Estimating the Cost of No-Shows and Evaluating the Effects of Mitigation Strategies

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Objective. *To measure the cost of nonattendance ("no-shows") and benefit of overbooking and interventions to reduce no-shows for an outpatient endoscopy suite.* **Methods**. *We used a discrete-event simulation model to determine improved overbooking scheduling policies and examine the effect of no-shows on procedure utilization and expected net gain, defined as the difference in expected revenue based on Centers for Medicare & Medicaid Services reimbursement rates and variable costs based on the sum of patient waiting time and provider and staff overtime. No-show rates were estimated from historical attendance (18% on average, with a sensitivity range of 12%–24%). We then evaluated the effectiveness of scheduling additional patients and the effect of no-show reduction interventions on the expected net gain.* **Results**. *The base schedule booked 24 patients per day. The daily expected net gain with perfect attendance is $4433.32. The daily loss attributed to the base case no-show rate of 18% is $725.42 (16.4% of net gain), ranging from $472.14 to $1019.29 (10.7%–23.0% of net gain). Implementing no-show interventions reduced net loss by $166.61 to $463.09 (3.8%–10.5% of net gain). The overbooking policy of 9 additional patients per day resulted in no loss in expected net gain when compared with the reference scenario.* **Conclusions**. *No-shows can significantly decrease the expected net gain of outpatient procedure centers. Overbooking can help mitigate the impact of no-shows on a suite's expected net gain and has a lower expected cost of implementation to the provider than intervention strategies.* **Key words**: *efficiency; discrete event simulation; operations research; gastroenterology; colorectal cancer.* **(Med Decis Making XXXX;XX:xx–xx)**

Endoscopy suites employ expensive human and physical resources that have high fixed costs. As a result, providers must carefully consider the number of cases scheduled per day. Unfortunately, patient attendance is uncertain. Patients may fail to attend their appointments (no-show) without prior notice, resulting in wasted capacity and a lost provider revenue opportunity. No-shows also include patients who cancel appointments on short notice (e.g., <24 hours). This equates to a no-show since a minimum time threshold is required for patients to prepare for the procedure, yielding short notice rescheduling impractical. No-shows are prevalent in outpatient endoscopy suites, causing underutilization of expensive personnel and equipment, as well as decreased revenue. As a result, the occurrence of no-shows effectively increases the endoscopy cost, which may create a patient access barrier.

Endoscopy suite no-show rates have been reported to range from 12% to 24%[1–5] and occur for a variety of

reasons such as illness on the day of the procedure,[1,2,4,6] procedure anxiety,[1,2,4] improved symptoms,[1,2] and forgetting the appointment.[2,4,6] Patients are also more likely to no-show when they have to wait longer from the time the appointment is scheduled until the time the procedure occurs.[2,4,7]

Several interventions offer providers the ability to lower no-show rates. These include telephone reminders, SMS (Short Message Service), and preassessment appointments. These no-show intervention strategies have been reported to produce relative reductions in the no-show rate of 75%, 39%, and 35%, respectively.[1,5,7] In a review of 29 studies reporting intervention results for telephone reminders, SMS, and automated phone calls, the weighted (adjusting for study quality) mean relative reduction in the no-show rate was 34%.[8] In addition, new interventions such as interactive voice response systems are continually being evaluated.[9] Although such methods show decreases in no-show rates, they can be costly to implement and are not completely effective; thus, uncertainty in patient attendance often persists.

In addition to changing patient no-show behavior directly, endoscopy suites can also mitigate the no-show effects by scheduling additional patients (i.e., overbooking). Similar methods have been employed by hotels, car rental agencies, and airlines.[10,11] However, those service industries are quite different because they have established recourse options for situations in which too many customers arrive for service. For example, they may reward customers who opt out of service or outsource business to another competitor. Overbooking methods have also been examined in outpatient clinic settings.[12–14] However, for outpatient procedure centers, such as endoscopy suites, applying overbooking methods is problematic due to longer process durations, multiple stages of duration uncertainty (intake, procedure, recovery), and the coordination of many expensive resources (procedure rooms, endoscopists, recovery beds). It is neither feasible nor appropriate to deny service for a patient who has prepared for a procedure as a result of overbooking. Furthermore, it is important to include patient waiting time costs because waiting or rescheduling can cause significant patient dissatisfaction. Therefore, the benefit of seeing more patients must be weighed against the risk of increased patient waiting time and staff overtime.

