Improving operating theatre utilization time in New Najran General Hospital using lean six sigma approach, is it still a valid strategy in healthcare?

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KEYWORDS

Six sigma, Lean, Operation theatre, Utilization.

ABSTRACT

Background: Operating rooms (ORs) are resource-intense and costly hospital units. Maximizing OR efficiency is essential to maintaining an economically viable institution.
Lean Six Sigma is a widely practiced method that offers organizations a systematized means of pursuing sustainable improvement of processes and achieving a higher level of excellence, New Najran General hospital (NNGH) is located in Najran province, Saudi Arabia, known as being a trauma center in addition to providing other elective and emergency services. We investigated our OT utilization which was found to be lower than benchmarks. So there was a call for action to be taken to identify the root cause(s) and seek corrective measures.
Methods: Lean Six Sigma (LSS) methodology was used to detect root cause(s) using data driven analysis, DMAIC, the 5 phases of the methodology, in addition to selected lean tools were implemented between 15th of February to 15th of May 2024 by cross functional team.
Results: at the end of the three-month study, we succeeded in raising the indicator of OT utilization from 43.5% to 78%, raising sigma level from 1.69 to 2.97. Key interventions included strict attendance monitoring, optimized scheduling and preoperative process improvement.
Conclusion: LSS methodology was very helpful in detecting the root cause of this chronic problem, provided framework for designing solution plans, streamline processes and sustaining improvement outcomes.

INTRODUCTION AND AIM OF WORK

Health care is a complex industry in which professionals are facing the challenge of balancing lower costs with better health and quality of care, the classic triple aim of healthcare according to institute of healthcare improvement (IHI)[1].

Operating rooms (ORs) are resource-intense and costly hospital units, at the same time are considered the money factory of any hospital, maximizing operating room efficiency has important implications for cost savings, patient satisfaction, and medical team morale [2].

Poor operation theatre (OT) utilization, defined as improper usage of Operation rooms time, leads to waste of precious time for surgical cases, resulting in hard and soft losses to the institute, affecting hospital revenues and negatively impacting hospital reputation and customer satisfaction, both internal and external[3].

Originating from Motorola in the mid-1980s, Six Sigma methodology aims to reduce defects and variability in processes through a structured, data-driven approach known as DMAIC: Define, Measure, Analyze, Improve and Control. Initially developed for manufacturing, Six Sigma has shown substantial potential in healthcare, where reducing errors, costs, and time is critical[4].

When integrated with Six Sigma (SS), lean principles (developed by Toyota in the fifties of last century, aiming at reducing waste) help to eliminate unnecessary processes and reduce waiting times between value-added activities to enhance quality which helps, accordingly, hospitals to gain a sustainable competitive advantage. A combination known as lean six sigma (LSS)[5].

New Najran General Hospital (NNGH) is a general hospital in Najran province, KSA, known as being a trauma center in addition to providing other elective and emergency services through 3 fixed equipped rooms in addition to one room for emergency situations.

In our hospital, improper operative theatre (OT) utilization was a chronic complex multifactorial problem that has existed for long time. As the hospital administration is interested in improving whole hospital performance (in line with the future direction of 2030 national transformation plan), including OT utilization, there was a call for action from hospital director through the quality committee to the quality department to investigate improper utilization indicators and establish solutions for the problem, in a scientific, data driven way. The goal is to reduce inefficiencies, minimize delays, and optimize the use of ORs.

In response to that call, a cross functional team was chosen to initiate an improvement project using LSS methodology, the primary outcome was improving OT utilization time and raising process sigma level

METHODOLOGY

We opted for Six Sigma (DMAIC) methodology, a five-phase approach, standing for (define, measure, analyze, improve, control), combined with lean tools, starting 15th of February 2024 and ending on 15th of May as a phase 1 improvement. A three-month period endeavor to diagnose possible causes and to implement robust solutions, the results are assessed, and further action plans are to be decided and implemented.

1-Define Phase:

The initial phase is concerned about proper definition of the problem scope and extent through the tools depicted in Fig. (1).

