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Lean Six Sigma: a new approach to the management of patients undergoing prosthetic hip replacement surgery

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Keywords
efficiency of care, health care management, health economics, health services research, Lean Six Sigma, public health, reducing length of stay

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Abstract

Rationale, aims and objectives In 2012, health care spending in Italy reached €114.5 billion, accounting for 7.2% of the Gross Domestic Product (GDP) and 14.2% of total public spending. Therefore, reducing waste in health facilities could generate substantial cost savings. The objective of this study is to show that Lean Six Sigma represents an appropriate methodology for the development of a clinical pathway which allows to improve quality and to reduce costs in prosthetic hip replacement surgery.
Methods The methodology used for the development of a new clinical pathway was Lean Six Sigma. Problem solving in Lean Six Sigma is the DMAIC (*Define, Measure, Analyse, Improve, Control*) roadmap, characterized by five operational phases which make possible to reach fixed goals through a rigorous process of defining, measuring, analysing, improving and controlling business problems.
Results The following project indicated several variables influencing the inappropriate prolongation of the length of stay for inpatient treatment and corrective actions were performed to improve the effectiveness and efficiency of the process of care. The average length of stay was reduced from 18.9 to 10.6 days (–44%).
Conclusion This article shows there is no trade-off between quality and costs: Lean Six Sigma improves quality and, at the same time, reduces costs.

Introduction

Italy holds one of the first positions in Europe for the number of hip prostheses implanted, about 100 000 a year. The number of hip surgeries is growing at the rate of 5% each year, resulting in €1.3 billion spending for surgeries and hospitalizations, as well as rehabilitation costs amounting to more than €0.5 billion [1].

The steady increase in National Health Service spending is one of the major problems affecting national economy. In 2012, health care spending in Italy reached €114.5 billion, accounting for 7.2% of the Gross Domestic Product (GDP) and 14.2% of total public spending [2]. Therefore, reducing waste in health facilities could generate substantial cost savings.

The main cause of the increase in health care spending, not considering uncontrollable factors such as the increase in the average age of the population, is the inappropriateness of the processes that should be properly measured and reduced through the implementation of appropriate corrective actions. Some inefficiencies derive from purely medical or clinical processes, while others are related to administrative, logistic and operational activities in general.

In this scenario, there has been a great development of excellence-oriented management models based on the use of methodologies developed in the industrial and manufacturing sectors but now also spread to the transactional and service field [3–7], and other methods aimed at assisting, supporting and advising decision makers on health care policy issues [8–12].

Costs and quality are two key points concerning the health care industry worldwide: one of the major problems is to find a solution that allows to improve quality [13] and to reduce costs [14,15]. In particular, *Lean Six Sigma* (LSS) methodology, thanks to the synergy of both Lean and Six Sigma methodologies, is the most innovative and effective approach in terms of 'Operational Excellence' [16–18]. LSS is a combination of *Lean Thinking* and *Six Sigma* aimed at the continuous improvement of a production

process through the push for speed and flexibility given by Lean Thinking and statistical support provided by Six Sigma.

Lean allows for speed and elimination of waste, *Six Sigma* seeks quality understood as less variability in the results of a process. *Lean Thinking* has been used to describe the *Toyota Production System* whereas *Six Sigma* was created in 1987 by Motorola company [19–24].

Nowadays, in order to improve the organization of care of patients with a specific clinical problem, health care facilities use clinical pathways which are structured multidisciplinary care plans [25–27]. LSS, providing a systematic approach, is an ideal tool to develop clinical pathways capable of achieving optimized processes, which are continuously improved with *plan – do – check – act* cycles [28–35].

According to the national and international literature [36–43], one of the most important indicators to measure the performance of the health care process is the length of hospital stay (LOS), or the number of days comprised between the date of admission of a patient and the date of his discharge, since being in some cases influenced by several factors not related to the clinical diagnosis of the patient, but to an inappropriate organization of the process of care. In fact, excessive length of stay is in most cases associated with the lack of standardization of the health care process, generating an unjustified variability from the original length.

In order to improve the quality of the provided services and clinical outcomes, as well as to reduce costs and length of stay, in 2012, the direction of the Department of Public Health of the University Hospital Trust 'Federico II' decided to develop a new clinical pathway for patients undergoing prosthetic hip replacement surgery, and for the achievement of the targets set, they chose LSS methodology, since it was considered as particularly suitable to perform a deep analysis of the process aiming at the identification of critical factors, the selection and the following implementation of corrective measures. Achieving the set goals had a significant impact both on the health care facility budget and the satisfaction of patients treated. The implementation of corrective actions and the standardization of some procedures performed in optical LSS [44,45] reduced unnecessary variations in the process, in addition to a significant reduction in length of stay.