We used a discrete-event simulation model to evaluate alternatives for mitigating the effect of no-shows. Simulation models have been applied to many problems related to health care delivery, including endoscopy suites,[15] surgical suites,[16–20] primary care clinics,[21,22] a pediatric emergency department,[23] and other settings.[24] Simulation models provide a means to test hypothetical policy changes or scenarios and limit experimentation in the practice setting, which can be time-consuming and expensive. Comparisons of different scenarios can then be made based on performance measures that are important in measuring efficiency.

METHODS

Our discrete-event simulation model is based on an outpatient endoscopy suite affiliated with a large academic medical center. The cost of no-shows was quantified by analyzing the difference in net gain due to the presence of no-shows compared with a perfect attendance reference scenario. We define *net gain* as the difference between the revenue gain from seeing each patient and the costs associated with managing the endoscopy suite. The effects of no-show interventions as well as overbooking are evaluated using this net gain definition.

Model

Our simulation model was designed by a group of systems engineers working in conjunction with several content experts from the University of North Carolina (UNC) School of Medicine and UNC Health Care System, Chapel Hill, North Carolina. The group developed a conceptual model of process flow through on-site visits, meetings, e-mail, and weekly conference calls. Periodic review of the model was performed throughout the model development as part of the validation process.

Patient Flow

In a typical day, the off-campus facility uses 4 procedure rooms, 2 gastroenterologists, 4 intake bays, 4 recovery bays, 1 intake nurse, 4 procedure nurses, 2 float nurses, 1 recovery nurse, and 4 endoscopy technicians. The model was based on 3 major process areas: an intake process involving the patient changing and preparation for the endoscopy, a procedure process involving sedation and procedure, and a recovery process:

Intake. Patients check in and wait in a lobby until called back by the intake nurse or an endoscopy technician. The patient changes in 1 of 3 changing rooms and goes to 1 of 4 intake bays. Once in the

Table 1 Patient Arrival Schedules for Overbooking 4 and 5 Patients

Number Overbooked	All at 8 AM	Early Morning	Morning	All Day
4	8:00, 8:00, 8:00, 8:00	8:00, 8:40, 9:20, 10:00	8:00, 9:20, 10:40, 12:00	8:00, 10:00, 12:00, 2:00
5	8:00, 8:00, 8:00, 8:00,8:00	8:00, 8:30, 9:00, 9:30, 10:00	8:00, 9:00, 10:00, 11:00, 12:00	8:00, 9:30, 11:00, 12:30, 2:00

intake bay, the intake nurse reviews the patient's medical history and checks vital signs. There is 1 nurse designated for intake and 2 float nurses who may help with intake.

Procedure. Once intake is complete, the patient is transferred to a procedure room. The patient's procedure is reviewed, and sedation medication is administered. Each procedure requires 1 procedure room, 1 endoscopy technician, 1 registered nurse, and 1 provider to perform the endoscopy. Once the procedure is complete, the patient is transferred to recovery and room turnover begins.

Recovery. One recovery nurse is designated to cover 4 patients. Once the patient is awake and recovered, the physician reviews the case with the patient. The patient is then discharged.

A scheduling process defines the time of patient arrivals throughout the day. This process reflects the probabilistic no-show patient behavior. Each scheduled patient passes through this decision process and has a probability of failing to attend the appointment. If a patient fails to attend, he or she is tallied as a no-show and exits the model; otherwise, the patient will continue to pass through the endoscopy process of the model.

The number of patients scheduled was increased iteratively, starting with 1, to determine the number that maximized the net gain for the perfect attendance reference scenario. The iterative process was terminated when the expected net gain began to decrease, with respect to the previous iteration.

Overbooking

Overbooking involves booking additional patients relative to the base case schedule currently in use at the observed facility. The existing policy is as follows: 2 patients arrive at 8:00 AM. Following the initial arrival, 2 patients arrive at a time with interarrival times alternating between 30 and 40 minutes. The last 2 arrivals of the day occur at 2:20 PM.

