Optimizing Efficiency and Operations at a Large California Safety-Net Endoscopy Center: A Modeling and Simulation Approach

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Abstract Improvements in endoscopy center efficiency, especially in safety net hospitals, are needed, but scant data are available. A time and motion study was performed and a discrete simulation model constructed to assess changes in scheduling, staffing models, and the pre- and post-procedure process and its impact on several performance measures in a safety net hospital endoscopy center. Using discrete simulation modeling a number of changes to the endoscopy center were assessed. Decreasing the endoscopy appointment time from 60 to 45 minutes led to a 21% rise in the number of procedures performed per week, but unfortunately increased patient wait time by 42% while further reductions in appointment times led to even more significant queuing. However, increasing the number of pre-procedure nurses from 1.5 to 2 resulted in a 22% increase in the number of procedures performed per week and increased provider, nurse and procedure room utilization with minimal impact on patient wait time. Further increases in nurse staffing resulted in no significant changes to measured outcomes. Increasing the number of endoscopists by one each half day resulted in procedure volume rising, but there was a concomitant rise in patient wait time and nurse utilization exceeding capacity. A significant improvement in performance metrics was created by moving patient appointments from afternoon to morning appointments. In this simulation at 45 and 40 minute appointments procedure volume rose by 23% and 34% respectively, all utilization metrics increased and patient time spent in the endoscopy center declined by 17% and 13%. Thus the combination of minor, cost-effective changes such as reducing appointment times, minimizing and standardizing recovery time, and making small increases in pre-procedure ancillary staff maximized endoscopy center efficiency across a number
of performance metrics. The simulation made it possible to identify which changes were desirable and to what extent.

1 Introduction

1.1 Background

There has been a dramatic rise in the request for gastrointestinal (GI) specialty care, and in particular endoscopic services, over the last decade. At the same time, access to GI care in the safety net healthcare system is limited. Such disparity highlights the need for creative and innovative ways to increase access to GI care for underserved patient populations. A method to address this inequality is to develop more efficient endoscopy centers that can provide increased endoscopic services while at the same time maximize patient and provider satisfaction.

There is a dearth of information on the study of efficiency in endoscopy centers. Of the scant literature available there are varying conclusions about how to improve endoscopy center efficiency with no clear consistent message. Some studies have focused on altering staffing specifically focusing on the endoscopist [1, 5, 14] and utilizing more staff in the pre-procedure process [5]. While such changes improve physician efficiency and utilization, it does so at impairing non-physician staff utilization, sub-optimizing facility utilization and increasing patient length of stay [14]. Using simulation modeling others have discovered that identifying bottlenecks in patient recovery [3, 13], reducing room turnover time [6], modifying the patient arrival schedule [1, 7, 11] or reengineering the scheduling of patients [12, ?] can improve efficiency and decrease patient time in the endoscopy center. However, there are a number of limitations to these studies; they are small, examine efficiency solely from a physician perspective, and all are set in either an ambulatory endoscopy center or tertiary referral service. Given these deficiencies and with changes to the U.S. healthcare system, with more underserved patients being cared for, it is imperative to better understand safety net endoscopy centers and to improve efficiency within them.

1.2 Objectives

Our objective was to conduct a time and motion study of clinic work and use this data in simulation modeling to study changes in scheduling, staffing models, facility changes and changes in the pre- and post-procedure process in a safety net hospital endoscopy center. The simulation objective was to understand the bottlenecks limiting the endoscopy centers current operational performance and, in turn, to identify
opportunities to improve patient throughput while balancing resource utilization and patient wait times.

2 Methods

2.1 Study Design, Setting and Population

We conducted a time and motion study of the San Francisco General Hospital and Trauma Center (SFGH) endoscopy center and performed discrete simulation modeling to assess proposed changes to the endoscopy center with respect to specific performance and efficiency metrics. The study was conducted between November 2011 and May 2012. The SFGH endoscopy center provides subspecialty care for the safety net healthcare system of the City and County of San Francisco.

The SFGH endoscopy center performs colonoscopies and upper endoscopies as well as other advanced procedures in an ethnically diverse patient population. The majority of the endoscopy centers time is devoted to performing colonoscopy and upper endoscopies (EGD) (89.0% of procedure volume) with a no show rate of 17.7%. SFGH is a teaching hospital for the University of California, San Francisco medical school that has three GI fellows and one surgical resident rotating through the GI Division each month.

