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Improving Ambulatory Surgery Throughput Using SMED Approach

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Abstract

Access to timely endoscopic screening procedures is a critical challenge in ambulatory surgical centers (ASCs), particularly when demand exceeds system capacity. This study examines a throughput improvement initiative conducted in an ambulatory surgical center focused exclusively on endoscopy procedures, where a backlog of more than 1,100 patients had accumulated, limiting access to care. The center's design capacity was constrained to approximately 12 procedural cycles per shift, with room changeover time identified as the primary bottleneck resource. Using a resource-oriented bottleneck analysis combined with Lean methodologies, the intervention targeted the reduction of non-value-added time during room turnover. Single-Minute Exchange of Die (SMED) principles were applied through standardized work, appropriate allocation of staff and equipment to specific tasks, and takt time optimization. As a result of these interventions, process takt time was reduced by 25%, enabling a 33% increase in the number of patients treated per shift without additional rooms and more than 350% return on investment. The findings demonstrate that systematic bottleneck management and standardized changeover processes can substantially improve throughput and access to care in ambulatory endoscopy settings. This approach provides a scalable, resource-efficient framework for addressing procedural backlogs in similar healthcare environments.

Keywords
Lean, SMED, Flow, VSM, Healthcare

1. Introduction
Timely access to preventive endoscopic screening is a cornerstone of effective colorectal cancer prevention and early detection. Colonoscopy and related endoscopic procedures enable the identification and removal of precancerous lesions. Colorectal screening reduces disease incidence and mortality when performed at appropriate intervals. In an article titled "*An Update on Cancer Deaths in the United States*" published in 2022 by the Center for Disease Control and Prevention (CDC), a statistical analysis is presenting the decline of cancer death rate by 27% in the years between 1999 and 2020. Nonetheless, the same article is showing that colon and rectum cancer is the second leading cause of death due to cancer since the past two decades (CDC, 2022).

In 2021, the US Preventive Services Task Force published their report and recommendations to change the minimum age for screening colonoscopy from 55 to 45 years of age (Davidson, 2021). With the change in age interval, we anticipate increasing demand on access to inpatient and outpatient colonoscopy procedures. This change in policy puts increasing pressure on the existing healthcare delivery systems to improve their patient access by increasing healthcare systems capacity and to increase existing resource throughput.

This study comes in a critical time to focus on improving throughput and resource utilization. Endoscopic procedures, including both upper and lower endoscopy, are relatively standardized and highly repeatable. Because these procedures are performed in a sequential, process-oriented manner, reducing procedure time or minimizing non-value-added downtime can have a significant impact on overall throughput within the delivery system. My hypothesis was that investments in process redesign using Lean methodologies, coupled with staff training on pull-system principles, are likely to yield substantial increases in system throughput.

The setting for this study was an ambulatory surgery center (ASC) with two procedure rooms dedicated exclusively to endoscopic procedures. The ASC is part of an outpatient medical group located in northwest Washington State. The center is staffed by five proceduralists who perform endoscopic procedures on alternating days each week and provide care in clinic or hospital settings on non-procedural days. The ASC is equipped with a single reception desk staffed by one receptionist, four admission bays, and four recovery (post-procedure) bays. The system is staffed to handle enough.

The average number of procedures performed per room each day was 12, although this varied depending on proceduralist practice style, patient no-show rates, staffing levels, and the availability of anesthesia support. Most procedures were performed using moderate sedation, with anesthesiologist assistance provided on select days each month based on patient acuity and clinical need. This daily average was also constrained by a schedule of fixed appointment slots, with one patient scheduled every 40 minutes for each proceduralist. This tempo effectively set the pace of the whole system, so that even small reductions in delays or process improvements did not increase the total number of procedures performed.