Four overbooking scheduling scenarios were compared. These scenarios were generated based on previous research and heuristics found in the outpatient appointment scheduling literature.[25] The 4 scenarios presented were chosen to represent a wide variety of overbooking schedules. The first schedules all overbooked patients at 8:00 AM. The second equally spreads overbooked patients between 8:00 AM and 10:00 AM. The third equally spreads overbooked patients between 8:00 AM and 12:00 PM. The fourth schedule equally spreads overbooked patients between 8:00 AM and 2:00 PM. As arbitrary examples, Table 1 illustrates the cases of overbooking 4 and 5 patients for the 4 scenarios.

Data

Historical time data were collected from 1 July 2009 to 11 September 2009, resulting in 1184 observations. The data were extracted from ProVation RN (ProVation Medical, Minneapolis, MN), a third-party software package, which recorded times for major steps during the colonoscopy process. In addition, a time study was performed on 2 separate days to determine turnover times for both intake and procedure rooms. Historical data were used to evaluate the facility no-show rate. Nurses collected 84 samples of the daily no-show rate from July to November 2009. The average daily no-show rate during this period was 18%.

Simulation Model

The discrete-event simulation model was built using Arena 12.0 (Rockford Automation, Wexford, PA).[26] The model consisted of intake, procedure room, and recovery modules, with each having a first-come-first-serve queue discipline. Resources included intake bays, procedure rooms, recovery bays, endoscopists, nurses, and endoscopy technicians. A schematic of the processes included in the simulation model is illustrated in Figure 1.

The probability distributions for intake, procedure review, sedation, 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 that were collected using ProVation RN. Room turnover time, which was not collected in ProVation RN, was
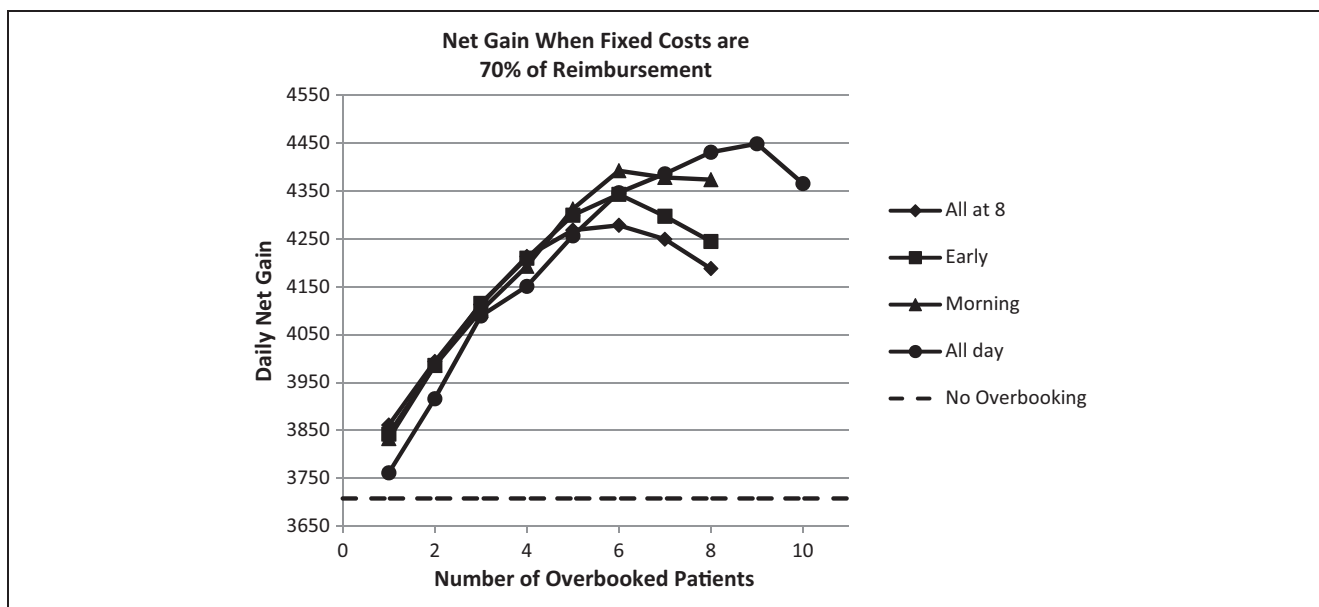
Figure 1   The expected net gain is presented for the baseline scenario (18% no-show rate) where fixed costs are assumed to consume 70% of reimbursements.

