RESEARCH ARTICLE

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Optimizing Chemotherapy Waiting Time in the Day Care Unit for Gastrointestinal Cancer Patients: A Lean Six Sigma Approach

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Abstract

Background: Delays in chemotherapy waiting in a day care unit (DCU) can lead to heightened patient anxiety, and reduced satisfaction, and unnecessary delays for the staff. **Purpose:** This study aimed to optimize chemotherapy initiation times for cancer patients by addressing inefficiencies and enhancing process reliability. **Methods:** The study was conducted in a DCU at a dedicated cancer center. Patients attending the gastrointestinal cancer program were selected. A pre-and post-one group design was employed to compare metrics before and after the intervention. Implementing the Lean Six Sigma (LSS), principles, and using the DMAIC (Define, Measure, Analyze, Improve, Control) approach, we collected baseline data, identified bottlenecks, and implemented targeted solutions. A multidisciplinary team of nursing staff, physicians, and administrators collaborated on the project. The study was approved by the institutional research and ethics committee. **Results:** Key interventions included the introduction of fast-track and normal-track pathways based on lab readiness, transitioning from round-based to clinic-based evaluations, optimizing patient and staff workflows, standardizing diagnostic processes, and addressing systemic issues such as network outages and resource shortages. The mean time for chemotherapy waiting decreased from 188.4 minutes to 128 minutes, reflecting a substantial improvement in process efficiency. Variability and outliers were notably reduced, as evidenced by improvements in process capability indices. The Process Potential Index (Pp) increased from 0.76 to 0.86, indicating better overall consistency in the process, while the Process Performance Index (Ppk) rose from -0.05 to 0.52, reflecting improved alignment with specification limits and reduced variability. Additionally, the percentage of cases outside the specification limits dropped significantly from 60.6% to 7.3%, demonstrating enhanced process reliability. The Defects Per Million Opportunities (DPMO) decreased dramatically from 606,060.6 to 72,727.3, highlighting a considerable reduction in defects and inefficiencies. **Conclusion:** Implementing LSS principles successfully reduced chemotherapy waiting times and enhanced process efficiency in the DCU. These findings demonstrate the potential of LSS to address systemic inefficiencies and improve patient-centered outcomes in healthcare. Future efforts should focus on expanding these methodologies to other areas and incorporating advanced technologies to sustain improvements.

Keywords: Lean Six Sigma- chemotherapy initiation- gastrointestinal cancer- Day Care Unit- process improvement

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Introduction

Chemotherapy is an integral part of cancer treatment and is usually administered in day care setting. Chemotherapy administration to cancer patients involves multiple interconnected processes. A very important component of chemotherapy administration is patient satisfaction with the treatment procedure, and this is directly related to work efficiency. In the Day Care Unit (DCU), patient volumes, turnover time, and tight schedule require that the processes and managed efficiently, minimizing patient's stay in the DCU [1, 2].

Typically, the DCU visit for the patient and the caregiver entails patient registration, pre-treatment evaluation, laboratory testing for blood works, preparation and verification of chemotherapy drugs in the pharmacy, and treatment administration by trained nurses. Each step in this workflow is dependent on the preceding step, creating a system where inefficiencies at any point can have a ripple effect, leading to cumulative delays. A seamless coordination between receptionists, oncologists, nurses, laboratory personnel, and pharmacists is required. Any disruption in this complex chain of events can result in longer waiting times for patients and caregivers [1, 3]. For example, delays in receiving results from the laboratory or preparation of chemotherapy in the pharmacy, or its delivery to the DCU can result in unnecessary delays, creating dissatisfaction amongst patients [1, 4, 5].

Waiting time to receive chemotherapy is a cornerstone of high-quality cancer care, particularly for patients with gastrointestinal (GI) cancers [1]. These patients often face aggressive disease progression, making timely treatment essential to improve clinical outcomes and enhance survival rates [6]. However, delays in chemotherapy waiting can have significant consequences, including heightened patient anxiety, dissatisfaction, and a sense of helplessness, further compounding the emotional burden of cancer treatment [7-9].

There are multiple reasons for inefficient workflows, such as poorly defined roles and responsibilities leading to duplication of efforts or missed steps, communication gaps between departments, logistical barriers, such as inadequate scheduling systems or limited resources during peak hours [5,7]. All these factors can further compound the problem. These challenges highlight the need for a comprehensive process improvement approach that addresses operational inefficiencies and team dynamics [7-9].

Addressing these issues requires a structured, data-driven approach that identifies the root causes of inefficiencies and implementation of targeted, sustainable solutions (5-7). The principles of such an approach include defining the problem, measuring the current state, analyzing data to identify root causes, implementing solutions, and establishing controls to sustain improvement. By leveraging methodologies that focus on eliminating reasons for inefficient workflows, the timeliness of care delivery in DCU can be optimized. This approach requires the multidisciplinary teams to analyze existing workflows, propose evidence-based interventions, and monitor the impact of changes [7-11].