Methods

This study was conducted at the Complex Operative Unit (UOC) of Orthopedics and Traumatology of the University Hospital 'Federico II', one of the largest and most complex health care facilities in Southern Italy. The UOC of Orthopedics and Traumatology provides regular inpatient treatment (elective or emergency), day surgery inpatient treatment as well as outpatient services. The Unit has 24 beds available, 18 of which are dedicated to regular admissions and 6 of them to Day Surgery activities, 3 operating rooms.

In accordance with the problem solving provided by the methodology, the project was divided into five phases, each coinciding with one of the DMAIC (*Define, Measure, Analyse, Improve, Control*) roadmap steps [23].

To measure the performance of the process, prior to any change suggested by the team [32], a retrospective analysis was conducted on a sample of 82 patients undergoing prosthetic hip replacement surgery during the 18 months before the project was launched (July 2011 – December 2012). Three *outliers*, or patients who had post-operative complications, were identified and excluded from the analysis. To check the validity of the new clinical pathway developed, information was collected on a sample of 48 patients operated during the 12 months following the implementation of the new standards formulated (January 2013 – December 2013).

Data for this project were collected both from printed medical records and from the digital information system database of University Hospital 'Federico II'.

For each patient included in the study, the following anamnestic, demographic and clinical variables were collected:

- gender (male/female);
- age (<60/60–75/>75);
- presence of allergies, cardiovascular diseases and diabetes (yes/no); and
- American Society of Anesthesiologists (ASA) score (I–II/III–IV).

Furthermore, each patient was taken into consideration:

- date of admission;
- date of surgery; and
- date of discharge.

The data analysis was performed using STATSOFT Statistica 8.0 and IBM SPSS Statistics 20 software for statistical analysis.

Define

During the define phase of a LSS project, the problem was defined clearly and allocated to a team for execution. In this project, a team was formed with the director of the Department of Public Health of the University Hospital 'Federico II' as the leader, an orthopaedic and trauma surgeon with years of experience as the project champion, three engineers and one orthopaedic surgeon as team members, with proven experience in health care management or in the specific type of surgery herein considered. The Director of Public Health Department was appointed as leader considering that she has the full knowledge of the organization and the context in which the corporation operated, she represented the right expert in order to carry out a thorough assessment of economic and human resources. The project leader had overall responsibility of managing the team, completing the project as per the schedule and communicating with the champion about the status of the project. The champion was responsible for reviewing the project periodically for its progress, providing support to the team in terms of infrastructure and other resources, including manpower for execution of the project. The team members were responsible for contributing towards the project by participating in team meetings, collecting and analysing data from the respective processes, and acting as change agents within the process.

The team prepared a project charter with all the necessary details of the project: the project title, the question, the critical to quality and the target (the chart is presented in Fig. 1).

The critical to quality characteristic defined in this case was the LOS, measured in days. The team observed that in the database the length of hospitalization of some patients was longer than 14 days. Hence, after discussion with the champion of the project and a literature survey, the goal statement of this project was defined as 'reducing of hospital days less than 14 days'.

The team decided to perform a Supplier-Input-Process-Output-Customer (SIPOC) analysis so that every team member can have

Project title: " Lean Six Sigma: a new approach for the management of the patient to be submitted to replacement surgery prosthetic hip".	
Question: Inappropriate prolongation of hospital stay for patients undergoing replacement surgery prosthetic hip.	
Critical to Quality The greatness of CTQ is therefore the duration of hospital stay.	**Target** Realize corrective measures in order to reduce the CTQ.
Project Leader Project Champion Team Members	**Prof. M.D. Maria Triassi** Prof. M.D Rosa Donato Prof. Eng. Mario Cesarelli Dr. Eng. PhD Giovanni Improta M.D. Giovanni Balato Dr.Eng. Francesco Carpentieri
Timeline	Define: Dic 2012 Measure: Dic 2012 Analyse: Dic 2012 Improve: Gen 2013 Control: Gen 2013 - Dic 2013
In Scope 1. Prosthetization of hip 2. Department of Orthopedics A.O.U. "Federico II"	**Out of Scope** 1. Whatsoever other type of intervention 2.All other structures

Figure 1 Project charter.