Project charter is established by the leadership and quality team. Defining the opportunity statement with current OT utilization of 43.5% and sigma level of 1.69, business case analysis, showing the high impact of this problem on the cost of service, our goal is to raise OT utilization time to 80%, increasing Sigma level to 3.

The team was then selected (hospital leadership, surgeons, anesthesiologists, nurses, technician and quality specialists), considering a cross functionality with different backgrounds to ensure comprehensive understanding of the problem, (Fig. 2).

Project timeline (Gantt Chart) spanned over 3 months' period as an initial phase project to stand on all aspect of the process, with the define phase duration of one month as seen in the project time plan.

Stakeholders (Surgeons, anesthesiologists, nurses, OT staff, hospital administration, and patients) mapping, analysis and management were then set in order, communication plan was put into action, including all persons of different categories involved in patient care across the whole scope of the process from calling for the patient to be transferred to OT till being transferred out from Recovery room. Listing the impact and interest of each one of those stakeholders and identifying the suitable communication way and frequency was established.

collecting voice of customers (VOC), both internal and external was done using different tools, a SWOT analysis was done, then findings were stratified into categories as seen in Kano model of VOC Fig. (3). After understanding the whole process, and identifying the defect per million opportunities (DPMOs), we calculated Sigma level using electronic calculator and found to be 1.69

Fig. (1): Tools used during define phase.

<table>
<tr>
<td>2) <u>Business case</u>

Recent data analysis revealed low OT utilization leading to internal and external customers' dissatisfaction, increased cancellation rate and negative impact on hospital image
<u>The financial impact:</u>
● Cost of repeat preparations
● Cost of increased length of stay
● Cost of staff salary</td>
<td>1) <u>Opportunity statement</u>

In our hospital NNGH, the overall OT utilization rate was 43.5% in year 2023 performance analysis. The international agreement of OT utilization time is 80-85%
Our current sigma level is (1.69)</td>
</tr>
<tr>
<td>3) Goal statement

After 3 months:
-Elevation in OT utilization time to 80%
-Increase sigma level up to (3)</td>
<td>4) project scope

All processes beginning with patient call to transfer to OT till exiting OT, for elective scheduled cases</td>
</tr>
<tr>
<td>6) Project plan
Gantt Chart

 
</td>
<td>5) team selection
- Hospital director (Champion)
- Medical director (team head)
- Six sigma team (corresponding author, a surgeon, quality member and anesthesiologist)
- OT Head nurse
- Head of technicians</td>
</tr>
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Fig. (2): Project Charter.

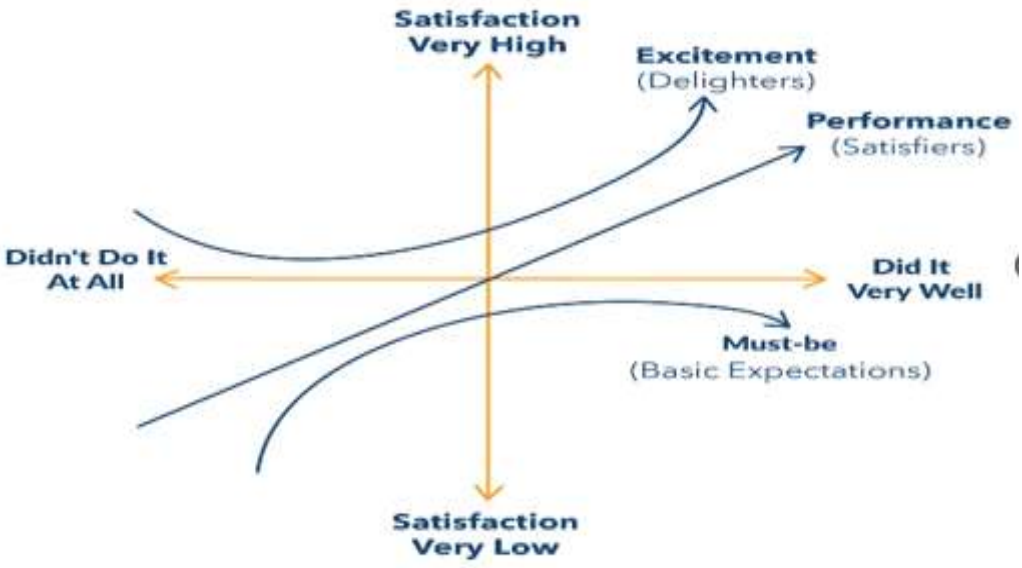

Fig. (3): Kano model for VOC.

