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Research Article

Using the Lean Sigma Six Methodology to Reduce Delays in Operations Rooms in Brazil

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Abstract

Healthcare systems are composed of several interconnected and interdependent processes and therefore can be defined as complex and critical. When one of these processes presents a critical failure, the whole subsequent chain will suffer the consequences.

Objectives: To demonstrate how the use of the "Lean Six Sigma" methodology can lead to the improvement of hard indicators and reduce delays in operations rooms of the brazilian public healthcare system.

Methods: With the support of a specialist in continuous improvement, guided interviews, process mapping, data extraction from the electronic health system and data modeling were carried out, focusing on the time of admission of surgical patients. Root cause analyses, chrono analysis and value stream mapping were also performed. The main stakeholders were involved and actively participated in the processes changing and in the creation of a standard operating protocol.

Results: Reduction in 57% of the average time of admission of surgical patients, decreasing from 64% to 24% of patients who arrived late in the operation room and changing the average of arrivals in the operating room from 44 minutes late to 16 minutes early.

Future considerations: Improvement programs become increasingly necessary for health facilities. The "Lean Six Sigma" methodology has a robust arsenal of tools and should be considered as an option in improvement projects, especially in complex environments like healthcare facilities .

Introduction

The phrase "what cannot be measured cannot be managed" is famously attributed to Peter Drucker [1], management guru and considered one of the fathers of modern management. With the aging of the world population leading to an increase in the cost of treatments, an efficient management of health facilities becomes not only desirable, but a basic condition for the sustainability of the business model. In 2011, Berwick and Harckback estimated that 34% of what was invested in the American healthcare system was wasted [2,3]. Although we do not have similar studies in our country, it can be extrapolated that Brazil has the same challenges [4]. This waste can take many forms. Mark Graham categorizes the 8 main types of waste as: defects, overproduction, transportation, waiting, inventory, moving, overprocessing, and wasted human capital [5]. Regardless of the form taken, waste needs correction, in a systematic way, based on data and that can be monitored by indicators. In the present case report, the Lean Six Sigma methodology was used to improve the waiting time of a surgical center that provides exclusive care to the SUS, the Brazilian public healthcare system. This methodology, originated from manufacturing, seeks operational excellence, through data and process analysis tools, focusing on cost reduction and improvement of the processes quality [6]. The application of these tools is carried out by professionals qualified in the methodology, through the application of a structured script and the use of basic statistical tools. In this way, it is possible to translate processes of the company's routine into indicators, and thus assess if the implemented changes have generated sustained positive impacts. In addition to implementing improvements, qualified professionals are responsible for training teams, thus ensuring that the improvements achieved will be sustained [7].

Among the tools used by the methodology, the mapping of inputs and outputs "SIPOC" (Supplier, Input, Process, Output and Client) was used. This tool allows global visualization of the macro process, identifying what each participant receives from the previous process and provides to the next. The objective is to identify waste (such as the generation of outputs that are useless to the process) and disconnections between inputs and outputs. This tool is used in conjunction with process mapping, which gives a granular view of the small processes that are necessary for the macro process to occur. While the "SIPOC" observes the inputs and outputs of the main sectors of the process, the process mapping observes, in detail, the way in which each participant carries out the activities that will give rise to the outputs. Another tool used was the "VOC" (Voice of Client), which seeks to remove subjectivity from the concept of quality, trying to reach, through a structured interview, the indicators that will be monitored and that will indicate that there has been improvement. The improvement contract is the tool that closes the problem analysis phase. Briefly, it delimits the project's scope of action and aims to prevent the project from losing focus, either due to the emergence of new problems or a change in the stakeholders'' desires. For this, it is necessary that the main leaders, formal and informal, are involved and in agreement with the content of this contract.