Suppliers	Input	Process	Output	Customer
U.O.C. Orthopaedics and Traumatology and his staff (doctors, nurses, nursing coordinators, anaesthesiologists administrative staff, physical therapists, operator social welfare)	Surgical services Medical services	Care process (administration services)	Recovery of the functional state of the hip Diagnostic and therapeutic information Health	Patient A.O.U general hospital Federico II

Figure 2 SIPOC for the Department of Orthopedics and Traumatology.

greater clarity about the process steps and project scope [46]. This SIPOC table (presented in Fig. 2) has helped the team to have a more clear idea about the scope of the project.

Measure

Identifying the problem, the scope of the methodology and the Critical to Quality (CTQ), the current process performance was measured in the measure phase.

First, we collected retrospective data from 1 June 2011 to 31 December 2012 of all the admissions to the UOC Orthopedics and Traumatology from the database (79 patients). The second set of data was collected from a prospective sample survey (from 1 January 2013 to 31 December 2013 – 48 patients). The following information was collected for all patients: gender, presence of allergies, cardiovascular diseases and diabetes, American Society of Anesthesiologists (ASA) score, pre-hospitalization, age, date of admission, date of surgery, date of discharge. The data from the

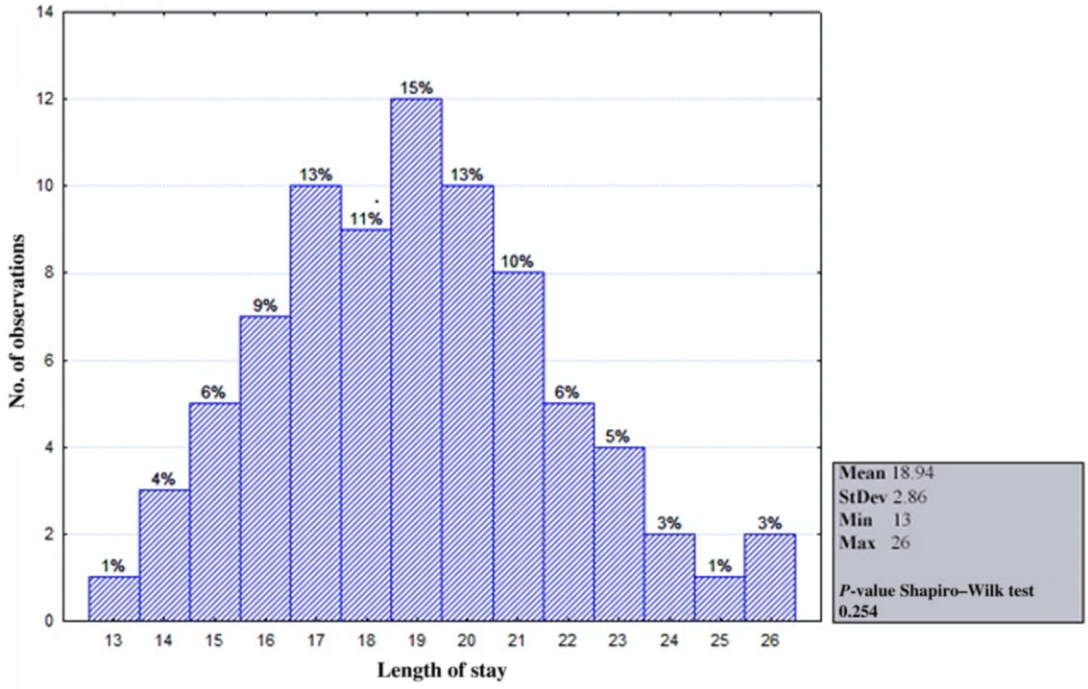

Figure 3 Histogram of length of stay for patients undergoing prosthetic hip replacement surgery from July 2011 to December 2012.

prospective sample survey (2013) provided us with information on the LOS after the new process started.

In order to visualize a graphical representation of the distribution of data and to obtain information regarding measures of location and dispersion relative to length of stay, we drew a histogram and calculated the mean and the standard deviation (Fig. 3).

We applied a test of normality, Shapiro–Wilk test with a significance level α of 0.05 [47], to test the normality of the sampling distribution, which was essential for the application of various statistical tests. Thereafter, using a *run chart* and *run tests*, with a significance level α of 0.05, we verified the presence of possible special influence factors such as specific periods of inefficiency in the performance of the process [41] (Fig. 4).

Analyse

In the next phase, we analysed the data collected and measured in the previous phase in order to identify the factors causing process variations. To assess and shape the flow of the process analysed herein, a simple *Value Stream Map* was made and it was determined from the patient's point of view (Fig. 5). This tool was necessary for the identification of the 'value' (activities carried out in the process, meeting solely the patient's needs), the waste, delays and inefficiencies [42–51].