1.1 Objectives

The objective of this study was to improve system throughput of an ambulatory surgical center (ASC) using Lean methodology, namely Value Steam Mapping (VSM), Single Minute Exchange of the Die (SMED), Theory of Constraints (ToC), and ergonomic principles. The ASC is part of a medical group practice located in Washington State. The growing population in the region coupled with the increased demand for routine colorectal screening, put this center under a lot of pressure to keep up with demand. This pressure led the practice to increase its capacity by adding more providers and yet, lead time for patient access was growing to triple digits. This called for a system level analysis of the manner the procedures were organized and executed. Benchmarking with the national average led to the conclusion that the throughput of each procedure room could be improved by 15%. The goal of this study was to improve patient throughput by 15%.

2. Literature Review

Applying Lean principles in healthcare has been proven to be fertile area research with numerous studies demonstrating improvements in operational efficiency, increased patient throughput, and better control of increasing healthcare cost. Our study focused on procedure room activities and patient time across the pre-procedure, intra-procedure, and post-procedure phases. In a study by Kidambi et al. (2024) that focused on reducing the patient's overall visit duration (total time in the facility) and turnover time in an outpatient surgical center, they concluded that applying Lean improvements using Plan-Do-Check-Act (PDSA) resulted in statistically significant improvements and in waiting room time (13.1 minutes vs. 25.6 minutes, $p<0.001$), and "Total facility time" (172.5 minutes vs. vs. 196.1 minutes, $p<0.001$). This proved to us that the room changeover time can be improved from an average of 24.8 minutes in our case. The Lean methodology published by Kidambi et al. (2024) consisted of three parts. 1) The process mapping and data collection, 2) gathering input from the team and analyzing the process, and 3) the implementation Lean principles: to apply various Lean ideas to improve flow and resource utilization, and the reduce waiting time.
In another study by Fang et al. (2014) investigated whether Lean methods could improve efficiency in a gastrointestinal endoscopy unit by reducing the time between one procedure ending and the next one beginning (room changeover time). They aimed to reduce room turnover time by 20% by conducting root cause analysis (RCA), standard work, and checklists. They claim that turnover time decreased significantly, from 28.5 minutes to 21.5

minutes, a ~24.6% reduction. Additionally, the average procedures performed per day increased from about 6.2 to 7.9. Fang et al. provided a more structured method for analyzing and applying Lean ideas to achieve their goals. In our case, we needed to achieve a stricter target to ensure that we can meet our intended takt time.

A very practical Lean application, borrowed from manufacturing, to reduce the room changeover time would be a technique called single minute exchange of die (SMDE) originally published by (Shingo, 1985). This Lean technique was utilized by Amati, et al., (2022) to reduce the hospital operating room (OR) changeover time (measured from when one surgery ends to when the next begins), which represents non-value-added time that limits OR capacity and overall throughput. Their method included observing workflow, identifying sources of waste and variability, proposing, and implementing improvements. They achieved their goal of 25% reduction in changeover time. A key insight from this study was the importance of appropriately scoping the improvement effort and accurately mapping the sequence of changeover process steps. While the authors did not explicitly describe how the analytical focus was narrowed from a macro-level system view to a micro-level process view, they concluded that SMED must be applied at the room changeover level to be effective. This finding reinforces the need for precise bottleneck identification and targeted process redesign when applying Lean methodologies in complex healthcare environments.

Cerfolio et al. (2019) demonstrated that the application of Value Stream Mapping, the "pit crew" concept, and Lean principles can effectively reduce room turnover time, thereby improving procedural efficiency. Similarly, Sanchez et al. (2023) reported a statistically significant 15% reduction in turnaround time through the use of parallel task execution. While both studies emphasize the importance of implementing parallel activities, neither clearly articulates the methodological steps used to narrow the scope of analysis and identify the specific activities targeted for improvement.

3. Methods

A review of the existing literature indicates that methodological details are not always reported with sufficient granularity to fully explain the sequence of improvement activities or the decision logic used to narrow the focus to a specific problem area. In particular, several studies emphasize outcomes of Lean and SMED interventions while providing limited detail on how scope boundaries were defined or how changeover activities and roles were structured to support effective implementation.