Data analysis of this report used the root cause diagram (also known as Ishikawa's diagram) and the control chart. The root cause diagram seeks, through successive questions, to find the root cause of problems. In this way, instead of the improvement team focusing on the symptoms, it will address the origin of the problems, aiming to prevent their recurrence. The control chart is a statistical representation, over time, of the distribution of the collected data. When determining upper and lower bounds of 3 standard deviations, the vast majority of data points are expected to fall between these bounds, assuming a normal distribution. This tool allows you to observe process stability (when the data is distributed around the mean) and special causes, such as, for example, when one of the collected data is out of the limits. Finally, to demonstrate the results obtained, a chronoanalysis chart was used. This allows us to demonstrate, in a graph of vertical bars, the distribution of the time spent in each step of the process. It is a visual tool that allows obtaining relevant insights, especially when non-essential steps occupy a high percentage of the process. It is worth mentioning that several other tools are present in the arsenal of the Lean Six Sigma methodology [8]. However, the use of all of them is not always necessary, and it is recommended to use the most complex tools as the need arises. As an example of these, we can cite statistical tests, analysis of variance and capability tests, which find wide application in the manufacturing industry.

Materials and Methods

The surgical center reported in the present study had constant complaints of excessive delay in admissions, by patients, companions and care team. This delay started to generate strain between the medical and nursing staff, in addition to considerably increasing the number of complaints filed with the ombudsman. Employee turnover, especially at reception, was considered high when compared to other healthcare facilities of the same size. After a brief evaluation by the management of the establishment, it was noticed that the problem was not simple, focal or of a single cause. As the team had a certified expert in the "Lean Six Sigma" methodology, he suggested the start of a pilot improvement project, using the methodology's tools. The management accepted the proposal and the work began.

Statistical Methodology

For 60 days, the lean six sigma specialist followed the team and gathered data from over 700 outpatient surgeries. These data were obtained from the electronic medical record system. After data extraction, they were submitted to the calculation of means, amplitudes and standard deviation. It was then observed that the data followed a normal distribution (Kolmogorov–Smirnov test, p-value > 0.05). For checking the process stability, the upper and lower limits of the control chart were defined as 3 standard deviations above and 3 below the mean. After plotting the data into the control chart it was observed, using Montgomery rules [9], that the process was stable. After the changes were implemented, a paired t-test was performed, which showed that there were statistically significant changes (p-value < 0.01).

Understanding The Scenario

As this was a new proposal for the whole team, the first step consisted of interviewing everyone involved in the admission process of surgical patients. In this phase, the specialist used the interview with receptionists, nursing technicians, nurses, surgeons, anesthesiologists, pharmacists and pharmacy technicians to identify the process to be improved. Through targeted questions, it was possible to prevent the interviews from becoming unproductive, generalized or disconnected criticisms with the project's purpose [10]. It was then concluded that the process in question was the admission of surgical patients. With the process identified, it was possible to start the next phase: defining the scope of the project.

Scope Definition

To avoid wasting energy, conflicts with areas that were not engaged in the project or the need for major systemic changes, the specialist opted for a clear definition of the project scope, as well as for the clarification of all those involved in it about what would be the scope of the changes. In the case exposed in the present report, the changes would only occur in the surgical center and sectors immediately adjacent to it, such as reception and nursing triage. More importantly, it was defined that the project would not change other causes of complaints, such as the daily number of surgeries, team size, size of surgeries, distribution of surgeries throughout the day or the post-anesthetic recovery process. Despite all these suggestions having emerged during the interview of those involved, the "Lean Six Sigma" methodology is the progressive and focused solution of systemic problems. Attempting to solve all problems at the same time would inevitably lead to failure and abandonment of the method.

Overview of The Process

After identifying the process to be improved, a global view of it was necessary. As it was a relatively complex process, the "SIPOC" tool was used. An acronym that stands for Supplier, Input, Process, Outputs and Clients, this tool identifies the main suppliers of a process, the inputs that enter it, the processes that occur to process these inputs, the resulting outputs and the customers (internal or external) that will receive them [11]. In the case studied here, the following was mapped (Table 1):

S	I	P	O	C
Reception	Patient data	Patient arrival	Filled registration form	Nursing technician
Nursing technician	Vital signs	Reception registers patient	Screened patient	OR nurse
OR Nurse	Safe surgery checklist	Nursing screening	Checked patient	Anesthesiologist
		Vital signs check		
		Transportation to the surgical center		
		OR nurse checks name, laterality and written consent		
		Surgery starts		

Table 1: SIPOC tool demonstrating the main processes that occur in a surgical admission, as well as their inputs and outputs, customers and suppliers