Table 2   Process Duration Means, Standard Deviations, and Distributions in the Model Fit Using Arena 12.0 Input Analyzer

Model Process	Duration Mean, min	Standard Deviation, min	Probability Distribution
Prep	17.12	5.39	6.5 + LOGN(11.5, 9.4)
Procedure review	23.07	8.63	8 + BETA(1.14, 1.28)
Sedation	12.49	4.26	5 + GAMM(3.12, 2.41)
Procedure	21.80	10.26	8 + LOGN(14.1, 11.5)
Recovery	50.47	14.55	22 + LOGN(29, 17.4)
Room turnover	2.41	1.28	NORM(2.42, 1.28)

The distributions included shifted lognormal (LOGN), uniform (UNIF), shifted beta (BETA), shifted gamma (GAMM), and a truncated normal (NORM).

measured as the time the patient left the procedure room until the room was ready for the next procedure. Probability distributions were fit using visual fit and square error terms. Descriptive statistics and distribution information are provided in Table 2.

To simplify the analysis, it was assumed that the only procedures performed were colonoscopies. The simulation model also assumes that 2 endoscopists shared the 4 procedure rooms. This is consistent with the current practice and also reported to be an efficient configuration.[15] Finally, certain processes such as scope cleaning and endoscopist dictation were not included in the simulation model since neither was a bottleneck in the system (procedures never waited for clean scope and room turnover was always longer than endoscopist dictation).

Net Gain

Three major costs were used to define the net gain from the colonoscopy procedures: operating costs, overtime costs, and patient waiting time costs. Consistent with a previous study, fixed operating costs were assumed to be 70% of the colonoscopy reimbursement.[27] Fixed operating costs include capital investment, equipment costs, and staffing costs. These are fixed costs that are not affected by appointment scheduling decisions and are therefore not included in evaluating the overbooking strategy performance. The variable costs associated with the overbooking and scheduling decisions, however, are included in the overbooking strategy evaluation. The cost for patient waiting time was $18.62 per

hour, based on the 2005 national average wage rate.[28] Patient waiting time costs are included since we considered the societal perspective of the overbooking decisions. The waiting cost was multiplied by 2 to account for the companion who must accompany the patient due to the sedation used in the procedure. Reimbursement for a colonoscopy was obtained from Centers for Medicare & Medicaid Services published rates and is estimated at $671.52.[27] Overtime costs for the facility are assumed to be $12.37 per minute based on an expert opinion estimate for a surgery practice.[29] Overtime was measured relative to an 8.5-hour workday. Net gain is defined as expected reimbursements minus each of the costs, where n is the number of patients screened during the day:

$$\text{Net Gain} = 0.3 \times \text{Reimbursement} \times n$$
$$- \text{Overtime Costs} - \text{Patient Wait Costs} \times 2.$$

Validation

The simulation model was validated in multiple ways. First, the model was validated through code review by multiple authors, each with extensive familiarity with the modeling software. Second, results were reviewed with experts at a departmental meeting, including the nurse administrator, nurses, and gastroenterologists. The consensus was that the results were reasonable and consistent with past experience and expectations. Third, total time in the endoscopy suite, estimated using the model, was compared with observed times recorded in ProVation RN. Intake times in ProVation RN that were less than 10 minutes were eliminated and regarded as data entry errors because experts indicated a minimum time of 10 minutes for intake. Other data were examined, and unreasonable times, indicating likely data entry error, were not found. The mean (95% confidence interval [CI]) expected time in the system for colonoscopy patients according to ProVation RN was 138.8 (135.5, 142.1) minutes. The mean time estimated using the simulation model was 136.5 (135.6, 137.4) minutes.

Finally, simulation results were examined for extreme scenarios. For example, results were obtained for evaluating the system when only a single patient is scheduled. This resulted in an expected system time of 126.33 (124.24, 128.42) minutes with zero patient waiting time, which is consistent with the sum of the individual process means, 124.95 minutes. Other scenarios evaluated include varying the time for recovery and evaluating the resulting system and waiting times; all behaved as expected.

Table 3 Expected Net Gains for Scheduling 23, 24, and 25 Patients Where a 0% No-Show Rate Is Assumed as a Reference Scenario

Number Scheduled	Expected Net Gain	95% Confidence Interval
23	$4364.44	$4340.28, $4388.59
24	$4433.32	$4406.33, $4460.31
25	$4339.27	$4308.09, $4370.44

RESULTS

Table 3 illustrates that net gain peaks with 24 patients scheduled under the perfect attendance scenario. All estimates were based on 500 samples (days), which provides sufficient precision for an expected net gain point estimate error of approximately less than 1%.