2)Measure phase:

The idea of this phase (Fig. 4) is to describe the processes, gathering information about the current situation to obtain baseline data on current performance and to identify problem areas; determining characteristics of process/product that are critical to customer satisfaction.

Our OR has 3 fixed suites, all cases in the scope of general surgeries can be scheduled. The typical start time for elective surgery is set at 8.00 AM, end is at 4:00 PM. Total block time per room is 480 minutes.

Process mapping (flow charts, high level and detailed) were established, then we identified their relationship with suppliers and input on one side prior to the process, output and customers on the post process side (SIPOC diagram), aiming at full understanding of the process streamline from all perspectives.

Brainstorming sessions were held, and an Ishikawa (fishbone) diagram was designed to collect and organize possible bottlenecks and inefficiencies attributing to the problem. Common issues included: Poor scheduling practices, Inadequate preoperative preparation, Delays in patient transfer, Equipment or supply shortages, staffing shortages, among other causes.

X-Y matrix was then constructed to give weight for the causes identified, then a Pareto analysis, Fig. (5) was done to prioritize causes leading to 80% of the problem (Pareto principle) for further analysis and improvement solutions, called VITAL FEWS. Findings are:

- 1st case related causes.
- Anesthesia-related.
- Surgeon-related.
- Turn-over time.

At this stage, there is a consensus among process owners that delayed staff affects mainly 1st case related times so data collection will concentrate on the following key metrics:

- Actual time to skin incision (1st case)
- 1st case duration
- Turnover time after first case

Data collection plan with responsibilities identified was done, baseline data collected on OR utilization, included:

- Surgery start and end times
- Turnover times

- Reasons for delays (e.g., late patient arrival, equipment unavailability, staff delays)
- Cancellation reasons (e.g., patient no-show, lack of beds, medical reasons)

Data type was continuous numerical, mean daily utilization times of the 3 rooms were collected as the dependent variable plotted on the Y axis.
To determine causation, independent variables are collected and plotted on the X axis, these variables as mentioned before are mean time to skin incision of first case, mean first case duration and mean turnover time after first case.
These data are also continuous numerical, all collected daily for one month (from 15 JAN to 14 Feb).
Statistical analysis was applied using Minitab 17 software, using linear regression model.
Control chart was then done Fig. (8) to describe variation in the mean daily utilization time.
The duration of *measure* phase was 2 weeks (first half of February)

Fig. (4): Tools used in measure phase.