2.2 Time and Motion Study

Prior to constructing a discrete event simulation model, multiple days of direct time observations and interviews were conducted to identify patient flow, key parameters and process attributes. Time was spent shadowing physicians, nurses, and support staff at the endoscopy center in order to develop an understanding of the work flow.

2.2.1 SFGH Endoscopy Center Workflow

The SFGH endoscopy center has four distinct workflow processes: check-in, pre-procedure, procedure and recovery. A patients visit begins at check-in after which patients move to a waiting room where they remain until called to the pre-procedure room. Patients complete the pre-procedure process in a dedicated pre-procedure bed (maximum of 3 beds). In situations where a procedure room is available and no prepared patients are waiting to begin a procedure, pre-procedure activities are conducted in the procedure room. From the pre-procedure process, a patient then moves to a procedure room. At the conclusion of the procedure, patients either recover in the recovery room (maximum 3 beds), or if a recovery bed is unavailable then pa-
tients are kept in the procedure room. Once in the recovery room, patients stay for at least 30 minutes as required by state regulations. Patients are held in the recovery room until a ride home arrives to sign them out.

2.2.2 Data Collection

Observation and timing of the processes was done to provide a statistically significant picture of operations. Arrival times were collected from the hospital’s appointment scheduling system. The pre-procedure process was quantified using a paper form that nurses completed. Procedure data was collected from the time of endoscope insertion and removal, as documented in procedure and nursing notes. Recovery data was collected from time stamps present on discharge paperwork. Observation and use of the SFGH endoscopy centers electronic record keeping system provided 278 patient arrival times, 257 procedure times and 257 recovery times.

2.3 Discrete Simulation Modeling

The discrete event simulation model was programmed using Process Simulator (Process Simulator is a Microsoft Visio add-on software from ProModel Corporation, 556 East Technology Ave., Orem) software based on the diagram shown in Figure 2. The simulation included process times using probability distributions derived from clinic time observations. Patients often arrive before their appointment time and this earliness was also modeled as a probability distribution based on clinic observation. After arrival, the patient goes through a sequence of processes which, if busy, result in a queue of patients waiting. Each process is defined by a process time distribution that was determined through time measurements. The check-in, in room recovery, and recovery time process distributions were represented by a triangular distribution. The process time distributions for the pre-procedure and procedure processes followed a lognormal distribution and varied based on procedure type. The endoscope cleaning process required a discrete amount of time for decontamination and reprocessing. There was a certain probability that a patient did not show up to their scheduled appointment (i.e. no-show). There was also a probability that a patient did not require sedation and could therefore exit the system prior to being routed to the recovery room process step. All probability distributions were checked to assure a high confidence of fit between the modeled distributions and the distributions observed in the clinic.

2.3.1 Outcome Statistics

Various scenarios were run and outcomes measured. The first outcome measured was overall time in the system spent by each patient. The percent of the patients visit
that was spent waiting was tracked to understand how much waiting was occurring due to bottlenecks. Total throughput was also tracked. Resource utilization rates including procedure room utilization, nurse utilization, and provider utilization were all calculated based on use and availability. Utilization was computed as the hours a resource was in use divided by the available hours for the resource.

2.3.2 Validation

Validation included the following to ensure the simulation was accurate:

- Parameters were verified by expert opinion.
- The workflow diagrams logic was verified by the providers.
- An assumptions document was developed and maintained for review by the providers during regular meetings to discuss updates to the model.
- The outcome results were verified with those experienced within the actual system.
- A separate analysis was conducted to ensure that the system was operating properly on Tuesdays, the most tightly scheduled day.
- Simulation animation was inspected by model developers and the providers at the endoscopy center to check that the patients were following the proper flow of events and queuing at various points.

Fig. 1 Process model of the SFGH endoscopy center developed for discrete simulation modeling.
All the parameters and distributions were based on historical data and Minitab was used to determine the distributions from the historical data.

2.3.3 Scenario Development

After validation of the base case model was completed, several scenarios were studied. The primary scenarios included altering the patient appointment schedule from 60 minutes to 45-minute, 40-minute, 35-minute and 30-minute appointment slots and assessing outcomes. For the shorter appointment slot schedules, limited resources were added to avoid extreme amounts of queuing. Also, changes to room availability through the adding of additional resources (i.e. endoscopists and nurses) were assessed.