We report here our results to optimize chemotherapy administration process in a the DCU in a specialized cancer center in the Middle east, using the Lean Six Sigma principles. This study explores applying Lean Six Sigma principles to optimize chemotherapy initiation times for GI cancer patients in a DCU.

Materials and Methods

Setting

The project was conducted at the Sultan Qaboos Comprehensive Cancer Care and Research Center (SQCCCRC), University Medical City in Muscat, Oman. This facility is a leading cancer center, with a dedicated DCU for chemotherapy administration. The DCU consists of 38 chemotherapy chairs and 8 beds. The unit operates between 8Am and 6 PM on weekdays. Most patients receive chemotherapy on chairs. Patients who need longer infusions, elderly or frail patients, and those who may have back pain issues receive their chemotherapy on the beds. The unit receives patients from within and around Muscat, some of whom may have to travel 2-3 hours to receive chemotherapy. Patients with cancers of different organ systems receive chemotherapy on certain days.

Design

A pre-and post-one group design was utilized to evaluate the effects of Lean Six Sigma (LSS) interventions on optimizing chemotherapy administration process times. The details of LSS approach have been published before [7-11]. Briefly, it consists of 5 phases (Define, Measure, Analyze, Improve, Control), known by the acronym DMAIC. The definition phase consisted of acquiring data on patient wait times from arrival at the registration desk to chemotherapy initiation, and patient satisfaction. The measurement phase consisted of collecting data using time tracking logs, direct observations, staff interviews, and a review of patient records. The analysis phase consisted of drawing fishbone diagrams and Pareto analysis to identify contributing factors to delays. The improvement phase consisted of streamlining laboratory result reporting, implementing pre-mixing protocols for chemotherapy drugs, enhancing communication through real-time tracking systems, and cross-training staff to improve flexibility. Pilot testing of these solutions was conducted to ensure feasibility and effectiveness before full-scale implementation. Finally, the control phase consisted of revision of Standard Operating Procedures (SOPs) and the use of monitoring tools such as dashboards to track the delays in real-time (Table 1).

This design facilitated the comparison of key metrics before and after implementing process improvements, providing insights into the effectiveness of the interventions. To reduce variability amongst patient population, and the treating team, patients with gastrointestinal (GI) cancers for chosen for this study.

Sample

Patients included in this study were those receiving chemotherapy for gastrointestinal (GI) cancers in the Day Care Unit (DCU). To minimize variability, we focused

Table 1. Lean Six Sigma Steps (DMAIC Cycle)

DMAIC Phase	Description
Define	The project team identified delays in the chemotherapy initiation process as the primary issue. A problem statement was developed focusing on workflow inefficiencies and their impact on patient waiting times and resource utilization. Key performance indicators (KPIs) included patient wait times from arrival to chemotherapy initiation, staff coordination efficiency, and overall patient satisfaction.
Measure	Data on the current chemotherapy initiation process was collected using time-tracking logs, direct observations, staff interviews, and a review of patient records. Baseline metrics included average patient wait times. These measurements highlighted bottlenecks in various workflow stages, such as lab testing, drug preparation, and communication between departments.
Analyze	Root cause analysis techniques, such as fishbone diagrams, were applied to identify contributing factors to delays. Process mapping revealed inefficiencies in communication, scheduling, and workflow sequencing. Feedback from staff provided qualitative insights into operational challenges, such as resource limitations and unclear role definitions.
Improve	Targeted interventions included streamlining lab result reporting, implementing pre-mixing protocols for chemotherapy drugs, enhancing communication through real-time tracking systems, and cross-training staff to improve flexibility. Pilot testing of these solutions was conducted to ensure feasibility and effectiveness before full-scale implementation.
Control	Standard Operating Procedures (SOPs) were revised to sustain improvements, and monitoring tools such as dashboards were introduced to track real-time KPIs. Regular audits were scheduled, and staff were engaged in feedback sessions to identify emerging issues and ensure continued compliance with optimized workflows.

Source: [7-11]

exclusively on GI cancer patients, ensuring homogeneity in treatment protocols and clinical workflows. Patients receiving chemotherapy for other malignancies were excluded from the study. The sample size was determined based on an expected reduction in chemotherapy waiting time of at least 30 minutes, with a standard deviation of 40 minutes from previous internal audits. Using a power of 80% and an alpha of 0.05, the minimum required sample size was calculated to be 85 patients. We recruited 87 patients to account for potential missing data or dropouts. The calculation was performed using a standard two-tailed paired t-test formula for pre- and post-intervention comparisons.