A statistical analysis was conducted to better understand the variables actually influencing the values examined (Table 1). We used study factors (gender, age, allergies, cardiovascular disease and diabetes, American Society of Anesthesiologists (ASA) score) as grouping (independent) variables and the length of hospital stay as a variable (dependent) test and compared the groups through Student's *t*-test for dichotomous independent variables and analysis of variance for those who were not dichotomous (age).

At the end of the *analyse* phase, to identify as many influence factors as possible and then relative solutions, a brainstorming session was performed in which nurses, physical therapists and anaesthesiologists of the department were also involved [8]. Before starting the session, the brainstorming rules were shown to participants.

At the end of the session, we developed a cause and effect diagram, or Ishikawa fishbone (root cause) diagram (Fig. 6), to determine the root source of the longer LOS. This diagram represented the relationship between a problem or effect and its potential causes. It also helped us sort and relate the root causes for the identified problem. There were a total of 11 potential causes identified at this stage. We identified four major causes (patient, health care staff, system, process), see Fig. 6, with the relative secondary causes, which are also listed in Table 2 (the cause validation plan).

Improve

After analysing the process, the team developed and implemented appropriate corrective actions to eliminate waste, reduce waiting times and delays, based on the results obtained during the previous phases.

Among the weaknesses detected by the *Value Stream Map* and brainstorming session, a major role was played by the excessive delays and unnecessary waits that characterized the surgery preparation and the preoperative stay necessary for the surgery risk assessment (examinations, diagnostic and laboratory tests). To solve this problem, we have implemented a service of pre-hospitalization, aimed at carrying out all of the tests and examinations required for surgery preparation without patient hospitalization (Day Hospital), in accordance with a Lean vision of the health care process. Indeed, once the patient has been evaluated by

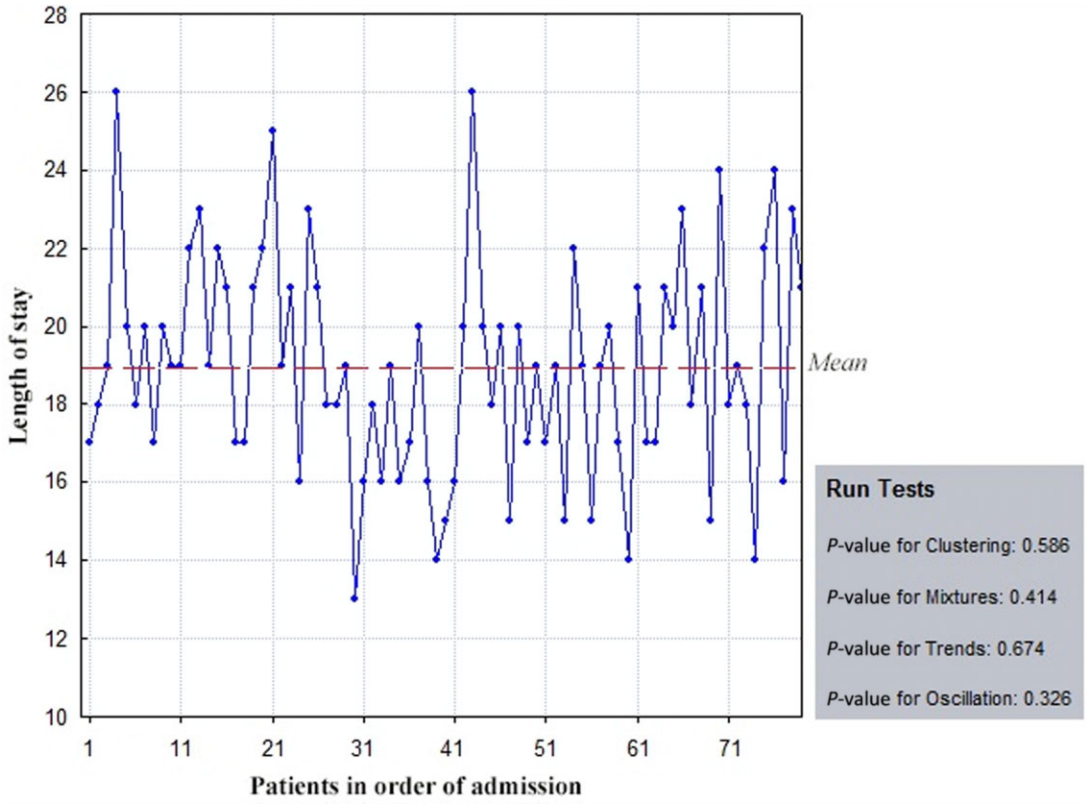

Figure 4 Run chart of length of stay for patients undergoing prosthetic hip replacement surgery from July 2011 to December 2012; the patients are reported in chronological order of admission.