2.4 Ethical Considerations

Our study was a quality improvement project and no personal health information was collected at any time. Thus formal institutional review was not required per the policy of the University of California San Francisco Committee on Human Research.

3 Results

3.1 Baseline Endoscopy Center Data

Utilizing data from the time and motion study, baseline arrival patterns as well as pre-procedure, procedure and recovery room times were determined. Patients with the latest scheduled appointment times arrived earliest; for example patients with afternoon appointments (after 1PM) arrived 179 minutes earlier for their appointment compared to patients scheduled at 8AM who arrived 28 minutes earlier. Little variation was noted in the pre-procedure time regardless of the planned procedure, although EGD/colonoscopy required more time (31.2 minutes). Very little variation was noted with recovery room time and required 34.6 minutes if recovery occurred in the recovery room. Procedure time itself differed significantly depending on the type of procedure performed with EGD requiring 9.5 minutes, colonoscopy 28.5 minutes and combined procedures requiring 36.4 minutes. The mean number of procedures performed per week was 53.8. Patients spent 2.3 hours at the endoscopy center with 22.3% of that time spent waiting.

In order to determine the optimal scenario(s) that would increase throughput, optimize utilization and minimize patient wait time a series of simulation models were
run (Table 1). Scenarios included revising the endoscopy appointment times and weekly endoscopy schedule, increasing the number of nurses and providers, standardizing recovering room time and subsequently a combination of these scenarios.

### 3.2 Revision of Endoscopy Schedule

The first scenario examined a revised endoscopy schedule using shorter appointment times. When appointment time was decreased to 45 minutes (from 60 minutes) there was a 20.9% rise in the number of procedures performed/week with both patient time in the endoscopy center increasing to 3.2 hours and percentage of time waiting rising to 41.2%. Additionally, there was a rise in overall utilization with the greatest rise noted in procedure room utilization. At shorter appointment times of 40 and 35 minutes the model was not sustainable without additional resources to serve patients; at these times there was queuing of patients in the pre-procedure area as the

| Table 1 Changes simulated with the endoscopy center model, mean and 95% confidence interval |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
|                                | Procedures performed/week      | Patient time in endoscopy center (hours) | Provider utilization (%)       | Nurse utilization (%)       | Procedure room utilization (%) | Wait time (%) |
| Baseline                       | 55.8 (50.5-61.6)               | 2.3 (2.2-2.5)                           | 24.6 (23.9-25.3)               | 40.0 (37.9-42.0)               | 29.6 (27.1-32.5)               | 22.3 (19.8-24.6)               |
| Reducing endoscopy center appointment times |
| 45 minutes                     | 66.0 (60.8-69.2)               | 3.2 (2.8-3.6)                           | 28.9 (27.1-30.6)               | 40.0 (36.5-43.4)               | 55.8 (53.8-57.7)               | 37.9 (32.5-43.7)               |
| 40 minutes                     | 65.6 (60.3-69.7)               | 2.8 (2.6-2.9)                           | 27.1 (24.8-29.4)               | 46.6 (43.3-47.9)               | 60.2 (55.9-64.5)               | 21.8 (18.7-24.8)               |
| 35 minutes                     | 75.4 (73.6-77.3)               | 3.3 (3.1-3.6)                           | 30.6 (28.2-32.5)               | 52.9 (50.4-55.4)               | 73.9 (71.7-76.2)               | 41.3 (38.1-43.5)               |
| Modifying endoscopy center weekly schedule |
| 60 minutes                     | 55.9 (50.5-61.6)               | 2.4 (2.3-2.5)                           | 23.3 (21.3-25.4)               | 49.9 (46.4-53.4)               | 62.5 (58.4-66.5)               | 31.8 (28.1-36.6)               |
| 45 minutes                     | 65.6 (60.3-69.7)               | 2.8 (2.6-2.9)                           | 27.1 (24.8-29.4)               | 46.6 (43.3-47.9)               | 60.2 (55.9-64.5)               | 33.1 (30.1-37.2)               |
| 35 minutes                     | 75.4 (73.6-77.3)               | 3.3 (3.1-3.6)                           | 30.6 (28.2-32.5)               | 52.9 (50.4-55.4)               | 73.9 (71.7-76.2)               | 41.3 (38.1-43.5)               |
| 40 minutes                     | 65.6 (60.3-69.7)               | 2.8 (2.6-2.9)                           | 27.1 (24.8-29.4)               | 46.6 (43.3-47.9)               | 60.2 (55.9-64.5)               | 33.1 (30.1-37.2)               |
| 35 minutes                     | 75.4 (73.6-77.3)               | 3.3 (3.1-3.6)                           | 30.6 (28.2-32.5)               | 52.9 (50.4-55.4)               | 73.9 (71.7-76.2)               | 41.3 (38.1-43.5)               |