As part of the process's clarification, it was necessary to establish the boundaries and restrictions of the project. As it is a complex and critical environment, some changes are not possible to be carried out, either for patient safety or for the bureaucracy required for all health services. Thus, it was defined that:

- Every patient admitted for surgery would need a complete filled registration form
- Every patient would need to be screened before surgery, when their vital signs would be checked
- Every patient should have their identification, demarcation of laterality and written consent forms checked before entering the operating room

Understanding Customer Requirements

After defining the process to be improved and its limitations, the next step was to understand the client's requirements. Briefly, the specialist interviewed the main stakeholders asking them to define what was considered as a quality admission process. Initially, mostrespondents pointed out that a quality admission process was an agile one. However, one of the roles of the improvement specialist is the transformation of subjective data (such as an agile admission process) into objective indicators, which can be monitored, to verify the improvement and monitor whether this improvement was sustained after the end of the project. In this way, an agile admission process can be translated as one without delay time per patient, as well as a few percentage of delayed patients. With these objective data, indicators for follow-up can be generated. In the present case, we opted for daily monitoring of the average delay time per patient (in minutes) and the daily percentage of delayed patients (Figure 1).

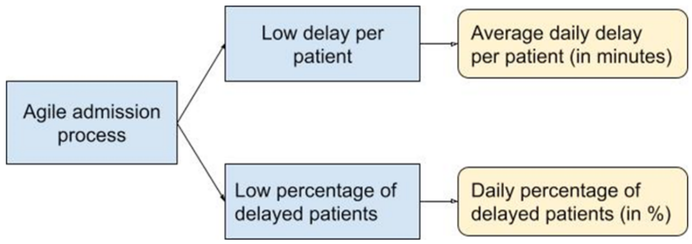

Figure 1: Transforming a subjective requisition (agile admission process) into a concrete and trackable indicators

Definition of Project's Goals

After defining the indicators to be monitored, it is possible to establish the goals of the improvement project. It is recommended that goals are:

- Specific
- Measurable
- Achievable
- Relevant
- Time bound

Thus, a goal was set to reduce the average daily delay time per patient by 50% and the percentage of delayed patients by 50% after 2 months of the start of the project. Any patient who entered the operating room after the scheduled time would be considered late and the delay time would be considered as the difference between the time of entry into the room and the scheduled time.

Improvement Contract

Being it a relatively long-term project and because of the need of support from the director's board, the improvement specialist formalized an improvement contract, making it clear which processes would be improved, deadline, project limitations and indicators to monitor results. The medical board, nursing management and administrative management participated in the making and signing of the contract.

Process Mapping

After the clear definition of the inefficiency to be solved, the process detailing phase began through its mapping. While the SIPOC tool gives a global view of the processes that take place, the mapping will allow knowing granular details of the process and its inefficiencies (Figure 2)[12].

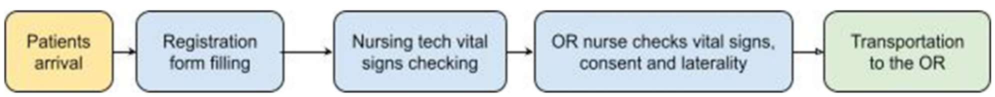

Figure 2: Details of the admission process

a) Patients arrival

It was observed that all surgical patients were instructed to arrive at the hospital at 7:00 am, regardless of the time scheduled for surgery. This schedule was established as a standard, without any justification for it being found. In addition, there was no differentiation between surgical patients and outpatient consultations, all entering the same queue, although the number of daily consultations was approximately 10 times greater than the number of surgeries. It was noticed that some patients arrived late to the hospital, but the majority arrived before 07:00h, however they were delayed in reception. In addition, it was observed that, even with all the counters functioning and without staff shortages, the reception sector was constantly overloaded.

b) Opening the service form

All forms were opened on a first-come, first-served basis, with no distinction between outpatient appointment or surgery appointment times. In addition, the reception overload was again observed, since many patients used public transport or chartered transport by the municipal health departments, which often synchronized the arrival time of many patients at the same time.

c) Outpatient screening

After filling the registration forms, the patients were referred to a triage room, performed by a nursing technician in a room outside the surgical center. If the patient presented alterations in the vital signs, the technician was instructed to contact the nurse at the surgical center. Once again, patients were treated on a first-come, first-served basis, with no distinction between surgical and outpatients.

d) Screening operating room

After being sent to the surgical preparation room, the written consent, demarcation of the laterality and identification of the patient were checked. Again, vital signs were checked and only then was the patient referred to the operating room.