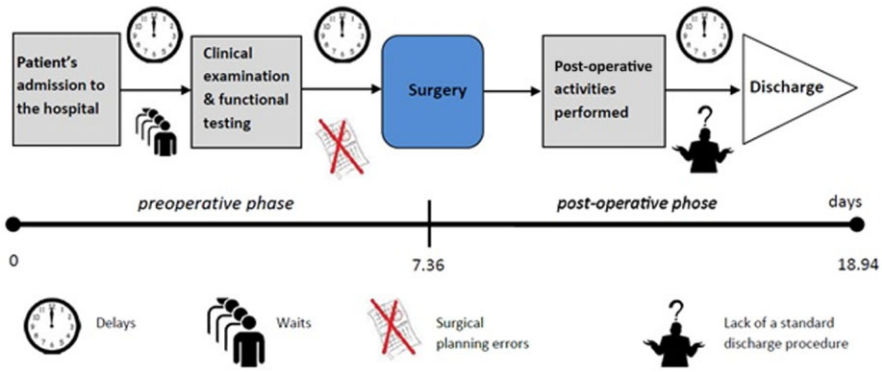

Figure 5 Value stream map of process performance, July 2011 to December 2012.

the surgeon in outpatient and a surgery was planned, he was added to the appropriate waiting list and returned to the Department of Orthopedics and Traumatology to carry out, in Day Hospital, blood tests, Electrocardiography (ECG) with possible cardiac examination, chest X-rays, and other standard radiographic examinations specific to the treated knee and anaesthetic examination. If the patient is eligible, he will be admitted to the surgery programme and the department will notify him of the date of surgery.

In accordance with a Six Sigma vision, we performed a standardization of the discharge process: we supposed that the discharge plan must be designed in advance, at admission or, at most, by the third day of stay, in order to identify in a timely manner the patient's needs, to facilitate post-hospital care and to reduce the unnecessary hospital stay. The analysis shows that the delayed discharges are particularly problematic because of their significant impact on hospital admissions and patient throughput and that clinical dimension is not the only criterion defining patient's discharge process. Discharge process includes many dimensions: the social, the patient's functional abilities, mental state and family support. Thus, we organized it as a systematic process of evaluation, preparation and coordination, aimed at facilitating the provision of health care and social services before and after the discharge. Moreover, we decided that a crucial role in discharge must be played by the nurses and the physical therapists staff who

Table 1 Effects of potential influence factors on length of stay

Variable		*N*	Length of stay: average ± SD	*P*-value
Gender	Male	13	18.46 ± 4.27	0.504*
	Female	66	19.04 ± 2.53	
Age (years)	<60	28	17.83 ± 2.32	<0.001†
	60–75	20	18.25 ± 3.10	
	>75	31	20.38 ± 2.59	
Allergies	Yes	23	19.65 ± 2.37	0.162*
	No	56	18.66 ± 3.01	
Cardiovascular diseases	Yes	49	20.42 ± 2.26	<0.001*
	No	30	16.53 ± 1.94	
Diabetes	Yes	12	19.5 ± 3.34	0.384*
	No	67	18.85 ± 2.78	
ASA score	I–II	42	17.23 ± 2.15	<0.001*
	III–IV	37	20.89 ± 2.29	

*Student's *t*-test.
†Analysis of variance.

must provide technical, relational and educational assistance. For example, they must promote healthy lifestyles, health culture and proper physical rehabilitation, prepare the patient to his discharge home and face the post-discharge complications.

Furthermore, along lean thinking, we adopted a simplification of complex bureaucratic procedures in order to reduce errors in compilation and communication among users involved in the process. We optimized the procedures for the reservation of operating rooms to limit the wrong compilation of daily and weekly surgery programmes.

Moreover, health care information system has been promoted: meetings were held in which clinical staff was invited to overcome preconceptions against the information system, showing the benefits in terms of speed, sharing and optimization of the process.