| Expanding Human Resources |
|----------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Increase in pre-procedure nurse, 5 |
| 65.4 (54.3-76.5)           | 2.4 (2.2-2.6)                 | 30.3 (28.3-32.3)               | 65.6 (46.0-127.2)              | 65.7 (58.0-85.4)               | 22.4 (18.4-26.4)               |
| Increase in endoscopy to each half-day of endoscopy |
| 60 minutes                  | 70.9 (67.7-74.1)              | 2.3 (2.1-2.6)                 | 24.9 (22.8-27.5)               | 169.9 (158.2-181.7)            | 58.2 (52.7-63.9)               | 21.0 (18.2-23.8)               |
| 45 minutes                  | 87.6 (83.1-91.5)              | 3.0 (2.6-3.4)                 | 30.5 (27.5-32.9)               | 217.9 (199.1-235.4)            | 65.5 (61.1-69.8)               | 34.9 (31.1-40.7)               |
| 35 minutes                  | 91.9 (89.3-94.5)              | 3.9 (3.7-4.2)                 | 32.8 (31.1-34.5)               | 250.7 (218.4-282.0)            | 70.6 (68.3-73.3)               | 49.2 (45.2-53.1)               |
| Minimizing recovery room time |
| No recovery in procedure room 6 |
| 68.1 (58.5-79.3)           | 2.6 (2.4-3.2)                 | 29.5 (26.6-32.3)               | 42.5 (39.9-45.0)               | 49.6 (46.5-52.7)               | 35.0 (29.0-41.0)               |
| 30 minute recovery 8        | 67.4 (58.6-79.4)              | 2.7 (2.5-3.2)                 | 28.7 (25.6-30.9)               | 38.9 (37.2-40.6)               | 45.3 (43.1-47.5)               | 35.4 (30.8-40.0)               |

1 Simulation not feasible as a significant number of patients did not have their procedures completed at the end of the day.
2 Simulation not feasible as appointment times were close to mean procedure times.
3 Shuffling one afternoon half-day of endoscopy from Friday to a Wednesday morning session.
4 Appointment time of 45 minutes.
day progressed to the point where a significant number of patients would not have had their procedures performed by the end of the day. If the appointment was decreased further to 30 minutes the simulation was not feasible since the appointment time was nearly identical to the procedure times and a queue built up infinitely. An additional change was to the overall weekly schedule. Given that patients preferred earlier appointment times and the endoscopy center had been closed on Wednesdays - a half day of endoscopy appointments was moved from Friday afternoon to Wednesday morning. This change (compared to baseline) meant volume slightly increased to 55.7 procedures/week and procedure room utilization rose. Moreover, we found that when appointment times were shortened under this scenario to 45 and 40 minute intervals there was a steady rise in procedures performed/week (an almost one-third increase) as well as improved procedure room and nursing utilization. However, these changes did so at a cost of increasing the number of hours a patient spent in the endoscopy center and increased patient wait time by 32.6% and 46.0% respectively when compared to baseline.

### 3.3 Human Resources Expansion

The next area explored was to improve endoscopy center operational efficiency by adding human resources. The number of staff dedicated to the pre-procedure area was modeled to determine if such changes improved efficiency. The addition of 0.5 nurses to the pre-procedure area (from 1.5 to 2) resulted in no significant differences in outcomes when compared to baseline data. Yet, by increasing the number of pre-procedure nurses to 2 with an appointment time of 45 minutes resulted in a 21.3% increase in the number of procedures performed per week, rises in provider (20.8%), nurse (39.0%) and procedure room (19.3%) utilization, with minimal impact on patient wait time. There was no significant change in performance outcomes with more than 2 nurses in the pre-procedure area.

The number of providers that performed endoscopic procedures during the week was also varied; one additional endoscopist was added to each half-day of endoscopy. With appointment time held constant, procedure volume increased by 23.1% but it did so at a cost of increasing nursing utilization beyond capacity to over 100%. The results were similar if appointment times were lowered less than 60 minutes.