Data Analysis

The data analysis followed a structured approach to evaluate the effectiveness of Lean Six Sigma (LSS) interventions in reducing chemotherapy waiting times in the Day Care Unit (DCU). Descriptive statistics were used to calculate mean, standard deviation, and variability in chemotherapy initiation times before and after the intervention. Process capability analysis was conducted by measuring the Process Potential Index (Pp), Process Performance Index (Ppk), and Defects Per Million Opportunities (DPMO) to assess process efficiency and variability. A t-test was used to determine statistical significance in the reduction of waiting times. Control charts (IMR charts) were applied to monitor process stability over time. Root cause analysis was performed using fishbone diagrams and Pareto analysis to identify key inefficiencies contributing to delays. Additionally, thematic analysis of qualitative staff feedback provided insights into workflow improvements. All statistical analyses were performed using Minitab and Microsoft Excel to ensure accuracy and validity of the findings.

Ethical Considerations

Ethical approval was obtained from the Institutional Research and Ethics Committee (CCCRC-02-2025 SV). Patient confidentiality was maintained throughout the project, and all interventions were designed to minimize disruption to clinical care. The study adhered to ethical principles, ensuring transparency, respect, and stakeholder collaboration.

Results

The study was conducted between April 2024 and Nov 2024. A total of 87 patients with underlying GI cancers were studied. The study results are organized according to the phases of the DMAIC cycle.

Measures

The time required for chemotherapy preparation before the intervention is shown in Figure 1. The mean time to initiate chemotherapy was 188 minutes, exceeding the Upper Specification Limit (USL) of 180 minutes. This comparison revealed that the process failed to meet the desired target. The clustering of data around the mean and the portion exceeding the USL emphasized the variability and delays within the workflow. As part of the measure phase, this analysis established the baseline, and the need for process improvement.

The blue bars represented the actual observed data, while the red curve depicted a normal distribution fit to highlight the overall trend of the dataset. The mean time to initiate chemotherapy, shown as the vertical green line, was calculated at 188.36 minutes.

This visualization highlighted the inefficiency in the chemotherapy preparation process in day care.

Analysis

The root-cause analysis is shown in Figure 2.

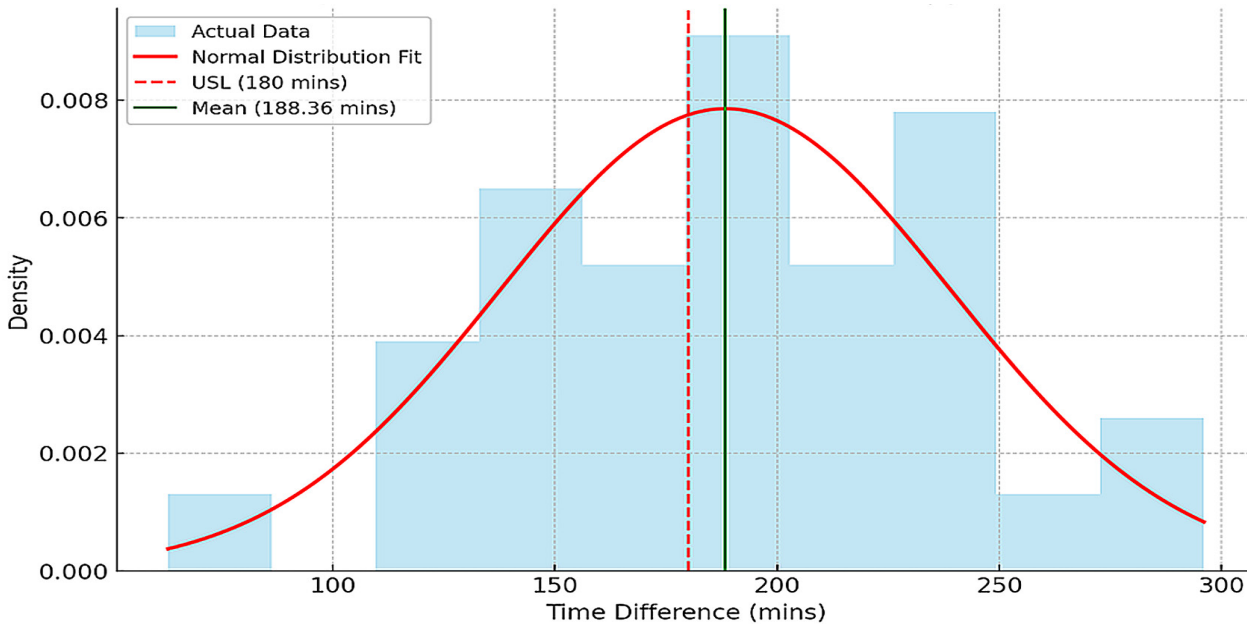

Figure 1. Waiting Time to Start Chemotherapy Administration in DCU: Pre-Intervention Data Distribution