In this study, we respond to this limitation by presenting a structured and transparent process for defining the scope of improvement efforts in procedural healthcare settings. Specifically, we outline a systematic method for identifying the appropriate level of focus at which process redesign yields the greatest impact on throughput. Furthermore, rather than treating SMED as a standalone technique, we frame it as an integrated approach that guides both *when* and *how* changeover improvements should be pursued in conjunction with complementary methodologies such as Value Stream Mapping (VSM) and the Theory of Constraints (ToC). This integrated perspective is intended to enhance the transferability, reproducibility, and practical applicability of SMED-based interventions across similar clinical environments.

This study began with a broad analysis of clinic workflow using VSM. The VSM provided a comprehensive view of all process steps and their relationship to takt time required to meet current patient demand. Through this analysis, the procedure area was identified as a potential bottleneck in patient flow, highlighting an opportunity for targeted improvement. Subsequently, the study focused on reducing turnover time for a single procedure room used by one proceduralist. The scope was on balancing three procedures performed: upper endoscopy, lower endoscopy, or combined upper and lower endoscopy.

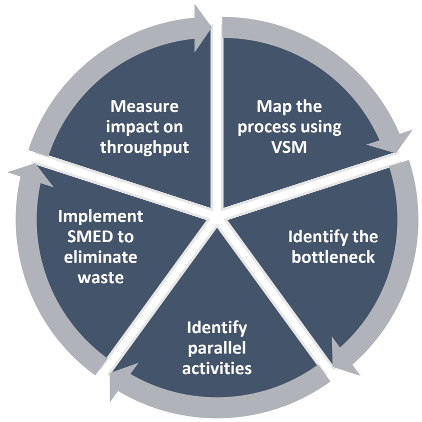

Figure 1. Methodology for reducing the room procedure changeover time.

The overall methodology is illustrated in Figure 1 and can be described as follows:

1. **Map the process using VSM**: Create a comprehensive map of the entire workflow, from patient arrival to discharge, to visualize all process steps and their interrelationships.
2. **Identify the bottleneck**: Apply the Theory of Constraints (ToC) to identify the step(s) that limit throughput by comparing each process step to the takt time required to meet demand.
3. **Identify parallel activities**: Analyze the bottleneck activities to determine which of them can be performed concurrently. Parallel tasks are visualized using a Gantt chart to inform process redesign.
4. **Implement SMED to eliminate the waste**: Break down each activity into the smallest measurable tasks, eliminate non-value-added steps, assign tasks to the appropriate roles or scope of practice, and develop standardized work instructions.
5. **Measure impact on throughput**: Adjust the schedule and refine activities to ensure that each process step remains below the desired takt time and evaluate the resulting effect on overall patient throughput.

4. Data Collection

Data were collected from the ASC's electronic health record system, supplemented by direct observations conducted by the improvement team and structured interviews with members of the procedural staff. Additionally, more quantitative and qualitative data was collected with Gemba walks. According to Womack et al. (2007), Gemba is Japanese term that refers to "the real place where the work is done." Gemba walks helped the analyst with verification of data obtained from the electronic health records and complement data that was incomplete of missing. The dataset included 297 patients treated at the ASC over a three-month period. Data were processed and analyzed using spreadsheets to perform statistical analysis and derive meaningful insights. The results were subsequently modeled using Value Stream Mapping (VSM) and visualized through Gantt charts to evaluate improvement opportunities and inform the selection of implementation strategies.

5. Results and Discussion

This study provided a clear methodology of SMED integrated with other Lean tools to focus the improvement activities on the bottleneck and improve procedure cycle time. The following discuss the results with each step of the proposed methodology.

5.1 Mapping the process using VSM

The VSM, shown in Figure 2, illustrates the pre-Lean patient flow through the ASC, with cycle times indicated below each process step. Although the ASC operates two independently running procedure rooms, only one room was analyzed. Patients are first checked in, followed by a pre-operative phase lasting approximately 25 minutes, which includes patient disrobing, intake assessment, consent, and IV catheter insertion.

