15 minutes. The model consisted of an intake, procedure room, and recovery module; each having a first-come-first-served queue discipline. Resources included intake bays, procedure rooms, recovery bays, gastroenterologists, nurses, and endotechs. The probability distribution for intake, procedure, recovery, and room turnover were fit using Arena 12.0 Input Analyzer. Samples for activity times were based on differences between time

stamp data entries for patients, collected using ProVation RN. Room turnover time, which was not collected in ProVation RN, was measured as the time the patient left the procedure room until the room was ready for the next procedure.

Validation

The base model was validated using total expected process time measured as patient check-in to discharge. First, results were reviewed with experts at a departmental meeting including the nurse administrator, nurses, gastroenterologists, and project sponsors. The consensus was the results were reasonable and consistent with past experience and expectations. Second, output from the base model was compared to observed times recorded in ProVation RN. The mean expected time in system for colonoscopy according to observation was 129 (127,131) minutes. The mean time estimated using the simulation model was 137 (136, 137) minutes.

Proposed causes for the differences between observation and the simulation model were as follows. First, some of the distributions fit for process times were fit from a limited amount of data, including prep and room turnover. Second, there may be data collection errors for situations in which patient discharge is logged after discharge causing the model to overestimate the expected total process time.

The practical impact of the differences was deemed acceptable since the absolute differences are small (8 minutes), any bias in the model is consistent across all scenarios compared, and the objective of the study was a relative comparison between recovery time scenarios.

RESULTS

The baseline, with the current sedation agent, was compared to a hypothetical change to propofol. A distribution for recovery time using propofol was developed by combining current recovery times in the endoscopy suite with a recent published study on propofol recovery time[3]. A patient arrival schedule was developed such that patient throughput differential could be quantified for different recovery time scenarios. Sensitivity analysis was performed on the recovery distribution. The baseline distribution was the distribution for the current practice (midazolam and fentanyl). Variation in the recovery time distribution, such as could be affected by the use of propofol, was defined using a scale factor such that

$$\textit{new recovery time} = r(\textit{current recovery time})$$

where r=1 corresponds to the current recovery time.

Recovery Time Distributions

The current practice has a mean recovery time of 50 minutes and standard deviation of 14.5 minutes. A recent study was used to estimate mean recovery time (15.6 minutes) for patients receiving propofol as

a sedation agent[1]. The recovery distribution was scaled based on the ratio of the mean times to recover, which corresponds to a scale factor of r=0.309.

Quantifying Patient Throughput

The simulation model was used to estimate the expected number of additional patients that could enter the suite in a day, expected end of day time, patient waiting time, and resource utilization including procedure room, intake and recovery bays, gastroenterologists, nurses, and endotechs.

The current sedation practice was used to estimate the expected baseline end of day time and patient throughput. In this scenario, patients arrived at 15 minute intervals between 8 am and 4pm. At 4pm, all arrivals in the simulation were terminated and patients remaining in the system continued processing through discharge. A total of 500 samples (days) were collected. This scenario yielded an expected patient throughput of approximately 33 patients per day and an expected length of day of 11.09 hours. These values were used as the baseline value to calculate relative percentage improvements.

Next, the model was modified to quantify the change in throughput as a result of varying recovery time using the scale parameter, r. Patients continued to arrive every 15 minutes until the baseline end of day time (11.09 hours) was reached. Patient throughput was again computed based on 500 samples. For the estimated propofol recovery time reduction (r=0.309) expected patient throughput was approximately 36 patients, or a 9.1 % gain.

Sensitivity Analysis

Sensitivity analysis was performed for the recovery scale factor, r, which was varied from 0 to 1.0 to include extreme cases in which no sedation is used (r=0) and the current practice (r=1.0). Sensitivity analysis was also performed on the number of recovery bays which varied from three and five. In Figure 1 increases in the percent gain of expected patient throughput resulting from propofol use are higher when recovery resources are constrained, and lower when there is a surplus of recovery resources relative to baseline. Specifically, for r=0.309, the propofol recovery estimate, percent gain of patient throughput increases from 9.1% to 21% when the number of recovery bays decreases from four to three.

Figure 2 illustrates expected patient wait times for prep bays, procedure rooms, and recovery bays. Differences in wait times are trivial when the recovery scale factor is below 0.8. In general, wait times in

Figure 1 Caption: Illustration of the variation in expected patient throughput with respect to change in recovery time for three, four, and five recovery bays.

are insensitive to changes in recovery time as recovery duration decreases relative to the baseline of r = 1.0.