A combination of systemic inefficiencies, procedural gaps, staff shortages, communication issues, and environmental challenges causes the delay in receiving chemotherapy. Systemic issues like network outages, malfunctioning pneumatic tube systems, and limited computer access created logistical hurdles, while errors in documentation further exacerbated delays. Inefficiencies in processes, such as unclear workflows for Computerized Tomography (CT) scans and Pulmonary Function Tests (PFT), ineffective patient assessments, and batch transportation of chemotherapy from the pharmacy to the DCU prolonged treatment times. Additionally, bottlenecks occurred due

Figure 2. Root Cause Analysis-Factors Contributing to Increased Waiting Time for Chemotherapy Administration

to improper patient assignment, inefficient cannulation procedures, and delays in laboratory-related processes.

Human factors and environmental constraints contribute to chemotherapy delays. Staff shortages, teamwork issues, and documentation errors slow delivery, while miscommunication and poor coordination disrupt workflows. Physical challenges, like patient distance and small medication rooms, further add to delays. Addressing these issues requires systemic improvements, better communication, and optimized infrastructure for timely chemotherapy administration.

Improve

A series of targeted interventions were implemented to address waiting time in starting chemotherapy in day care (Table 2). These intervention were adopted based on the results of previous steps and previous studies [3, 7-21]. The patient flow process was redesigned to establish two distinct paths based on the availability of lab results: a "fast track" for patients with lab results already available within 48 hours and a "normal track" for those requiring updated laboratory investigations. Priority was given to patient assessment and order confirmation for individuals on the fast track, ensuring their treatment proceeded without unnecessary delays. The nursing staff and the Admission/Discharge Team (ADT) collaborated to confirm lab readiness and coordinated with the DCU to streamline patient placement. Additionally, clinical nurse specialists (CNS) ensured that the fast-track patient list was distributed and adhered to by all relevant staff, replacing physician round-based evaluations with a more efficient clinic-based evaluation process.

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Table 2. Operational Action Plan for Optimizing Chemotherapy Administration Workflow

Theme	Operational Action	Responsible Team
Patient Flow Optimization	Establish two distinct patient paths: Fast Track (lab results within 48 hours) and Normal Track (requiring updated labs).	Nursing Staff, Admission/Discharge Team (ADT), Clinical Nurse Specialists (CNS)
	Prioritize assessment and order confirmation for fast-track patients.	Nursing Staff, Physicians
	Replace physician round-based evaluations with a clinic-based evaluation process.	Physicians, CNS
Enhancing Coordination and Communication	CNS to distribute and ensure adherence to the fast-track patient list.	Clinical Nurse Specialists (CNS), DCU Team
	ADT collaborates with nursing staff and DCU to verify lab readiness and patient prioritization.	ADT, Nursing Staff, DCU Team
	Designate specific patient locations based on treatment paths for workflow efficiency.	DCU Team, Nursing Staff
	Standardize urgent CT scan and PFT handling to prevent unnecessary delays.	Physicians, Radiology, Nursing Staff
Optimizing Pharmacy-to-Day Care Unit (DCU) Portal Movement	Implement a real-time tracking system for chemotherapy medication movement from the pharmacy to DCU.	Pharmacy Team, IT Support, DCU Team
	Establish a structured delivery schedule for medication transport at fixed 10-minute intervals.	Pharmacy Team, Transport Coordination Team
	Assign dedicated nursing and pharmacy staff to oversee the medication transfer process.	Nursing Staff, Pharmacy Team
	Automate notifications for medication readiness and delivery updates.	IT Support, Pharmacy Team
System and Infrastructure Improvements	Resolve networking issues to ensure seamless order processing and medication tracking.	IT Support, Administration
	Increase workstation availability for real-time data access and patient management.	IT Support, Administration
	Implement IT-driven solutions for tracking, coordination, and workflow reporting.	IT Support, Quality Improvement Team