Data Collection

The electronic medical record system was used as a data collection instrument. The following log data was extracted from it:

- Appointment date
- Patient registration code
- Surgery scheduling time
- Arrival time

- Completion of the registration form time
- Vital signs checking time
- Reception in pre-surgical room time
- Operating room entry time

The system allowed exporting these data in spreadsheet format. With this file it was possible to start the data modeling. Thus, it was defined as:

- Reception time, a continuous variable, measured in minutes, calculated by the difference between the arrival time and the completion of the registration form time
- Screening time, a continuous variable, measured in minutes, calculated by the difference between the vital signs checking time and the completion of the registration form time
- OR screening time, a continuous variable, measured in minutes, calculated by the difference between the reception in the pre-surgical room time and the screening time
- Patient status, a dichotomous categorical variable (late or not late), being classified as late any patient whose time of entry into the room was greater than the scheduled time of surgery

After defining and modeling the data, the collection process began (Table 2).

Surgery Date	Arrival	Registration	Reception Time	Nursing Techinician	Nurse OR	Nursing Technician Time	Operation Room	OR Nurse Time	Scheduled	Time Difference	Status
18/01/2026	07:05	07:11	00:06	07:19	07:32	00:13	07:35	00:03	07:00	00:35	DELAYED
18/01/2026	09:11	09:18	00:07	09:27	09:41	00:14	09:46	00:05	10:00	-00:14	On time
18/01/2026	13:09	13:29	00:20	13:44	13:52	00:08	14:00	00:08	14:00	00:00	On time
18/01/2026	10:57	11:03	00:06	11:28	11:45	00:17	11:47	00:02	11:00	00:47	DELAYED
18/01/2026	14:35	14:44	00:09	15:12	15:25	00:13	15:33	00:08	15:00	00:33	DELAYED
18/01/2026	11:57	12:20	00:23	12:51	13:00	00:09	13:09	00:09	13:00	00:09	DELAYED
18/01/2026	13:06	13:11	00:05	13:28	13:49	00:21	13:52	00:03	13:30	00:22	DELAYED
18/01/2026	07:09	07:25	00:16	07:39	08:06	00:27	08:10	00:04	08:00	00:10	DELAYED
19/01/2026	13:32	13:41	00:09	14:10	14:14	00:04	14:19	00:05	14:00	00:19	DELAYED
19/01/2026	13:56	14:07	00:11	14:39	14:52	00:13	14:59	00:07	15:00	-00:01	On time
19/01/2026	06:34	07:20	00:46	08:02	08:12	00:10	08:14	00:02	08:00	00:14	DELAYED
19/01/2026	11:39	11:48	00:09	12:50	12:58	00:08	13:01	00:03	12:00	01:01	DELAYED
19/01/2026	09:54	10:17	00:23	10:45	11:08	00:23	11:12	00:04	11:00	00:12	DELAYED
19/01/2026	12:30	12:37	00:07	13:21	13:37	00:16	13:45	00:08	13:00	00:45	DELAYED
19/01/2026	12:00	12:19	00:19	13:17	13:35	00:18	13:37	00:02	13:00	00:37	DELAYED
19/01/2026	16:43	16:45	00:02	17:08	17:25	00:17	17:30	00:05	17:30	00:00	On time
19/01/2026	16:10	16:15	00:05	16:42	17:03	00:21	17:10	00:07	17:15	-00:05	On time
19/01/2026	08:50	08:59	00:09	09:10	09:22	00:12	09:26	00:04	09:30	-00:04	On time
19/01/2026	09:56	10:15	00:19	10:54	11:05	00:11	11:09	00:04	11:00	00:09	DELAYED
19/01/2026	07:04	07:48	00:44	08:28	08:43	00:15	08:46	00:03	09:00	-00:14	On time
19/01/2026	10:47	10:59	00:12	11:27	11:46	00:19	11:48	00:02	12:00	-00:12	On time

Table 2: Database screenshot. The gray columns were obtained by subtracting arrival times in consecutive sectors.