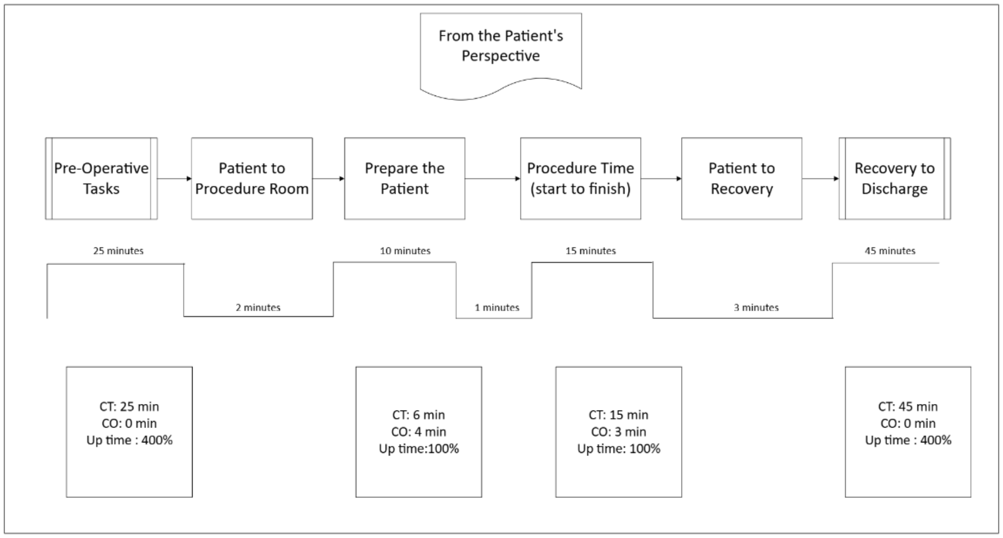

Figure 2. VSP of patient flow through the ASC.

Preparation for the procedure consists of activities performed both in the procedure room prior to the patient's arrival and after the patient enters the room. Post-procedure activities are divided into those occurring while the patient remains in the procedure room and those taking place in the recovery area, from the time the patient wheeled out of the procedure room until the patient is fully recovered and discharged from ASC.

When analyzed from the procedure room's perspective, the total duration was independently measured at approximately 40 minutes*, defined as the interval from when one patient is wheeled into the room until the next patient is wheeled in.* This discrepancy indicates the presence of parallel or non-patient-facing activities occurring within the procedure room that are not reflected in patient-centered cycle times.

5.2 Identify the bottleneck

The process step identified in the previous section represents the system bottleneck and therefore determines the overall pace of patient flow. Under the pre-Lean scheduling model, patients were booked at fixed 40-minute intervals per procedure room, regardless of the proceduralist's pace. For the purposes of analysis, the activities associated with turning over the procedure room between patients were combined with the preparation of the subsequent patient and defined collectively as room changeover time.