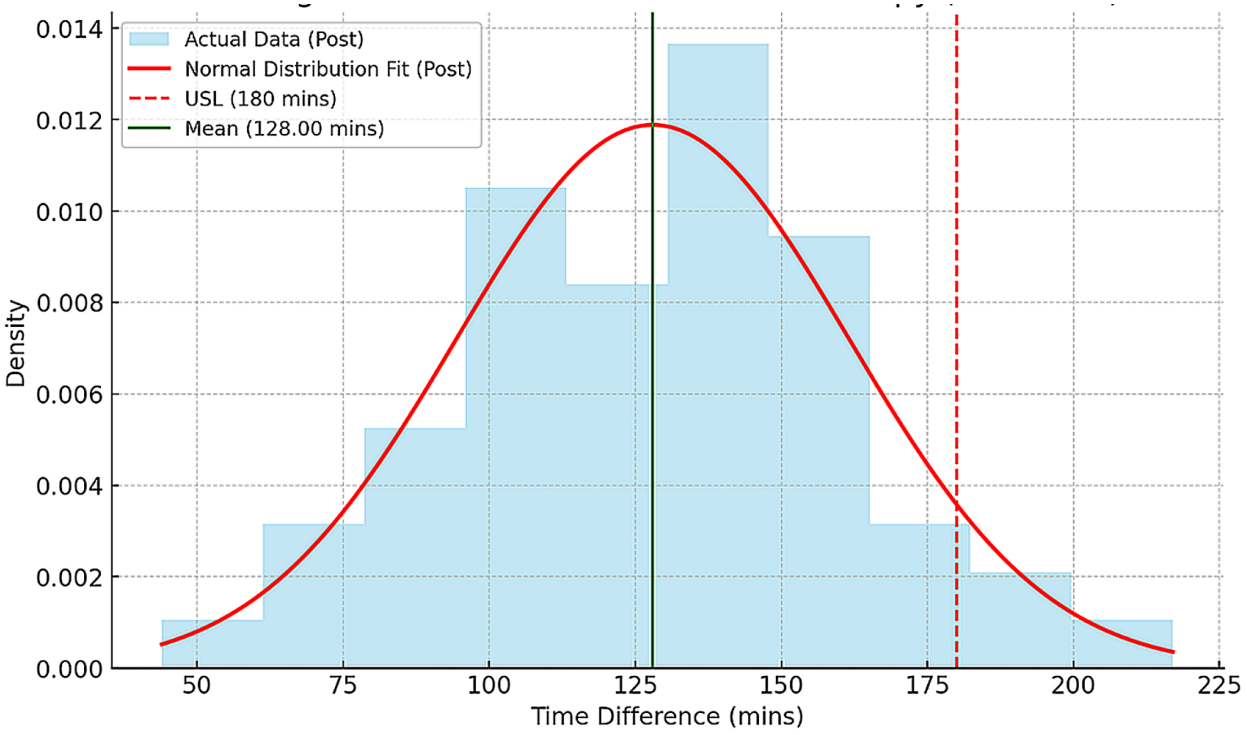


Figure 3. Waiting Time to Start Chemotherapy Administration in DCU: Post-Intervention Data Distribution

to confirm lab readiness and coordinated with the DCU to streamline patient placement. Additionally, clinical nurse specialists (CNS) ensured that the fast-track patient list was distributed and adhered to by all relevant staff, replacing physician round-based evaluations with a more efficient clinic-based evaluation process.

Efforts were also made to optimize the treatment environment. Patient locations within the unit were designated according to the specific treatment path, ensuring smooth transitions for those on the fast or normal track. To further reduce bottlenecks, the process for handling urgent CT scans and PFTs was standardized, allowing these critical tests to be conducted efficiently. Physicians and nursing staff worked together to align resources and ensure that patients in the clinic-based evaluation process experienced minimal disruptions and delays.

Nursing assignments and transportation logistics were another focus of the improvement efforts. Newly registered patients were promptly assigned to available nurses to reduce handoff delays and ensure continuous care. Furthermore, chemotherapy movement between DCU and pharmacy was scheduled at fixed intervals, with a dedicated plan for transportation every ten minutes. This structured approach ensured timely movement between departments, enhancing the overall efficiency of the DCU. Nursing staff took charge of assignments, while pharmacy and nursing teams jointly coordinated transportation schedules.

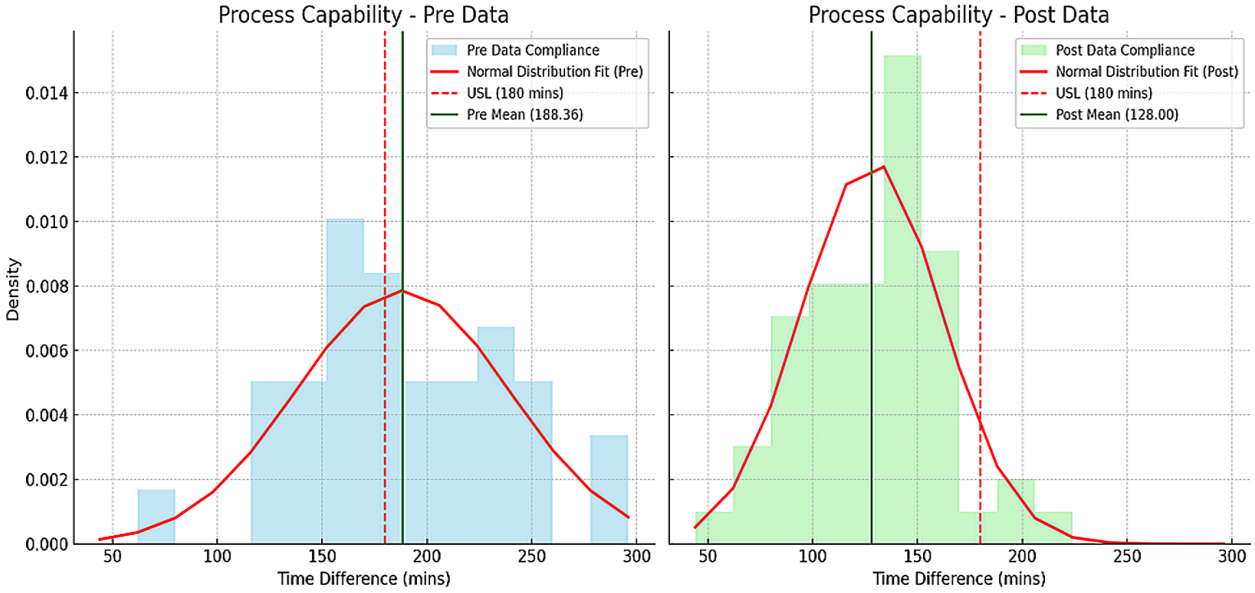
System improvements were also addressed as part of the initiative. Networking issues, which had previously hindered workflows, were resolved through IT support. Additionally, measures were taken to increase the number of workstations for the staff to access and input patient data.