The baseline scenario assumed a no-show rate of 18%. The difference in the expected net gain between the reference and baseline scenarios was $725.42, corresponding to a 16.4% reduction in net revenue. The net gain as well as overtime and wait time can be found for both scenarios in Table 4.

Sensitivity Analysis

Sensitivity analysis was performed on the no-show rate. Expected net gain was calculated to reflect the range of no-show rates for endoscopy suites found in the literature ranging from 12% to 24%. The expected daily loss increases as the no-show rate increases. However, the percent loss is not equal to the no-show rate. This is in part attributed to the manner in which overtime is incurred. For example, although the loss in expected revenue corresponds to the no-show rate (since it is proportional to the decrease in the expected number of patients attending), Table 4 shows that the expected overtime and patient waiting time for the no-show rates of 12% and 24% are very close to those of a no-show rate of 18% in Table 4. Thus, the change in expected costs differs from the change in expected revenue with respect to varying no-show rates.

Overbooking

Overbooking patients throughout the day increases the expected net gain by as much as $741.04 (20.0%) over the baseline scenario (18% no-show rate). Figure 1 shows the effect that overbooking has on expected net gain when 70% of

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Table 4 Sensitivity of the No-Show Rate on Expected Net Gain with 24 Patients Scheduled in Each Scenario

No-Show Rate, %	Expected Number of Patients Attending	Expected Net Gain	Expected Overtime, h	Expected Patient Wait Time, min	Expected Daily Loss
0	24	$4433.32	0.41	6.66	—
12	21.07	$3961.18	0.32	3.65	$472.14 (10.7%)
18	19.57	$3707.90	0.27	2.90	$725.42 (16.4%)
24	18.08	$3414.03	0.27	2.45	$1019.29 (23.0%)

The reference scenario (0% no-show rate) and the baseline scenario (18% no-show rate) are included.

Table 5 Sensitivity Analysis on the Estimate of the Endoscopy Suite's Fixed Costs Relative to Reimbursements

% Fixed Costs	Best Number of Patients to Schedule	Best Overbooking Schedule	Expected Net Gain
70	9	All day	$4448.94
80	6	Morning	$2737.74
90	3	Early	$1158.13

reimbursements are consumed by fixed costs, as previously described. Of the 4 candidate schedules, the overbooking schedule that worked best for the baseline scenario is the ''All Day'' schedule that equally spreads 9 overbooked patients throughout the day. Although the 4 candidate schedules are not exhaustive in their representation, they are intended to represent a diverse range of potential overbooking schedules.

When the estimate for fixed costs as a percentage of the reimbursements increases to 80% and 90%, the number of patients by which to overbook decreases, as shown in Table 5. Furthermore, the best-performing overbooking schedule also changes when fixed-costs estimates increase. The schedules that overbook patients earlier in the day (Early and Morning) result in the highest expected net gains.

The best number of patients to overbook differed based on how overbooked patients are scheduled to arrive during the day. For example, if overbooked patients were only scheduled during the morning, then it was best to overbook 6 patients. However, if overbooked patients were scheduled throughout the entire day, overbooking by 9 patients resulted in the highest expected net gain. This can be explained in part by the early part of the day becoming saturated with arrivals and patient waiting time quickly accumulating. If overbooked patients are spread throughout the day, lower expected patient wait times are incurred.

As illustrated in Table 6, the expected net gain from overbooking 9 patients scheduled throughout the day is not different from the expected net gain in the reference scenario with no overbooked patients. In other words, the best-performing overbooking policy for a no-show rate of 18% is no different in expected net gain than having a no-show rate of 0% with no overbooking.

When overbooking is used when the no-show rate is low, similar results show that the number of patients by which to overbook depends on how the overbooked patients are scheduled to arrive. Figure 2 illustrates this result with the number of patients to overbook being based on the scheduling policy providing the highest expected net gain. With a 5% no-show rate, overbooking by 4 patients and scheduling them to arrive throughout the morning results in the highest expected net gain.