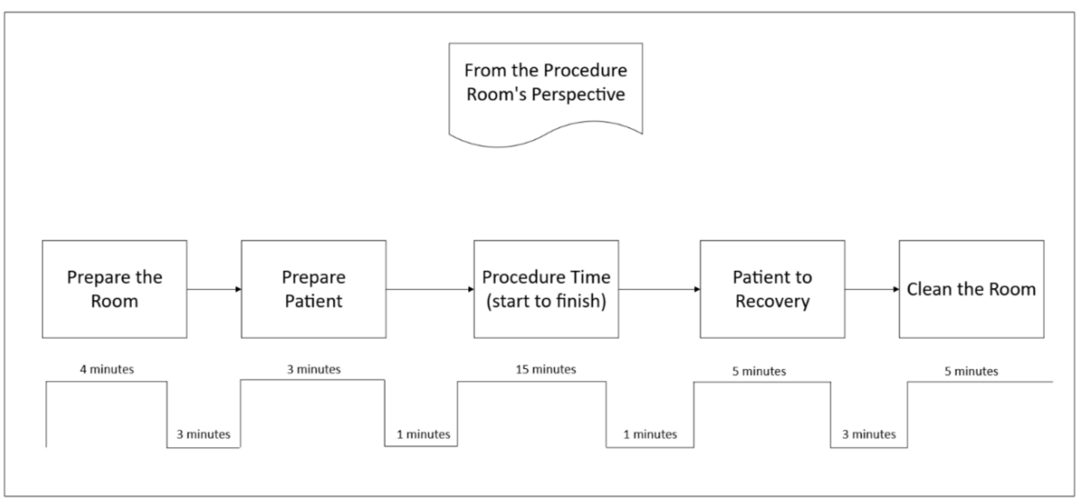

Figure 3. VSP of Procedure Room Cycle (Bottleneck).

The bottleneck identified in this step was analyzed by decomposing it into value-adding (VA) and non-value-adding (NVA) activities. The core value-adding activity within this process is the endoscopic procedure itself, labeled in the VSM as *Procedure Time (start to finish)*. All remaining process steps associated with the bottleneck, as illustrated in the Value Stream Map in Figure 3, were classified as non-value-adding activities. Although these activities are operationally necessary to support care delivery, Lean principles emphasize minimizing, streamlining, or eliminating NVA activities wherever possible in order to improve flow and increase throughput. Identifying opportunities for parallel activities is essential to reducing the cycle time of the bottleneck. This analysis should begin with NVA activities, as these are the primary candidates for parallelization or redesign.

5.3 Identify the parallel activities

Figure 4 illustrates all of the bottleneck NVA activities reorganized in a sequence starting from the end of the procedure of a patient until the start of the procedure of the next patient. This diagram includes all of the activities associated with each process step that can run in parallel and the roles that can perform these activities.

Analysis of the (NVA) room changeover activities shown in Figure 4, along with the tasks listed under each step with their assignment of responsibilities, revealed that these activities were rarely executed in parallel. This inefficiency was primarily driven by a lack of coordination among the nurse, nurse assistant, sterilization technician, and proceduralist. Contributing factors included unclear signaling mechanisms to initiate tasks and the absence of a defined pull system to engage additional resources in support of the room changeover process.

As a result, a more collaborative distribution of activities based on clearly defined roles was identified as essential. The redesigned model therefore focused on enabling parallel execution of tasks wherever feasible, without introducing additional resources beyond what was strictly necessary. A key underlying assumption of the redesigned process was that activities would be initiated promptly and performed back-to-back with high efficiency. Therefore, the introduction of signaling system (a bell that the nurse rings) at the end of each procedure was introduced to trigger the start of the room change over activities.