The post-intervention histogram demonstrates significant improvements in the time to initiate chemotherapy (Figure 3). The time was reduced from a mean of 188.4 minutes to 128 minutes. These results highlight the effectiveness of the implemented interventions in streamlining workflows, reducing delays, and ensuring a more reliable and patient-centered chemotherapy initiation process.

Figure 3 showed the mean waiting time after intervention. The distribution curve is narrower and centered closer to the mean, indicating reduced variability and greater consistency. The process improvements for chemotherapy waiting in DCU resulted in significant enhancements across multiple performance metrics. Process capability, measured by Pp and Ppk, showed marked progress. The Pp increased from 0.76 to 0.86, indicating better overall process consistency, while the Ppk improved dramatically from -0.05 to 0.52, highlighting alignment with specification targets and a reduction in variability. Additionally, the Z.Bench, or sigma level, increased from -0.16 to 1.55, signifying that the process now operates well within acceptable limits, a key indicator of its success in delivering consistent and timely results (Figure 4).

Figure 4 showed the Process capability, measured by Pp and Ppk. The Pp increased from 0.76 to 0.86, indicating better overall process consistency, while the Ppk improved from -0.05 to 0.52, indicating alignment with specification targets and a reduction in variability.

The improvements also had a profound impact on quality outcomes. The percentage of cases outside the specification limits dropped from 60.6% to 7.3%, a reduction of over 53%, showcasing the effectiveness of the



Metric	Before	After	Change
Total N	33	55	22
Pp	0.76	0.86	0.09
Ppk	-0.05	0.52	0.57
Z.Bench	-0.16	1.55	1.71
% Out of Spec	60.61	7.27	-53.33
PPM (DPMO)	606060.61	72727.27	-533333.33

Figure 4. Process Capability Analysis: Pre- and Post-Intervention Waiting Time for Chemotherapy Administration

interventions in minimizing delays and errors. Similarly, the Defects Per Million Opportunities (PPM) plummeted from 606,060.6 to 72,727.3, demonstrating a substantial decline in defects and inefficiencies. These results indicate that the process is significantly more reliable, patient-centered, and efficient, ultimately enhancing patient care and operational performance.

Control

The Combined Individual Moving Range (IMR) chart demonstrates a significant improvement in the chemotherapy initiation process following the interventions, with pre-intervention data concluding at Observation 33. These results confirmed the effectiveness of the interventions in streamlining and stabilizing the chemotherapy initiation process for gastrointestinal cancer patients (Figure 4).

The top chart, represents individual values, the pre-intervention period exhibiting high variability, with several instances exceeding the Upper Control Limit (UCL) of 263.81 minutes and an overall higher mean. In contrast, the post-intervention data stabilized, with values predominantly remained within the control limits and a reduced mean of 150.31 minutes, reflecting improved consistency and shorter delays (Figure 5). Similarly, in the bottom chart, representing the moving range, the pre-intervention period displayed large fluctuations, with many points nearing or exceeding the UCL of 139.43, indicating substantial variability between consecutive observations. Post-intervention, the moving range became more consistent, with most values falling well below the UCL, highlighting reduced variability and greater process control.

Discussion

This study effectively demonstrated the application of LSS principles in optimizing chemotherapy waiting times for GI cancer patients in the DCU. Through the structured DMAIC approach, the project team systematically identified inefficiencies, developed targeted interventions, and achieved significant improvements in patient flow, operational efficiency, and the overall quality of care delivery. The findings underscore the value of adopting LSS methodologies in healthcare to address delays, reduce variability, and streamline workflows [1, 3].