Results

After 30 days of data collection, the data analysis process began.Initially, it was observed that the average daily delay time per patient was 44 minutes and 63% of the patients were classified as delayed (Figure 3).

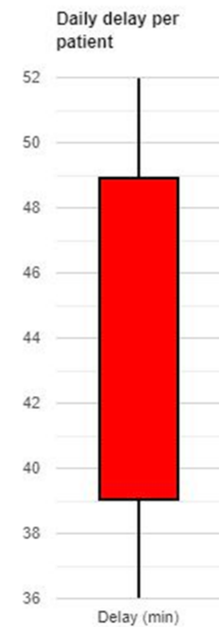

Figure 3: Daily delay per patient. Average of 44 minutes.

After entering the data in a control chart, it was possible to observe that all measurements were within 3 standard deviations above or below the mean, which represents a stable process, even if outside the expected standard (Figure 4).

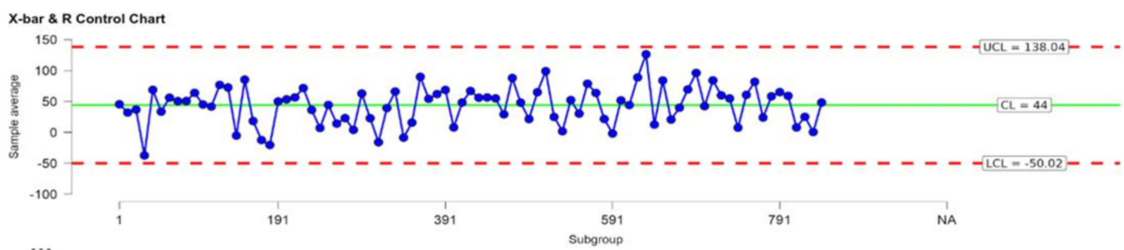

Figure 4: Control chart showing that all measurements were within 3 standard deviations above or below the mean. Note: Negative measures represent patients who entered the operating room early.

One of the causes of the delay was the lack of prioritization of surgical patients, especially those with surgeries scheduled as the first of the day. In addition, there was rework in the checking of the vital signs, a procedure performed both by the nursing technician screening. and by screening in the pre-surgical admission room. Additionally, the reception and outpatient triage sectors were constantly overloaded and pressured, as they were considered to be directly responsible for the delays.

Root Cause Diagram

With the data showing and quantifying the delays, the process of searching for the causes of this delay began. The specialist in improvement projects brought together the main leaders of the sectors involved, in order to analyze the factors that resulted in the delay of the admissions. Being it a complex process, several factors were mentioned and summarized in the following (Figure 5):