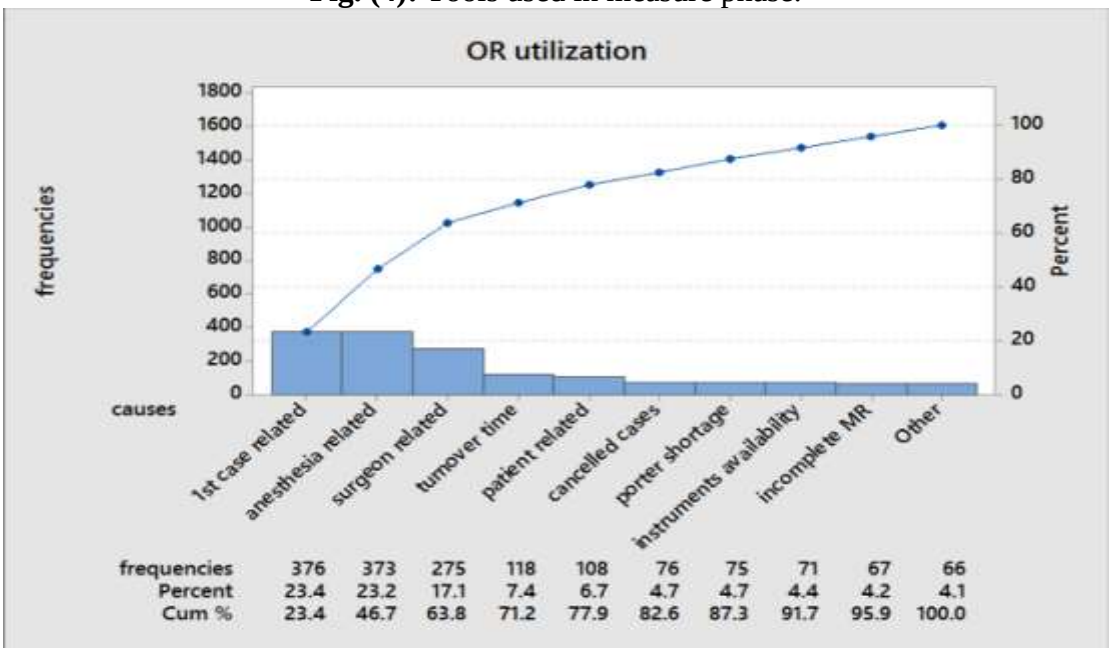

Fig. (5): Causes of improper OT utilization derived from XY matrix, plotted in a Pareto diagram to prioritize solutions.

3)Analyze phase:

The aim is to evaluate current operations to determine and confirm the root cause (s) of the problem using appropriate data analysis tools.
Statistical analysis was performed using Minitab 17, we used scatter plot and correlation co-efficient; regression analysis was then used with confidence interval and significance testing

applied to validate statistical significance of correlation co-efficient as shown later in Fig. (7). The duration of this phase was 2 weeks.

4) Improve phase:

Aim: design and implementation of the solutions that address the root causes and analysis of cost and benefit.

After detecting the root causes objectively, immediately the steps of *improve* phase were started as in Fig. (6). Brainstorming with process owners, to help find solutions, which are subjected to weighing through using solution (remedy) selection matrix, then Failure modes and effects analysis was applied for chosen solutions to proactively predict problems that can face the implementation of the solutions, fixing them before start, ensuring optimum outcomes and low failure rates.

Value stream mapping as a lean tool was implemented on the post-improvement low level flow chart to remove or minimize effects of wasteful (non-value add) steps.

Pilot trial during the 1st 2 weeks in March then full implementation of the plan till the end of April 2024.

Fig. (6): Tools used in improve phase.

5)Control phase:

This final phase is concerned about monitoring and evaluating the outcome of the improvement phase, to recommend, modify, add or remove solutions. Furthermore, its main aim is to maintain the continuous improvement cycle. Poka-Yoke, a mistake proof lean tool was used to sustain the gain and minimize failures in the process. This phase took 2-weeks duration.

RESULTS

VITAL FEWS were identified as mentioned before: these data were collected for the three rooms daily, mean daily values calculated and tabulated in special data collection sheet:

Actual time to skin incision (1st case), first case duration, turnover time after first case

Regression analysis was used in the *analyze* phase to validate statistical significance of correlation co-efficient shown in the following diagrams, Fig. (6), we can conclude with precision that the first variable, mean time to skin incision for the first case (left image) is the main root cause for improper utilization of OT time with evident strong negative correlation between both variables ($p<0.05$). Although all the 3 variables have some correlation, affecting utilization time negatively, but mean time to skin incision 1st case had the highest correlation co-efficient.