### 3.4 Minimizing Recovery Room Time

The next simulation examined minimizing patient time in the recovery room. Two simulations were tested: 1) limiting recovery room time to 30 minutes (minimum required by state regulations) and 2) not allowing patients to recover in a procedure room. In either simulation at 60 minute appointment times there were no signif-
significant differences with respect to outcomes when compared to baseline data. But when limiting recovery room time and changing the appointment time to 45 minutes, procedure volume increased to 67.6 procedures/week, but wait time increased by 13.1%. Similar results occurred in the model when patients were only allowed to recover in the recovery room.

### 3.5 Simultaneous Changes Incorporated into Endoscopy Center Models

Using the insight learned from above, a number of scenarios were examined with multiple changes tested (Table 2). Simultaneous changes included reducing appointment time to 45 minutes, increasing the number of pre-procedure nurses, minimizing recovery room time and expanding the hours of the endoscope re-processor to increase equipment usage (in order to make shorter appointment times feasible). The first endoscopy center scenario (appointment time of 45 minutes, 2 pre-procedure nurses, recovery room time of 30 minutes, and extending the endoscope re-processors day by 30 minutes) resulted in a 21.6% increase in procedures performed per week, 17.4%, drop in the patients time in the endoscopy center, and no significant change in patient wait time. A second endoscopy center scenario incorporated the same changes except appointment time was lowered to 40 minutes and endoscope reprocessing hours were extended by 1 hour. There was a steep rise in procedure volume, further reduction of patient time in the center and wait times remained unchanged.

The above changes were then combined with a half-day of Friday afternoon endoscopy appointments moved to Wednesday morning. In this scenario the number of procedures performed rose significantly in conjunction with provider, nursing and procedure room utilization improving, and patient time in the endoscopy center decreasing. For example, in simulations at 45 and 40 minute appointment times procedure volume rose by 23.4% and 34.2%, and patient time spent in the endoscopy center declined by 17.4% and 13.0% respectively.

Finally, the same changes were also incorporated into a scenario whereby one additional provider was made available on each half day of endoscopy. Again, procedure volume markedly increased by 39.6% and 46.7% for simulations at 45 and 40 minute appointment times with overall provider utilization increasing to its highest levels. However, nursing utilization exceeded capacity in both of these simulations. Furthermore, as appointment times were shortened patient wait time steadily increased to where patients spent nearly a third of their time in the endoscopy center waiting.
Table 2  Scenarios modeled and the resulting performance, mean and 95% confidence interval

<table>
<thead>
<tr>
<th>Endoscopy center simulations</th>
<th>Procedures performed/week</th>
<th>Patient time in endoscopy center (hours)</th>
<th>Provider utilization (%)</th>
<th>Nurse utilization (%)</th>
<th>Procedures room utilization (%)</th>
<th>Wait time (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endoscopy Center (baseline)</td>
<td>55.8 (51.0-56.6)</td>
<td>2.3 (2.2-2.5)</td>
<td>24.0 (21.9-25.5)</td>
<td>40.0 (37.8-42.0)</td>
<td>49.8 (47.1-52.5)</td>
<td>22.3 (18.9-24.6)</td>
</tr>
<tr>
<td>Endoscopy Center 1^1</td>
<td>68.6 (66.2-70.9)</td>
<td>1.9 (1.8-2.0)</td>
<td>30.1 (27.4-32.7)</td>
<td>69.9 (68.5-71.5)</td>
<td>51.2 (47.1-55.2)</td>
<td>21.7 (17.6-25.6)</td>
</tr>
<tr>
<td>Endoscopy Center 2^2</td>
<td>78.0 (76.4-79.6)</td>
<td>2.1 (2.0-2.3)</td>
<td>34.5 (32.5-36.6)</td>
<td>47.4 (44.8-50.0)</td>
<td>56.4 (53.2-59.6)</td>
<td>25.2 (22.4-28.0)</td>
</tr>
<tr>
<td>Endoscopy Center 3^3</td>
<td>79.2 (78.7-79.8)</td>
<td>1.9 (1.8-2.0)</td>
<td>29.6 (27.3-32.2)</td>
<td>41.9 (39.3-44.6)</td>
<td>61.9 (58.8-65.1)</td>
<td>18.2 (15.6-20.8)</td>
</tr>
<tr>
<td>Endoscopy Center 4^4</td>
<td>81.8 (80.5-83.0)</td>
<td>2.0 (1.9-2.1)</td>
<td>35.3 (32.5-38.2)</td>
<td>49.6 (47.4-51.8)</td>
<td>71.0 (67.4-74.7)</td>
<td>22.7 (19.7-25.8)</td>
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<td>2.1 (1.9-2.2)</td>
<td>32.5 (29.5-35.4)</td>
<td>15.8 (10.6-18.5)</td>
<td>55.9 (52.7-59.1)</td>
<td>25.3 (22.7-27.9)</td>
</tr>
<tr>
<td>Endoscopy Center 6^6</td>
<td>101.9 (98.9-104.2)</td>
<td>2.3 (2.2-2.7)</td>
<td>38.4 (33.3-39.4)</td>
<td>20.9 (19.0-21.8)</td>
<td>62.1 (58.5-65.2)</td>
<td>33.1 (27.3-34.7)</td>
</tr>
</tbody>
</table>