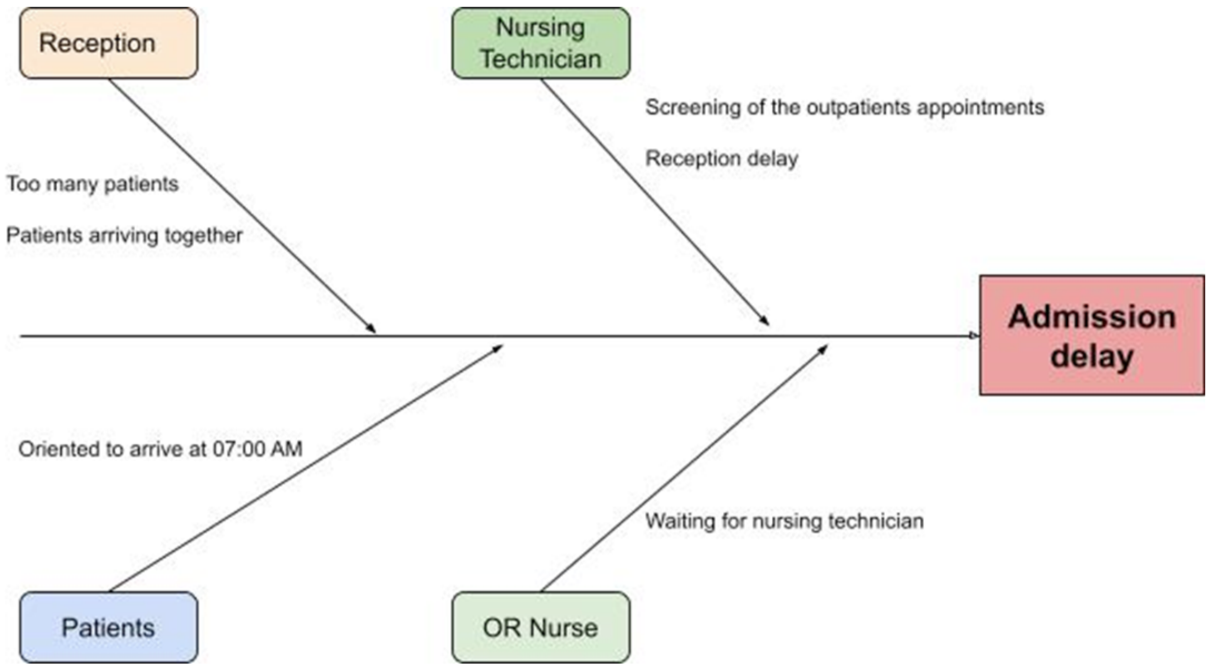

Figure 5: Diagram of root causes for admission delay

All areas concluded that the following causes were responsible for the majority of delays:

• Simultaneous arrival of patients

• Measurement of vital signs being performed twice, by the nursing technician and the OR nurse

• Surgical patients joining the same queue as outpatients

In common agreement among the teams, the following changes were made to the process:

• Removal of the fixed time of arrival of patients. Patients were instructed to arrive 1 hour before the time the surgery was scheduled.

• Dedication of one of the reception desks for prioritizing surgical patients

• Withdrawal of outpatient screening of patients who were being admitted for surgery. These patients would be screened only in the pre-surgical room (Figure 6).

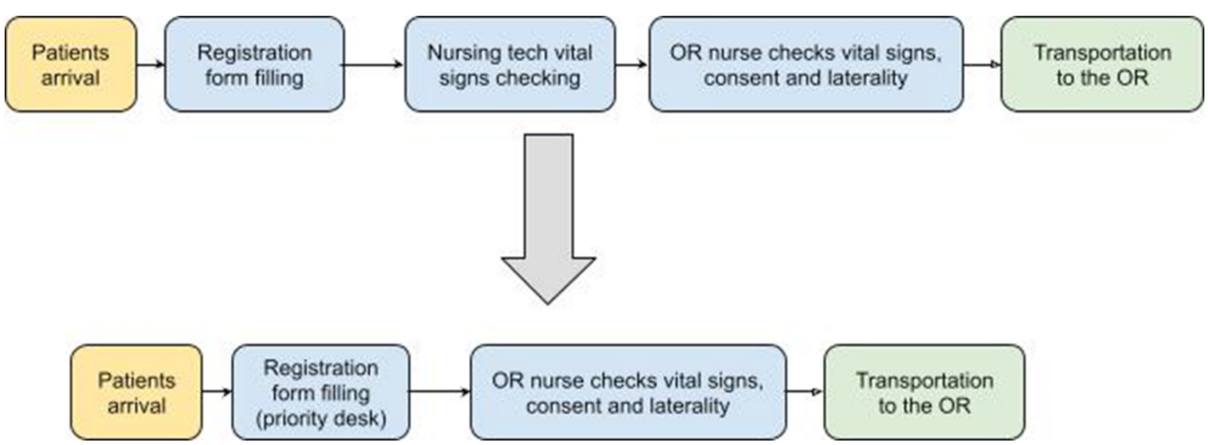

Figure 6: Process simplification.

By performing this simple change in the process, the average time between the patients' arrival and their entrance in the operating room dropped from 45 to 19 minutes. This is explained by the removal of a step in the process, outpatient screening by the nursing technician, which was one of the bottlenecks of the process, due to overload. This time is not representative of the delay of patients, but to the number of processes to which they are being submitted to (Figure 7).