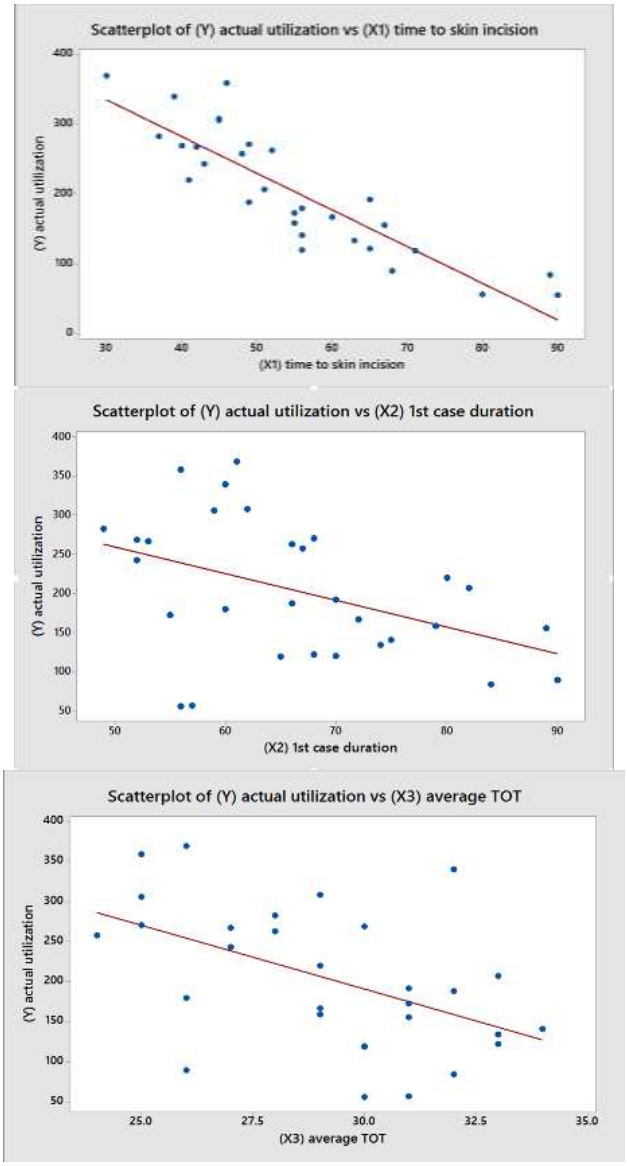

Fig. (7): scatter plots showing correlation and causation between independent variables and dependent variable

During the *Improve* phase, solutions recommended through the solution (remedy) selection matrix were:

1- Commitment to early start with strict attendance monitoring.
2- OR scheduling arrangement which does not allow bias towards some surgeons or specialties.
3- Preoperative process improvement, by standardizing preoperative checklists.
4- Turnover time reduction by standardizing cleaning and setup protocols and assigning dedicated turnover teams.
5- Cross-train staff to handle multiple roles.
6- Conduct daily briefings to align on schedules and priorities.

Pilot trial was started for two weeks then full implementation was endorsed.

In the *control* phase, mean utilization times collected daily for one month during the *improve* phase showed that mean daily utilization time per room rose from 204 to 375 minutes (from 43.5% to 78%), also SD decreased from 88.4 to 32 minutes, denoting better utilization and less variation in the process Fig. (8). Sigma level went up from 1.69 to 2.97.

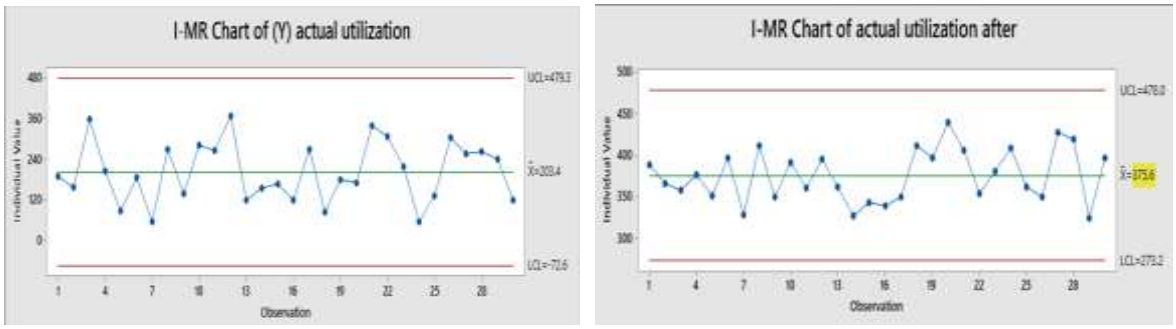

Fig. (8): showing control charts for utilization times before (left) and after (right) improvement, notice the reduced variations and increased mean time in the post improvement chart.