Sensitivity analysis was performed to evaluated the dependency of resource utilization on the recovery factor, r. Changes in utilization of prep bays, procedure rooms, recovery bays, nurses, endo tech, and gastroenterologists were estimated for choices of r=0 to r = 1.0. In general, varying r had a negligible effect on all resources with the exception of recovery bays. The effect on recovery bay utilization is roughly linear increasing in r with a minimum of 0 for r=0 and 80% for r = 1.0. Total patient time in the system, from check-in to discharge, was also evaluated; a linear improvement equivalent to the shortened recovery time was observed, as expected.

DISCUSSION

Utilization of endoscopy procedures continues to increase in the U.S. As a preferred method for colorectal cancer screening, colonoscopy has become the most common endoscopic procedure performed in U.S. gastroenterology practices [4]. Despite this increasing trend, about half of Americans aged 50 or over have not been screened [5]. As further preventative health measures are promoted, the utilization of colonoscopies in the U.S. is likely to rise. However, it is unclear whether there is sufficient capacity to support increases in screening demand without creating significant waiting times for the unscreened population[6]. Therefore, identifying changes to current endoscopy practice settings that add efficiency, and increase the number of patients that can be screened with the same level of resources, is increasingly important.

Figure 2 Caption: Mean patient waiting times for prep bays, procedure rooms, and recovery bays, for varying recovery time estimates.

Simulation modeling provides the opportunity to test hypothetical policy changes or scenarios and limits experimentation in the practice setting, which can be time consuming and expensive. Policy changes could include resource and staff allocations, patient arrival schedules, or process flow adjustments. Comparisons of different scenarios can then be made based on performance measures that are important in measuring efficiency. In this paper, we used a simulation model to evaluate the effects of using propofol as a sedation agent for patients undergoing a colonoscopy within an endoscopy suite setting. The primary performance measure was patient throughput; patient waiting time and resource utilization were also considered.

Identifying bottlenecks is an important step in improving efficiency and endoscopy suite performance. Recovery is an important bottleneck, because it is the final step prior to discharge. If patients are slow to recover, they back up to the earlier steps in the process including prep and the procedure. Thus, recovery is an intuitive process on which to focus improvement efforts. Because propofol has been shown to reduce recovery time and lacks a clear practice pattern, it is sensible to model the use of this agent[7].

Our results show that the use of propofol can lead to an increase in the effective capacity of an endoscopy suite as measured by percentage gain of mean patient throughput per day. Comparing an estimate from the literature to our baseline case, we found mean patient throughput increased 9.1% per day. An increase of 21% was observed when recovery capacity was constrained (three bays instead of four) relative to the baseline.

Increases in throughput occurred without adversely affecting other performance measures such as mean patient waiting time and resource utilization. Changes in resource utilization with respect to changes in recovery time were small, with the exception of recovery bed utilization which increased linearly as recovery time increased.

The present analysis has certain limitations. For simplicity, we assumed only colonoscopies were performed in the endoscopy suite. However, in practice a mix of other procedures may be performed and results may vary depending on the specific mix of procedures. Additionally, patient arrivals observed in practice may differ due to the occurrence of no-shows which were not considered in this study. Sources of additional cost, such as the need to staff a Certified Registered Nurse Anesthetist and anesthesiologist, and additional gains in efficiency, such as a decrease in time to sedation, were not accounted for in the model. The particular implementation of a change in sedation agent could influence the yield further benefit in terms of lowering resource utilizations and increasing patient throughput.

While costs were not explicitly modeled in this paper, it is reasonable to interpret the results as having the following implications. Although it may cost more to administer propofol, this cost may be defrayed in part by additional capacity gained. In an environment where potential screening demand exceeds capacity, careful consideration should be given to process changes that result in higher capacity. Ultimately, the results of this study will inform decision makers about the estimated operational gains in patient throughput from using propofol.

CONCLUSIONS

Patient throughput increased by 9.1% per day relative to the baseline as a result of using propofol. Sensitivity analysis indicates that improving recovery time has little effect on resource utilization and wait times other than recovery bays. The number of available recovery bays influences the total benefit of reducing recovery time. Thus, the reduction in recovery time could translate to lower physical space requirements or nurse coverage requirements in place of greater patient throughput.

Additional factors influencing the use of propofol, such as availability of an anesthesia provider, may influence the decision to use propofol. The results of this study will help determine the operational benefits that may help defray these higher costs.

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