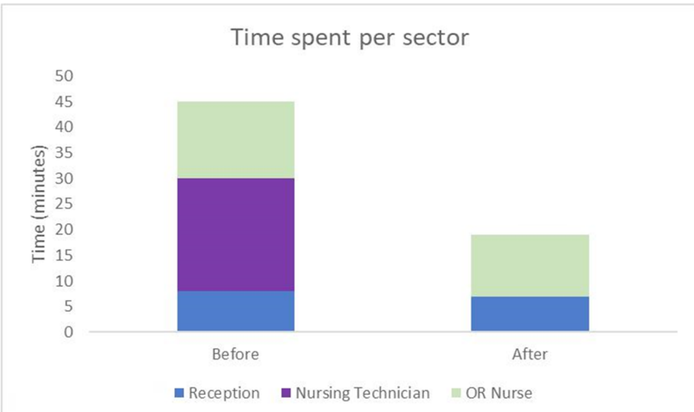

Figure 7: Drop of the average time to admission by 57% (Before: Range 84-32 min, SD: 12.7 min. After: Range: 9-22min, SD: 4.3 min. P < 0.01) .

With a more agile admission process and with patients arriving only close to the scheduled time, it was possible to reduce the average delay time (difference between the time of entering the room and the scheduled time) by 60 minutes. Before the improvement project, patients had an average delay of 44 minutes. Afterwards, on average, they were admitted to the room 16 minutes before the scheduled time (Figure 8).

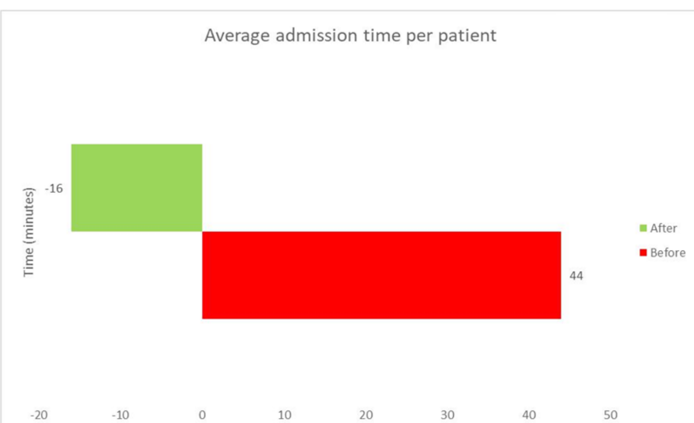

Figure 8: After the project, patients were admitted, on average, ahead of schedule. (Before: Range 84-32 min, SD: 12.7 min. After: Range: - 21 to +3 min, SD: 4.3 min. P < 0.01) Note, negative values represent pacients that started their surgery ahead of the time scheduled.

With the change in the admission process, the status of patients was reversed. While before the project an average of 64% of daily patients were late, after the project the percentage of late patients dropped to 24%. When the causes of these 24% were investigated, the vast majority were due to extra-hospital causes, such as transport delays or patients missing their surgery appointments (Figure 9,10).

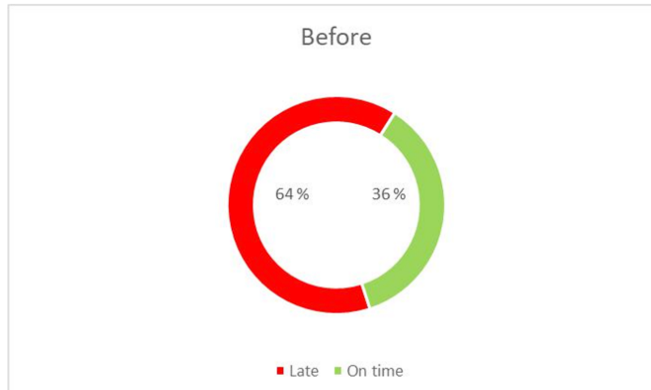

Figure 9: Percentage of late patients before the improvement project.