It is important to note that the studied endoscopy suite had 2 procedure rooms for each endoscopist. Thus, based on the low turnover times, it is unlikely that room turnover or scope cleaning would be a bottleneck in the system. However, in other practices, it may be the case that turnover times are much higher or there is only a single procedure room for each endoscopist. The implications of the procedure room turnover being a bottleneck are a lower number of patients by which to overbook. For example, when the mean room turnover times are increased by factors of 5 and 10, the resulting number of patients by which to overbook is 5 and 3, respectively, when the overbooked patients are spread throughout the day. In other words, the number of patients by which to overbook is sensitive to the room turnover time and

Table 6 Reference Scenario (0% No-Show Rate) v. Overbooking 9 Patients with a No-Show Rate of 18%

No-Show Rate, %	Number Overbooked	Expected Number of Patients Attending	Expected Net Gain (95% CI)	Expected Overtime, h	Expected Patient Wait Time, min
0	0	24	$4433.32 (4406.33, 4460.31)	0.32	6.66
18	9	26.976	$4448.94 (4408.59, 4489.29)	0.83	21.23

CI, confidence interval.

decreases as the turnover time increases. Each procedure requires additional procedure room time, and as a result, additional procedures scheduled later in the day are completed using overtime.

Intervention Strategies

Various no-show intervention strategies have been reported to reduce no-shows with varying success rates, including telephone reminders, SMS, and pre-assessment appointments. The lower and upper bounds of the intervention relative to no-show reductions were 34.5% and 75.5% based on reductions reported in the literature for endoscopy settings.[1,5] In the context of the practice we studied, such reductions would translate to no-show rates of 11.79% and 4.41%, respectively. The results of those no-show rates, presented in Table 7, are based on scheduling 24 patients using the baseline arrival schedule.

DISCUSSION

The net loss due to no-shows at the modeled facility was 16.4% ($725.42) per day. No-show intervention strategies were evaluated and were found to reduce the loss attributed to no-shows to between 3.8% ($167.38) and 10.5% ($464.27). In other words, the expected net gains resulting from intervention strategies recoup between 36.0% ($261.15) and 76.9% ($558.04) of the loss attributed to no-shows. The overbooking policy with 9 overbooked patients resulted in a minimal difference in expected net gain when compared with the reference scenario (0% no-show rate). However, the number of patients to overbook decreases as fixed costs increase. Furthermore, with higher estimates of fixed costs relative to reimbursements, the results show that overbooking earlier in the day is better. These estimates can be used to help justify implementing an intervention method(s) that will drive down no-show rates. Furthermore, the findings indicate that overbooking is a very effective measure for increasing performance at an endoscopy suite.

No-show behavior is a challenging problem with a negative chain reaction. The financial loss due to no-shows can be significant to practices such as the endoscopy suite we studied. As a result, no-shows increase the cost of each procedure performed. Through improved scheduling methods resulting in better efficiency, there are opportunities to mitigate such financial losses. As a result, overbooking methods and no-show intervention strategies have potential to reduce costs and the price of endoscopies and thus improve access. However, in the current system, any improvement in efficiency is likely to be realized in increased profits for the practice.

Overbooking methods have been examined in previous research in the scheduling literature.[12–14] LaGanga and Lawrence[12] proposed a utility model and used discrete-event simulation to show that overbooking can be an appropriate method in certain cases such as high patient throughput, high no-show rates, and low service duration variability. Muthuraman and Lawley[13] used queuing methods in their overbooking model with patient attendance uncertainty in which appointment decisions are made dynamically as patient requests occur. Their work was extended by Zeng and others[14] to include heterogeneous no-show probabilities that vary based on patient attributes. Although important insights about overbooking in outpatient clinics were developed in these works, they also include assumptions that are restrictive to a general outpatient procedure setting such as endoscopy suites, including deterministic service times, single server systems, or exponentially distributed service times.