In addition, meetings were held between health care managers and clinical staff with the aim of informing the latter about the health care facility's financial problems and the economic

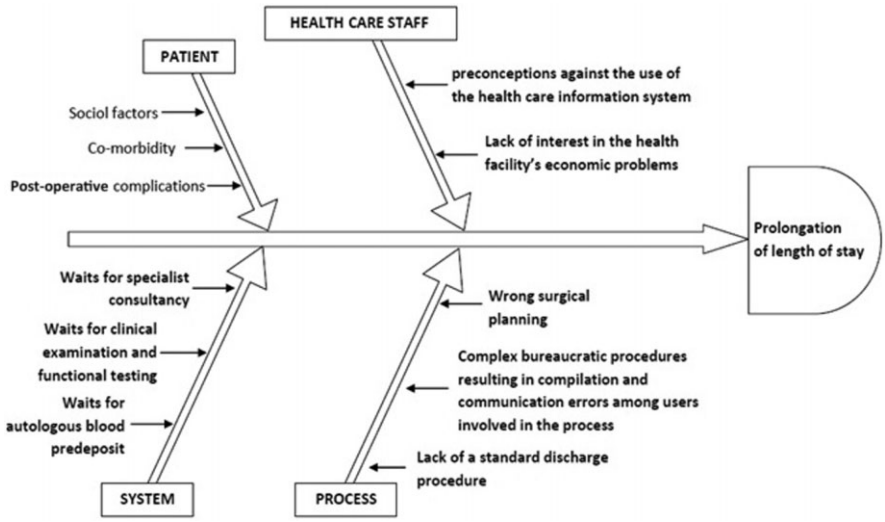

Figure 6 Ishikawa diagram of process performance, July 2011 to December 2012.

Table 2 Root causes of validation plan

Causes	Validation method	Observation/conclusion
Preconceptions against the use of the health care information system	Through an interview with the health staff	All the staff members
Wrong surgical planning	Number of cases detected in a month	Poor patient preparation
Lack of standard discharge procedure	Collecting data in the phase of hospital discharge	Hospital discharge protocols
Lack of interest in the health facility's economic problems	Control system	Management protocols
Social factor	Unexpected number of cases reported in a month	Waiting list with annotation
Waits for autologous blood predeposit	Number of cases reported in a month	Pre-hospitalization* (1 month before admission)
Complex bureaucratic procedures resulting in compilation and communication errors among users involved in the process	Number of cases detected in a month	Telemedicine (e-Health)
Co-morbidity	Anamnestic data gathering	Pre-hospitalization*
Waits for specialist consultancy	Number of cases reported in a month	Pre-hospitalization*
Post-operative complications	Increased hospitalization days (number of cases)	Maximum number of consultations for doctor
Waits for clinical examination and functional testing	Number of cases reported in a month	Pre-hospitalization*

*Before 2013, the University Hospital did not adopt the pre-hospitalization.

Table 3 Cause and solution

Causes	Solution
Waits for autologous blood predeposit	The activation of a pre-hospital service
Waits for specialist consultancy	
Waits for clinical examination and functional testing	
Lack of standard discharge procedure	Standardization of the discharge process
Complex bureaucratic procedures resulting in compilation and communication errors among users involved in the process	The simplification of bureaucratic procedures
Wrong surgical planning	The optimization of procedures for the reservation of operating rooms
Preconceptions against the use of the health care information system	The promotion of the health care information system
Lack of interest in the health facility's economic problems	The development of training and information activities

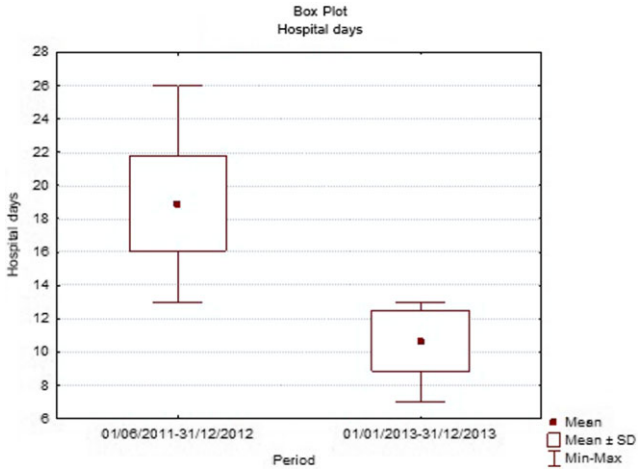

Figure 7 Box plot for length of hospital stay: before and after the study.

implications that may arise from non-compliance. So the main innovations include:

- the activation of a pre-hospital service;
- standardization of the discharge process;
- the simplification of bureaucratic procedures;
- the optimization of procedures for the reservation of operating rooms;
- the promotion of the health care information system; and
- the development of training and information activities.