^1Endoscopy center 1: Appointment time of 45 minutes, 2 pre-procedure nurses, recovery time of 30 minutes, recovery only in recovery room, and endoscopy recovery hours extended to 4:00PM.
^2Endoscopy center 2: Appointment time of 45 minutes, 2 pre-procedure nurses, recovery time of 30 minutes, recovery only in recovery room, and endoscopy recovery hours extended to 5:00PM.
^3Endoscopy center 3: Friday PM appointments moved to Wednesday AM, appointment time of 45 minutes, 2 pre-procedure nurses, recovery time of 30 minutes, recovery only in recovery room, and endoscopy recovery hours extended to 5:00PM.
^4Endoscopy center 4: Friday PM appointments moved to Tuesday AM, appointment time of 45 minutes, 2 pre-procedure nurses, recovery time of 30 minutes, recovery only in recovery room, and endoscopy recovery hours extended to 4:00PM.
^5Endoscopy center 5: One additional endoscopist added to each half day of endoscopy, appointment time of 45 minutes, 2 pre-procedure nurses, recovery time of 30 minutes, recovery only in recovery room, and endoscopy recovery hours extended to 4:00PM.
^6Endoscopy center 6: One additional endoscopist added to each half day of endoscopy, appointment time of 45 minutes, 2 pre-procedure nurses, recovery time of 30 minutes, recovery only in recovery room, and endoscopy recovery hours extended to 5:00PM.

4 Discussion

Through observation and a time and motion study we found that a large, diverse safety net hospital endoscopy center has weekly operational patterns, although variable, that are consistent and predictable. Our simulation model provides insight into operational changes that are beneficial. We found that patient throughput as well as provider and nursing utilization are sustainably increased with only simple changes such as decreasing endoscopy appointment times (to a point), realigning the endoscopy schedule with patient preferences and minimizing the recovery room and pre-procedure processes. Additional improvements in throughput are possible but only with adding costly human resources, over utilizing nurses and having unacceptable wait times.

Our study is not the first to conduct a time and motion study or employ simulation modeling in the endoscopy center; however there is sparse and disparate literature on this topic. Some studies have used only a qualitative approach [15], conducted solely a time and motion study [5], incorporated only one endoscopic procedure in their models [1] or limited their simulations to just one component of the endoscopy center process [6]. In addition, these studies are limited by their setting in that all of them examined large tertiary hospitals or a private setting or included endoscopy centers outside of the U.S. Our study has strengths compared to the available literature in that we examined multiple processes and procedures in the endoscopy center, utilized multiple scenarios that quantitatively studied their impact on a number of critical outcomes in an endoscopy center and we are the first to use such methods to
examine efficiency and change in a large safety net hospital system. We involved all clinical staff in developing and testing changes while other studies generally utilized GI data and worked on it separately from providers and staff.