Process mapping revealed inefficiencies in communication, scheduling, and workflow sequencing. Feedback from staff provided qualitative insights into operational challenges, such as resource limitations and unclear role definitions. The intervention's primary focus was tackling delays caused by systemic inefficiencies, communication barriers, and inconsistencies in workflow processes. Initial observations revealed significant challenges in laboratory result processing, chemotherapy drug preparation, and patient flow management. Insufficient coordination among departments further exacerbated these inefficiencies. The project team

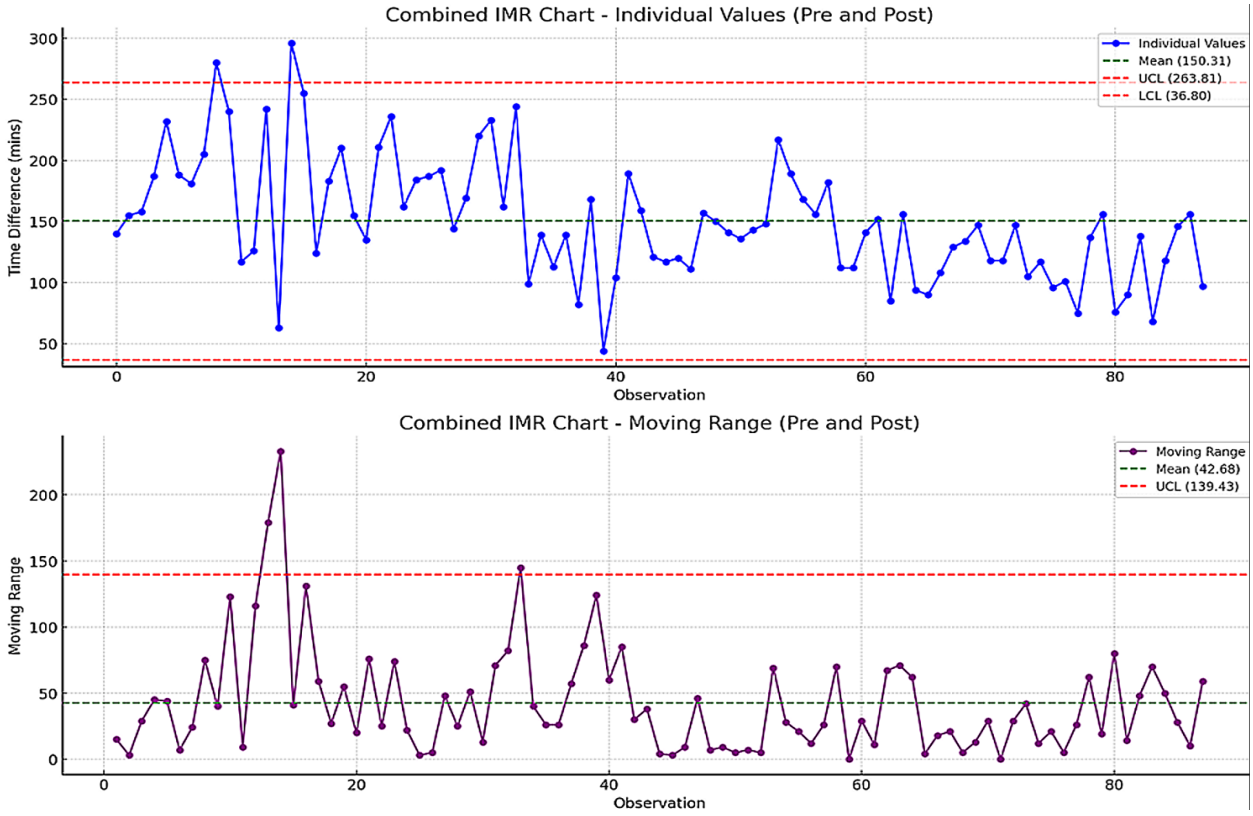


Figure 5. IMR Control Chart: Pre- and Post-Intervention Waiting Time for Chemotherapy Administration

identified specific bottlenecks that contributed to these delays using tools such as fishbone diagrams and Pareto analysis. This analytical phase provided critical insights that informed the design of focused interventions, ensuring that solutions were data-driven and targeted at addressing the root causes [7-9].

One of the most impactful interventions was the introduction of two distinct patient pathways based on laboratory result readiness. Patients with recent laboratory results were placed on a "fast track," while those requiring updated results were assigned to a "normal track." This stratification enabled better prioritization, reduced waiting times, and optimized the use of resources. Additionally, transitioning from physician round to clinic-based evaluations helped streamline patient assessments, ensuring a more consistent and efficient care process. This shift reduced delays, and improved coordination across the care team [4-6].