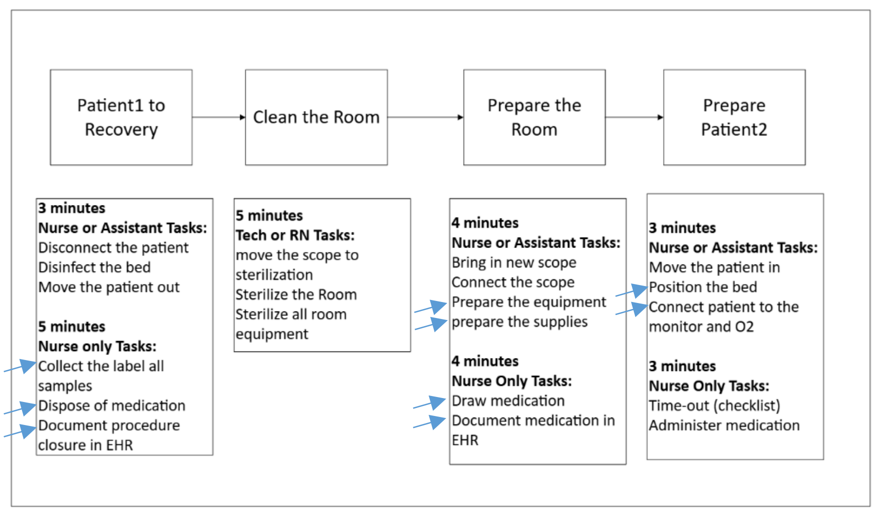

Figure 4. NVA activities in room changeover time

5.4 Implement SMED to eliminate waste

SMED proposes a three-step approach to reducing changeover time: (1) separating internal and external setup activities, (2) converting internal setup activities to external ones where feasible, and (3) streamlining all remaining aspects of the setup operation. Figure 4 illustrates the non–value-adding (NVA) activities associated with the identified bottleneck, reorganized into a sequence initiated by the completion of a patient's procedure. Indicators on selected activities denote tasks that can be performed independently of ongoing work in the procedure room. Representing these activities in a Gantt chart enabled systematic task reassignment by clarifying which activities should be performed, when they should occur, and by whom, based on scope of practice and labor cost considerations. To meet the target takt time of 30 minutes, the required reduction in room changeover time had to be precisely defined. Accordingly, the redesigned sequence limited the duration of changeover activities to 15 minutes. Within existing resource constraints, tasks were redistributed across roles to support parallel execution. The resulting reallocation and sequencing of activities are shown in Figure 5.

The second step of SMED is to convert internal setup activities to external ones where feasible. It is achieved using the approach shown in Figure 5, which illustrates all activities and their durations, enables clear visualization of task reassignment opportunities. The resulting visualization also provides a decision-making framework for leadership to evaluate alternative scenarios, including investments in additional resources, and to assess their associated financial return on investment. In our practice, this diagram continued to be used beyond the scope of this study to support incremental, ongoing improvements.

Similarly, other practices can apply the same methodology and redistribute activities according to their specific operational context to achieve the desired takt time. Because these activities occur at the system bottleneck, any reductions in their duration translate directly into measurable improvements in overall process cycle time.
The third step of SMED is: streamlining all remaining aspects of the setup operation. This step was achieved by implementing the following:

1. Streamlined all activities in the changeover operations to control their duration to the desired takt time.
2. Implemented a standardized call system to alert all required staff at the start of room changeover.
3. Separated changeover activities and assigned roles according to:
   - scope of practice
   - skill requirements
   - labor cost
4. Reallocated work so staff operated at the top of their licensure
5. Improved coordination, reduced idle time, and optimized labor utilization
6. Optimize the schedule with the right procedure mix.