After the notable improvement, control activities were set to sustain improvement, these activities included:

- Standardization: Develop standard operating procedures (SOPs) for OR scheduling, preoperative preparation, and turnover processes.
- Monitoring: Use dashboards to track OR utilization, turnover time, and on-time start rates.
- Continuous Improvement: Conduct regular audits and feedback sessions with staff.

Lean tools were used in combination with six sigma tools to eliminate waste and enhance improvement:

- Value stream mapping (VSM) was performed to identify value-added steps of the process to keep on and non-value added steps to remove.
- Poka-Yoke: mistake proof tool used to design measures to prevent wasteful processes from occurring.

DISCUSSION

Healthcare is one of the world's fastest-growing industries. But with increasing competition, hospitals face mounting challenges in controlling costs, maintaining quality, improving efficiency, and enhancing patient satisfaction Hundal et al. [6].

Given the critical nature of medical services, even minor errors can have far-reaching consequences, impacting countless lives and, in some cases, leading to tragic outcomes[7].

To tackle these challenges, continuous process improvement has become an essential approach across various industries, including healthcare. By following a structured method—identifying issues, collecting data, analyzing root causes, implementing solutions, and sustaining results—hospitals can significantly enhance service quality. One of the most effective methodologies in this regard is Lean Six Sigma (LSS), which combines Lean principles (eliminating waste) with Six Sigma tools (minimizing variation and defects) [8].

Originally developed by Motorola in the 1980s, Six Sigma was designed to enhance efficiency by reducing process variability and defects through a data-driven, systematic approach (DMAIC). Though initially applied in manufacturing, its success has made it invaluable in healthcare, where reducing errors, cutting costs, and optimizing patient care are top priorities[4].

Similarly, Lean methodology, pioneered by Toyota in the 1950s—focuses on eliminating non-value-added steps, streamlining workflows, and enhancing efficiency[9].

When integrated, Lean and Six Sigma provide a powerful hybrid framework to optimize healthcare processes and improve patient outcomes[7].

We adopted LSS strategy by incorporating two effective lean tools in our study to synergize the impact of six sigma methodology and to gain the benefits of both strategies.

Value stream mapping (VSM) is an important tool of the lean approach and is used to identify value-adding activities and those considered wasteful of materials, flow of information and people[10].

VSM used in our *Improve* phase returned some non-value add steps as admission process bottleneck for day surgery cases, which was remedied, while Poka-Yoke was applied in *control* phase to the proposed solutions as a mistake proof tool to achieve sustainability, for instance in our case, we linked sign-in process to the presence of main surgeon to ensure full accountability to start on time, also OR director approval on the elective surgical list and for any change or shuffling is essential to ensure adherence to scheduling policy.

In our hospital, a secondary 200 bed hospital, governed by Najran health cluster, Saudi Arabia there is a rising concern towards process improvement in all domains of healthcare, aiming at achieving the vision of the governing body, derived and aligned with the 2030 transformation vision in healthcare in Saudi Arabia. In the beginning of this transformation endeavors, it is natural to find some resistance from staff of variable categories, we had to address this resistance gently, being mostly due to fear of the future and lack of knowledge about aims and benefits of the proposed change.

Our strategy of managing resistance was to collect the voice of customers (VOC), internal and external, by various means suitable to each person and category, then we started motivating them through explaining benefits that will be achieved through improving the services provided (Fig. 9), staff engagement, educational sessions and frequent communication.

Fig. (9): Benefits achieved by implementing LSS in our hospital

Implementing LSS in our hospital led to several meaningful improvements. Studies by Hoefsmit et al.[11] and McDermott et al.[12], highlight key benefits of LSS, such as reducing waste, lowering costs, improving patient care, and increasing workflow efficiency. Our findings align with these researches, proving that LSS is a valuable tool for hospitals seeking sustainable improvements.