Similar to other studies, our study highlights the importance of two key areas in the endoscopy center: pre-procedure and recovery room processes. With respect to the pre-procedure process, no clear evidence exists on how to improve this process with only scant expert opinions available [8, 12]. A number of factors influence this process including obtaining vitals, placing intravenous catheters, completing paperwork, patient changing, and in some cases the use of interpreting services. The majority of these tasks center on nursing/medical assistant roles [5] and in most cases these tasks are fixed and difficult to streamline. Previous work in the operating room has realized this challenge and some work has demonstrated that parallel processing of tasks among staff members can lead to a dramatic reduction in operating room pre-procedure and room turnover time [2, 10]. In this same light, we modeled an increase in the pre-procedure personnel in order to utilize this strategy of parallel processing which to date has not been modeled in endoscopy centers. We noted an increase in procedure volume by 14.6 procedures/week (mean increase of 730 procedures/year) while at the same time significantly improving nursing, provider and room utilization and maintaining patient wait time constant. Other potential improvements in the pre-procedure process, but difficult to model, may focus on patient education for patient preparedness, prior communication with patients who do not speak English, and education programs aimed at improving the pre-procedure process for staff.

Another vital step in improving endoscopy center efficiency is the recovery room; specifically limiting recovery room time increases efficiency. Grossman modeled an ambulatory surgery center and demonstrated that recovery room time was the main bottleneck. In fact, a 50% reduction in recovery room time increased the number of patients per room per day and shortened the overall length of stay for patients. Similarly, in our study by limiting recovery to the recovery room (which reduces procedure room turnover time) and limiting recovery time to 30 minutes (a reduction of 13.3%) we observed an increase of 14.3 procedures/week with no harm to overall patient wait time. However, there is no clear method on how to address or improve this bottleneck. Aside from increasing the physical space of the recovery room (which is quite costly in a resource limited environment) the only specific intervention proposed to reduce this time has been sedation related. The use of Propofol or only using one sedating medication compared with two medications has been demonstrated to help not only reduce sedation time, but overall recovery time as well [9]. Further research on strategies aimed at improving the endoscopy recovery process is warranted.

Lastly, unlike previous work, our simulations/changes did not solely focus on maximizing the efficiency of endoscopists. Of the limited work on this topic, all studies have focused on two key outcomes: increasing patient throughput and improving physician efficiency. However, only focusing on physician efficiency doesn’t translate into overall efficiency for the endoscopy center. Rex et al clearly illustrated this concept by showing that increasing patients served and physician utilization
did so at a cost of the endoscopy center being sub-optimized with increased patient length of stays and decreased non-physician staff utilization [?]. Our model echoed this point whereby in several scenarios adding an endoscopist did increase patient volume but did so at a detriment to overutilization of the nursing staff, increased patient time in the endoscopy center, and increased patient wait time (ranging from a third to almost half of a patients visit). Also, adding additional endoscopists is a costly option (mean salary of $321,575/year) especially in resource limited areas such as public hospitals. On the other hand, personnel such as nursing, medical assistants, or extending endoscope re-processors hours, which can impact processes before and after a procedure, are far less costly and in our simulations not only provided improvements in volume and provider efficiency but did so in a more balanced approach.

5 Limitations

Our study setting occurred in a safety net hospital and may not be generalizable to other endoscopy centers. However, our model has much strength in that it demonstrates that with only small changes to resource assignments one can dramatically improve patient volume and other performance metrics and can be done so in a cost-effective manner. Also, by using time and motion studies and building a simulation model of an endoscopy center one can evaluate potential changes with a tool not currently being used in GI services. Lastly, we did not model other possible, but more complex changes, such as assessing the impact of same day bowel preparation which may increase the desirability of afternoon appointments, scheduling complex procedures at the end of the day as is done in surgery [?], scheduling a mix of procedures that vary by time throughout the day, or evaluating the impact of changes to arrival earliness as occurred in our patient population.

6 Conclusions

Through observation of the workflow and analysis of the results of a simulation model we illustrate that weekly patient flow patterns are predictable and the simulation provides insight into what changes are feasible and how they are beneficial to an endoscopy center. Relatively straight forward changes such as reducing appointment times, standardizing recovery room time and slightly increasing ancillary staff in the pre-procedure area significantly improves endoscopy center efficiency without substantially increasing costs nor changing procedure times. By balancing pre and post procedure capacity a continuous work flow is created and patient waiting is reduced. Thus, more patients can be seen a critical need at safety net providers. More costly changes such as increasing the number of endoscopists can improve procedure volume but this may result in overutilization of other resources.
and increase waiting for patients. Overall, we discovered that a better understanding of patient flow responses to changes using a simulation model can be used to develop cost effective solutions. Thus, we recommend the use of this modeling tool to increase the capacity of GI patient services, particularly in a safety net setting.

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References