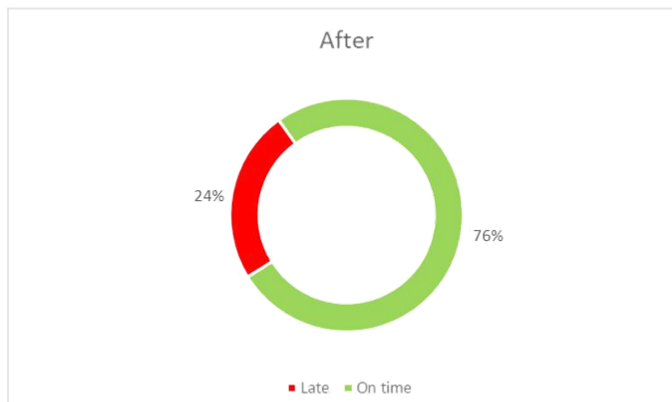

Figure 10: Daily percentage of late patients after the improvement project.

After implementing the changes, the number of complaints from staff, patients and family members dropped considerably. As these data were not previously collected, it was not possible to use them as an indicator of improvement. However, they were included in the improvement program (discussed below).As a way of sustaining the changes, a new standard operating protocol was created and validated by all leaders. The nurse responsible for the surgical center was trained and became responsible for monitoring the indicators and reporting them weekly to the hospital manager.

Discussion

The application of the lean six sigma methodology allowed the reduction of admission times in the operating room. At first, the statistical tools demonstrated, through concrete indicators, what was the problematic process behind the complaints. After the changes, these tools demonstrated the perpetuity of the implemented changes. After statistical tests (paired t-test) it was proved that the difference between the average admission time was not due to chance. The continuity of changes can be observed through the control chart.

The present case report demonstrated how the application of a methodology to carry out improvement projects can have tangible results in the change of systemic processes. Hospitals can be categorized as critical and complex systems [13], as defined by Bozzano: "A critical and complex security system is a system whose security cannot be demonstrated by testing alone, whose logic is difficult to understand without the aid of analytical tools, and which can directly or indirectly contribute to endangering human life, damaging the environment or cause great economic losses " (BOZZANO; VILLAFIORITA, 2010).

If we interpret a system as a series of consecutive processes, we can see a hospital as an interdependent system, where small changes will be amplified throughout the processes, which can have a catastrophic final consequence [14]. The present study evaluated this system in only one dimension, using delay to admission as the undesired consequence of systemic failure. In our project, it was possible to show that the participation of a qualified improvement specialist was essential to transform subjective complaints into concrete data. Thus, a surgical center considered lengthy was translated into several lengthy processes, rework, excess patient transport and generalized overload of the team. At no time was it chosen to hold the professionals as the sole responsibles for the systemic failure. Recognizing the search for constant improvement of processes as an institutional duty is the first step towards changing its culture.

It is worth mentioning that the considerable improvement was obtained without the purchase of new equipment, implementation of disruptive technologies or expansion of the workforce. This demonstrates that the good use of existing resources, including human capital, is sufficient to implement major improvements [15]. In this report, the presence of a qualified expert in the "Lean Six Sigma" methodology was crucial to obtain the results within the established deadline. We recognize that these professionals are not available in most healthcare facilities, and that hospitals that initiate structured improvement projects are rare. Even rarer are those that have a continuous improvement program, addressing the various processes that constitute a health system. Ideally, every healthcare facility should have a continuous improvement program, with professionals qualified to simplify complex problems and capable of implementing sequential improvement projects, progressively approaching all processes in search of operational excellence. Such a program would never be completed, as it's impossible to achieve complete excellence in the processes. However, continuous learning can be implemented and become an essential part of the organizational culture.

Future Considerations

Complex and critical systems are composed of several processes interconnected and interdependent. When failures occur, it is necessary to perform an objective and methodical evaluation of this system, in order to identify the causes and the most effective and efficient ways of resuming the system's functionality. The present case report demonstrated how the "Lean Six Sigma" methodology can improve a process in a healthcare facility. This methodology has a wide arsenal, of which only a fraction has been used. The popularization of this and other methodologies, as well as continuous improvement projects are increasingly necessary, because of the rising complexity of the hospital environment, whether due to the pace of changes that the health care has been subjected to or by the consequences potentially catastrophic failures that a small processes can cause.

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