To support these workflow changes, the treatment environment was restructured to facilitate smoother patient transitions. Patients were allocated to designated locations based on their pathway to minimize unnecessary movement and ensure timely access to care. Furthermore, processes for handling CT scans and PFTs were standardized to eliminate inconsistencies and improve turnaround times. Cross-training nursing staff provided additional flexibility in managing patient needs, enabling the team to adapt quickly to fluctuations in demand without compromising the quality of care. LSS approach has been shown to reduce overcrowding of patients and improving the discharge process [7-9].

Systemic issues, such as network failures and documentation errors, were also addressed through infrastructure improvements and technology enhancements. The introduction of real-time tracking tools improved communication and data management while ensuring the availability of computers and resolving network issues, reduced delays caused by technical disruptions. Nursing assignments were reorganized to allocate newly registered patients promptly, and transportation schedules were streamlined with fixed intervals to ensure predictability in patient movement across the facility. These systemic improvements reinforced the efficiency of the redesigned workflows and supported the overall objective of minimizing delays, as has been shown previously [3, 11, 12].

The interventions were piloted exclusively within the GI cancer program to evaluate their feasibility and effectiveness. This pilot phase allowed the team to identify potential challenges and make necessary refinements before scaling the interventions to a broader population. By focusing on a single patient group initially, the project ensured that improvements were tailored to the unique needs of the GI cancer program while providing a model for replication in other departments. This phased approach ensured that the interventions were sustainable and aligned with the hospital's broader goals [1-6].

A key strength of the project was its multidisciplinary approach, which involved contributions from nursing staff, physicians, IT teams, and administrators. This collaboration ensured that the interventions were practical, well-supported, and comprehensively addressing clinical, operational, and quality challenges. Staff engagement was integral to the project's success, as regular feedback

sessions enabled the team to refine workflows and foster a culture of continuous improvement [4-6].

The success of this project highlights the transformative potential of LSS in healthcare delivery. The interventions effectively addressed operational inefficiencies and patient-centered challenges by systematically reducing delays, enhancing coordination, and streamlining processes. This initiative demonstrates the importance of data-driven methodologies in achieving meaningful improvements, offering valuable insights for future quality improvement projects. Moreover, the study underscores the importance of aligning interventions with organizational goals and patient needs. The improvements achieved in this project enhanced operational performance by reducing waiting times and ensuring a seamless care experience. These outcomes emphasize the dual benefit of LSS methodologies in addressing institutional priorities while improving the overall patient journey.

Limitations

This study had few limitations. First, the focus on GI cancer patients within a single institution may restrict the generalizability of the findings to other patient populations or healthcare settings. However, a single program was chosen to minimize variations while focusing on improving efficiency. Secondly, external factors such as fluctuations in patient volume or staff availability during the study period could have influenced the results. Finally, the qualitative feedback was not quantified, which might have limited its integration into the improvement process.

Recommendations

To build on the findings of this study, future projects should consider incorporating a control group or using a randomized trial design to strengthen the causal link between interventions and outcomes. Expanding the application of LSS interventions to other cancer types would help evaluate the broader applicability of the methodology in the setting of DCU. Implementing ongoing staff training programs to sustain the improvements and foster a culture of continuous quality improvement is also recommended. Further studies should explore integrating advanced technologies such as artificial intelligence and predictive analytics to enhance workflow efficiency. Additionally, patient perspectives should be systematically collected and analyzed to ensure process changes align with their needs and expectations.

In conclusion, this study successfully demonstrated the application of LSS principles to optimize chemotherapy waiting times for GI cancer patients in the DCU. Significant improvements in patient flow, operational efficiency, and overall care delivery were achieved by identifying systemic inefficiencies and implementing targeted interventions. The structured DMAIC approach ensured the process redesigned was data-driven, targeted, and sustainable. While the study was limited to a specific patient group within one institution, the outcomes highlight the potential of LSS methodologies to address complex challenges in healthcare delivery. These findings provide a strong foundation for future efforts to improve patient-centered care and operational performance in oncology and beyond.

Author Contribution Statement

All authors contributed equally in this study.

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This research was reviewed and approved by the Institutional Research and Ethics Committee at Sultan Qaboos Comprehensive Cancer Care and Research Center (SQCCCRC). It is not part of a student thesis but was conducted as part of a quality improvement initiative within the institution.

Ethical Approval and Handling

Ethical approval for this study was obtained from the Institutional Research and Ethics Committee at Sultan Qaboos Comprehensive Cancer Care and Research Center (SQCCCRC), Muscat, Oman. All ethical guidelines were followed to ensure patient confidentiality, data protection, and minimal disruption to clinical care. No direct patient interventions were involved, and all collected data were anonymized before analysis ((CCCRC-02-2025 SV).).

Availability of Data

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request, subject to institutional and ethical restrictions.

Conflict of Interest Statement

The authors declare no conflicts of interest related to this study.

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