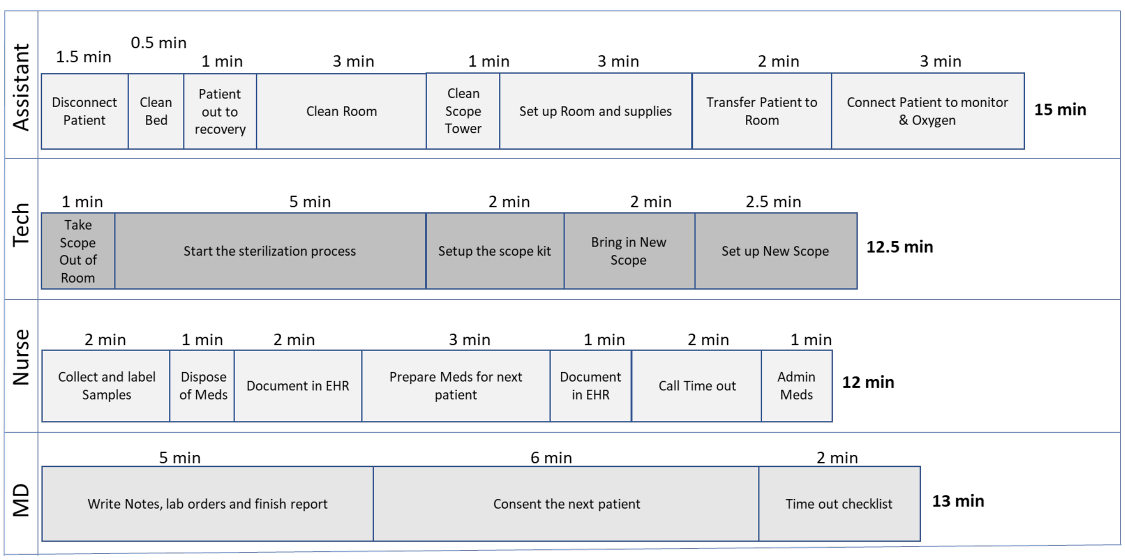

Figure 5. Gantt chart illustrating the parallel activities, average task time, and their proposed assignment.

5.5 Measure impact on throughput

The impact of improvement ideas was measured iteratively as the ASC team implemented each change. Because each modification required education and alignment of team members on the revised processes, improvements were introduced incrementally and tested for feasibility and effectiveness. Concurrently with the implementation of improvement ideas, the patient schedule was redesigned to allow procedures to be performed at 30-minute intervals (30-minute desired takt time). This adjustment increased the design capacity to a maximum of 16 procedures per day, representing a potential 33% improvement over the baseline of 12 procedures per day. The design capacity was not achievable due to resource availability and system efficiency.

However, during the pilot period, the effective capacity reflected a realized improvement of approximately 25%. Achieving higher throughput required greater process stability, including standardized work instructions, additional training, and improved coordination among team members. Over the course of the three-month study period, the team achieved a sustained throughput from 12 procedures per day before Lean ideas to 15 procedures per day, a statistically significant improvement compared to baseline ($p < 0.0001$).

5.6 Broader impact

To validate the sustainability of the improvements achieved, statistical analysis was conducted 12 months after the completion of the project to check the daily average number of procedures completed over 12 months. The result of the validation analysis showed an improvement from 12 procedures to 15.9 procedures or 33% ($p<0.001$) after employing additional resources to help with the room changeover. Direct financial ROI of the additional employed people was 376%. Furthermore, over the same 12 months, the backlog of patients who required access to screening colonoscopies reduced by 40%.

6. Conclusion

This study demonstrates that meaningful and statistically significant improvements in throughput in ambulatory surgical settings can be achieved through a disciplined, system-level application of Lean principles. By integrating VSM with ToC, the study provides a transparent and replicable method for identifying the true operational bottleneck and for narrowing improvement efforts to the process step with the greatest impact on system performance.

Applying SMED as a guiding improvement approach, rather than as an isolated technique, enabled a detailed redesign of procedure room changeover activities. Decomposition of non–value-adding tasks, identification of parallel work opportunities, and redistribution of responsibilities according to scope of practice resulted in a measurable reduction in room occupancy time. During the pilot phase, these process changes supported a reduction in takt time from 40 minutes to 30 minutes and produced a statistically significant throughput increase of approximately 25%, ($p<0.0001$) achieved without adding clinical resources. These findings highlight the extent to which coordination, standard work, and role clarity can unlock latent capacity in procedural environments.

Beyond the pilot phase, the structured visualization of activities and resource interactions served as a decision-support framework for leadership to evaluate targeted investments aimed at sustaining and extending the gains. Over a 12-month period following implementation, the strategic addition of support resources further increased average daily throughput from 12 to 15.9 procedures, representing a 33% improvement, while yielding a direct financial return on investment of 376% and reducing the screening colonoscopy backlog by 40%. This progression illustrates how Lean-based process redesign can inform not only operational improvements but also evidence-based resource allocation decisions.

Although conducted within a single ambulatory surgical center focused on endoscopy procedures, the methodology is broadly applicable to other procedural healthcare settings characterized by high demand and constrained capacity. Future research may extend this work by examining staff workload, patient experience, and replication across multiple sites. Nevertheless, the results suggest that disciplined scope definition, combined with Lean-informed operational and investment decisions, can produce sustained improvements in throughput and patient access to preventive care.

Acknowledgments

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