Overbooking has also been considered within the context of endoscopy suites.[6] In contrast with the previous analysis by Sonnenberg,[6] our study concludes that overbooking policies can achieve the same expected net gain that would be realized if all patients attended their appointments. In his research, Sonnenberg uses the binomial distribution to analyze no-show rates and states that the benefit gained from overbooking will increase as no-show rates increase and as the number of endoscopy slots available increases. In addition, he finds that the relative
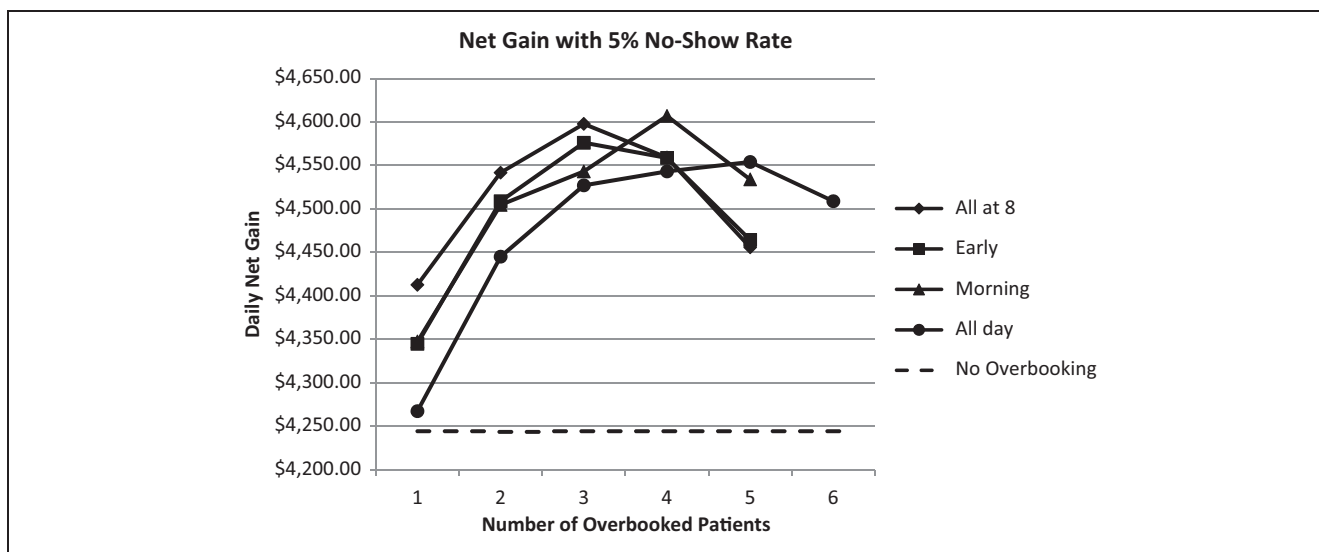
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Figure 2   The expected net gain is presented for when the no-show rate is 5%.

Table 7   Expected Net Gain over the Range of No-Show Rates Resulting from Implementing No-Show Intervention Strategies in the Baseline Scenario (18% No-Show Rate)

No-Show Rate, %	Expected Number of Patients Attending	Expected Net Gain (95% CI)	Expected Overtime, h	Expected Patient Wait Time, min	Expected Daily Loss
4.41	22.94	$4265.94 (4237.44, 4294.44)	0.37	5.37	$167.38 (3.8%)
11.79	21.15	$3969.05 (3936.46, 4001.64)	0.33	3.75	$464.27 (10.5%)

CI, confidence interval.

loss associated with overbooking increases as no-show rates increase and as the number of available endoscopy slots decreases. However, he concludes that overbooking is not able to completely recoup the loss attributed to no-shows.

Our study differs in the following ways. First, we used a validated discrete-event simulation model to evaluate the effects of no-shows on the endoscopy suite. This allowed us to include multiple stages (intake, procedure, recovery) and multiple resources (providers, procedure rooms, nurses) in our model as opposed to analyzing a single provider alone without considering the impact of patient flow in stages both up- and downstream. Since uncertainty is inherent in many aspects of the system, this modeling approach provided a method to accurately include the complexity of the endoscopy suite in our model. Second, Sonnenberg[6] measured the costs of overbooking as a ratio of the endoscopy suite's benefit. In contrast, we modeled expected revenue from reimbursements and expected costs using estimates for fixed facility costs, patient wait time, and overtime. Finally, we

modeled the uncertainty in process durations using historical data. This allowed us to include patient waiting and overtime directly in our cost estimates as compared with using the number of appointment slots and cost/benefit ratio estimates.

Thus, by avoiding closed-form analyses based on a single provider, our simulation model allowed us to more explicitly model the effects of no-shows on the endoscopy suite we studied with a greater level of fidelity. Although we conclude that overbooking can achieve more significant gains than has been previously reported for endoscopy suites, we affirm that overbooking can be a low-cost and easily implemented strategy for mitigating the effects of no-shows.