Starting January 2013, the improvement plan formulated in accordance with the new standards was initiated. All the proposed solutions were implemented and results were observed. The summary of all such action is presented in Table 3. The data on length of the hospital stay were gathered from the process to study the level of its improvement. Analysing the process capability with a target of 18 days, we obtained a Defect per million opportunities (DPMO) equal to zero.

The average length of the hospital stay was reduced from 18.9 to 10.6 days and standard deviation was reduced from 2.9 to 1.8 days. Thus, there was a reduction of 44% on average and 38% in standard deviation for length of the hospital stay of the patient. A box plot was arranged to compare the length of the hospital stay before and after the project and is shown in Fig. 7. The sample sizes used to construct the box plot were 79 and 48, respectively, before and after the study.

Control

During the *control* phase, the new process was actively monitored in order to verify the validity of the new clinical pathway developed. For this purpose, we carried out a comparative analysis concerning the length of hospital stay (Table 4) among the patients operated before and after the implementation of the project using the Student's *t*-test with a significance level α of 0.05. Finally, we performed a comparative statistical analysis for clinical and demographic variables using the chi-square test with a significance level α of 0.05 to find significant differences between the two groups (Table 5).

Obviously, it is important in the application of LSS methodology to ensure sustainability of results in the long run. To this aim, we have planned the following actions:

- Periodical review meetings to evaluate the status of the process implementation; the problems highlighted during the implementation are discussed in this meeting, and the actions to improve the implementation are planned.
- The internal audit checklist was modified with adding the specific checkpoints related to our project. This helps in the verification of the implemented solutions and of the control mechanisms in the internal auditing system.
- The run chart is periodically updated by the staff for taking immediate corrective actions on the process whenever signals for assignable causes are observed. Moreover, the Defect per million opportunities (DPMO), the average and the standard deviation of the process are also evaluated during this action.

Results

As shown by the distribution of the length of stay of patients who underwent prosthetic hip replacement surgery from June 2011 to December 2012 (Fig. 3), the average length of stay was 18.9 days, standard deviation was 2.9, minimum level was 13 days, maximum level was 26 days, with a variation range of 13 days. Furthermore, it was verified that was a normal sampling distribution (*P*-value Shapiro–Wilk test = 0.254).

The run chart and run tests (Fig. 4) have ruled out the presence of any special influence factor (special events) in the performance of the process analysed.

The univariate statistical analysis (Table 1) indicated the following variables as significantly influencing the length of stay: age, presence of cardiovascular disease and American Society of Anesthesiologists (ASA) score.

Table 4 Difference in length of stay related to variables

Variable		Length of stay: average ± SD 1 July 2001 – 31 December 2012	Length of stay: average ± SD 1 January 2013 – 31 December 2013	Difference average (%)	*P*-value
All patients		18.94 ± 2.86	10.66 ± 1.82	44	<0.001
Gender	Male	18.46 ± 4.27	11.28 ± 1.64	39	<0.001
	Female	19.04 ± 2.53	10.41 ± 1.80	45	<0.001
Age (years)	<60	17.83 ± 2.32	10.35 ± 1.57	42	<0.001
	60–75	18.25 ± 3.10	11.33 ± 1.68	38	<0.001
	>75	20.38 ± 2.59	10.15 ± 2.15	50	<0.001
Allergies	Yes	19.65 ± 2.37	11.26 ± 1.85	43	<0.001
	No	18.66 ± 3.01	10.27 ± 1.72	45	<0.001
Cardiovascular diseases	Yes	20.42 ± 2.26	11.22 ± 1.82	45	<0.001
	No	16.53 ± 1.94	9.95 ± 1.60	40	<0.001
Diabetes	Yes	19.5 ± 3.34	11.18 ± 1.60	43	<0.001
	No	18.85 ± 2.78	10.51 ± 1.88	44	<0.001
ASA score	I–II	17.23 ± 2.15	10.6 ± 1.60	38	<0.001
	III–IV	20.89 ± 2.29	10.8 ± 1.93	48	<0.001

Table 5 Comparative statistical analysis before and after implementation of clinical pathway

Variable		1 July 2001 – 31 December 2012 (*N* = 79) *n*	1 January 2013 – 31 December 2013 (*N* = 48) *n*	*P*-value
Gender	Male	13 (16.4%)	14 (29.2%)	0.0896
	Female	66 (83.6%)	34 (70.8%)	
Age (years)	<60	28 (35.4%)	17 (35.4%)	0.252
	60–75	20 (25.3%)	18 (37.5&)	
	>75	31 (39%)	13 (27.1%)	
Allergies	Yes	23 (29.1%)	19 (39.6%)	0.223
	No	56 (70.9%)	29 (60.4%)	
Cardiovascular diseases	Yes	49 (62%)	27 (56.2%)	<0.519
	No	30 (38%)	21 (4308&)	
Diabetes	Yes	12 (15.2%)	11 (22.9%)	0.272
	No	67 (84%)	37 (77.1%)	
ASA score	I–II	42 (53.2%)	33 (68.8%)	<0.083
	III–IV	37 (46%)	15 (31.2%)	

After a thorough investigation on patients' medical records, it has been supposed that these factors had been influential since, in most cases, they involved non-routine and non-scheduled specialized tests which required long waits for their booking and execution.