A study by Ahmed et al.[13] further supports the link between LSS and patient safety. Their research demonstrated that LSS has a direct positive impact on quality improvement in hospitals, with patient safety serving as a crucial mediating factor. LSS not only improved efficiency but also significantly enhanced patient safety.

Additionally, achieving a competitive advantage has become increasingly important for healthcare organizations. The industry is moving away from traditional models toward more market-oriented strategies. As competition grows, hospitals must rethink their processes and adopt innovative methodologies like LSS to optimize resource use while maintaining high standards of care[14].

Looking ahead, integrating advanced technologies with LSS will be key to driving further improvements in healthcare quality. Leveraging big data analytics in the DMAIC process can

enhance decision-making and predictive capabilities. Additionally, technologies like the Internet of Things (IoT), robotic process automation (RPA), and radio frequency identification (RFID) can further optimize real-time monitoring, patient tracking, and automation of repetitive tasks[15].

In our study, leadership commitment was paramount, as fortunately leaders in addition to being motivated, they were also qualified quality specialists by certification and experience.

This mix, associated with staff enthusiasm, and strategic direction, were the main determinants of success of our project in addition to other factors like biweekly problem-solving sessions and Work floor visits (Gemba Walks) that helped the project team better understand how value was created and learn about perceived bottlenecks.

Rathi and colleagues[7] identified Key Success Factors of implementation of LSS in healthcare as follows:

Leadership Support, Staff Engagement and Data-Driven Decisions, further supporting our findings.

Our performance metrics regarding OT utilization showed notable improvement after implementing solutions recommended by using LSS tools, mean daily OT utilization time rose from 204 minutes to 374 minutes, (43.5% to 78%) with reduction of SD from 88.4 to 32 minutes (minimized variation), raising also sigma level from 1.69 to 2.97, very close to our goal listed in the project charter.

These findings align with studies by Schretlen et al.[16] who applied LSS to reduce surgical cancellations in a Dutch university medical center. Their study achieved a 50% reduction in last-minute cancellations, a 67% decline in repeated preoperative diagnostics, and a 35% reduction in referral-to-treatment time, all contributing to a 14% increase in patient satisfaction. Similarly, Zhu et al.[17] successfully used LSS to cut unplanned surgery cancellations in a large Chinese hospital from 10.21% to 3.8% by optimizing patient admissions and standardizing communication processes.

More efficient use of OR and hospital bed capacity enabled eight additional CABG procedures per month and freed up approximately 600 hospital bed days annually, more effective scheduling of preoperative diagnostics (e.g., X-rays) cut 67% of duplicated tests, with positive impact on patient safety (less radiation), reduction of waiting times by 35% and achieving patient-centered care through increasing patient satisfaction by 14% [16].

Financial implications: Although cost savings were not directly measured, an estimated reduction in wasted OT time suggests significant financial benefits, future studies should include a cost-analysis component to quantify these savings.

Limitations of the study: We lacked the use of predictive analytics to allocate OR time more effectively. Short duration given to the project as there was compelling need for rapid deployment of improvement initiative.

Future perspectives: The incorporation of contemporary practices as predictive analytics, data science and big data into the practice of quality improvement performance including LSS is expected to be a paradigm shift in the coming years, taking healthcare practice to a whole new level.

CONCLUSION

Overall, studies illustrate that Lean Six Sigma remains a valid strategy and a robust quality improvement framework that enhances healthcare processes, reduces errors, eliminates waste and ultimately improves patient outcomes by systematically identifying and addressing inefficiencies across various healthcare domains, including OT utilization

RECOMMENDATIONS

We recommend widespread use of LSS in various areas of improvement in healthcare processes, also encouraging healthcare professionals to explore the realm of performance improvement, especially LSS, providing them with training opportunities and sponsoring their LSS certification. Hospitals also should develop ongoing monitoring systems and consider integrating real-time data analytics into their practices.

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DISCLOSURES

Conflicts of Interest: The authors have no conflicts of interest to declare.

Confidentiality of Data: The authors declare that they have followed the protocols of their work center on the publication of data from patients.

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Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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