The relative no-show rate reductions reported for various intervention strategies were evaluated and were found to recoup some of the loss attributed to no-shows. For example, the expected daily loss attributed to no-shows was reduced from 16.4% ($725.42) to a range of 3.8% to 10.5% ($167.38–$464.27) through intervention strategy implementation. However,

based on our results, no intervention strategy was found to completely mitigate the loss in net gain. Furthermore, depending on a practice's infrastructure, such strategies may be costly. Overbooking policies, on the other hand, were demonstrated to completely recoup the financial loss attributed to no-shows. The performance of an overbooking policy, however, is sensitive to how overbooked patients are scheduled to arrive throughout the day. Thus, although implementing an overbooking schedule in addition to a no-show intervention is a possible course of action, overbooking alone can provide the same expected net gain results.

Impact on Indirect Waiting

Implementing overbooking schedules will also result in decreased *indirect* waiting time, or the time a patient waits between when an appointment is requested and when the procedure is actually scheduled. To evaluate overbooking's effect on indirect waiting, we introduce a simple queuing model. In queuing theory, Little's law can be used to describe the relationship between the average number of customers waiting for service, L; the average time spent waiting for service, W; and the average service rate, λ.[28] Little's law states that $L = \lambda W$. Under the current scheduling practice where 24 patients are 'scheduled per day, patients typically wait 8 weeks for a requested appointment. Thus, $L = \lambda W = 24$ patients/d $\times$ 40 days = 960 patients waiting for their appointment at any given time. However, if $\lambda' = 33$ is based on the best overbooking scheduling rule and the same number of patients continues to request appointments, then $W' = L/\lambda = 960/33 = 29.09$ days. Thus, through overbooking, the indirect waiting time can be reduced by over 25%. Therefore, the potential effects of overbooking can be extended to settings with no-shows where patient access is a challenge due to high demand and low resource levels.

Limitations

Study limitations include using a single endoscopy unit, as well as cost structure assumptions, as the basis for our model. The effectiveness of no-show mitigation strategies will certainly depend on the structure of a particular practice. Along with this modeling limitation is the use of a small time study along with expert opinion for estimates where data could not be abstracted from electronic sources, such as procedure turnover times. Regarding the cost structure, we further assume that resource levels are fixed at their present state. However, incorporating planning decisions about resource levels over time, as well as their impact on overbooking decisions, is an important future research direction. Second, this study does not consider certain nonmonetary costs such as dissatisfaction associated with overtime. For example, although employees may tolerate a small amount of overtime in return for higher compensation, their tolerance will likely decrease as overtime continues to accrue. This would suggest that a nonlinear overtime cost estimate, where the overtime hourly wage increases for higher overtime hours, may be more appropriate and should be considered a direction for future work. Third, we did not discuss the low-probability case in which all of the patients attend when overbooking. Although the probability of this scenario is certainly low (1 in 1000 days when 33 patients are scheduled), provider fatigue is a challenge that should be considered. Fourth, our analysis assumed a homogeneous case mix of colonoscopy procedures. Since different procedures have different duration distributions, the case mix would likely affect the overbooking decision. Defining the optimal case mix remains an open question. Fifth, overbooking in endoscopy suites is likely to differ from other outpatient settings, such as primary care, in that patient visit frequency is comparatively low (every 3–10 years). Thus, patients are unlikely to modify their arrival habits based on their understanding of the booking practice being used. Although this may not necessarily be a valid assumption in other outpatient settings, it is an interesting direction for future research. Finally, overbooking serves as a helpful tool for the provider and management to increase practice efficiency. However, overbooking does not help individual patients who do not receive requisite care because of nonattendance. For the purpose of providing care to the patients likely to no-show, other intervention strategies should be continually evaluated.

CONCLUSIONS

In this article, we used a discrete-event simulation model based on an outpatient endoscopy suite to measure the cost of no-shows and evaluate the effects of mitigation strategies as well as overbooking policies. In summary, the financial loss attributed to no-shows can be very high based on reported no-show rates for the practice we studied and those in the literature and can significantly decrease the expected net gain of outpatient procedure centers. No-show

interventions reduce the no-show rate but can be costly, are challenging to implement, and do not resolve the problem entirely. Overbooking can help mitigate the impact of no-shows on a suite's expected net gain and has a lower expected cost of implementation to the provider.

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