A complete run chart for length of the hospital stay for both observed periods is displayed in Fig. 8. On this complete 'run chart', it is easy to monitor the variation of the Critical to Quality (CTQ).

The comparative statistical analysis (Table 4) revealed a significant decrease in the length of stay after the implementation of the improvement actions. The average length of stay of patients who underwent prosthetic hip replacement surgery decreased from 18.9 to 10.6 days (44%). Patients older than 75 years showed the most significant decrease, approximately 50% in terms of average values. For the anamnestic variables examined in the comparative statistical analysis (Table 5), there was no statistically significant difference between the two groups.

Discussion

The purpose of the project was to examine the usefulness of LSS as a tool to improve the management of patients undergoing prosthetic hip replacement surgery. In particular, LSS could help in developing a clinical pathway that improves quality and, at the same time, reduces costs.

The project charter creates ownership by health care team. The analysis phase, using statistical methods on valid and reliable data, gives an objective diagnosis of the current status. Finally, the tools and the structure to monitor the process are useful tools for the continuous improvement process. LSS methodology, providing a systematic approach to the analysis, allowed us to focus on the critical points [52–54] of the process and brought in each participant awareness of a new way of acting and a new way of thinking about improvements.

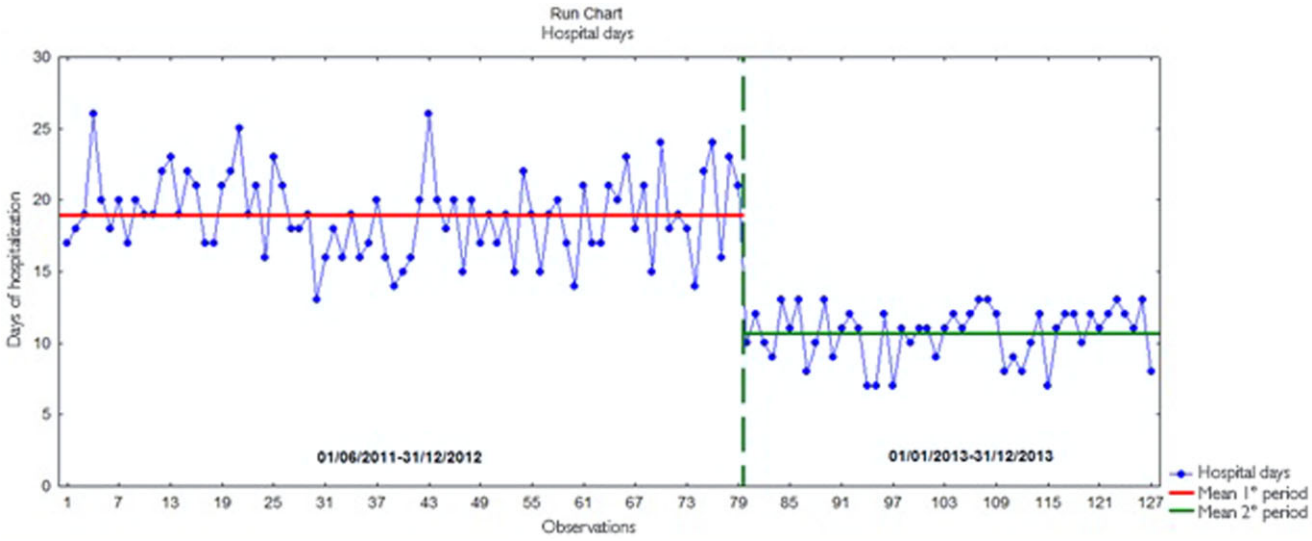

Figure 8 Run chart of length of stay for patients undergoing prosthetic hip replacement surgery from July 2011 to December 2012 (left part) and from January 2013 to December 2013 (right part); the patients are reported in chronological order of admission.

Close collaboration between health care managers and clinical staff allowed both a correct analysis, as it was possible to apply statistical tools to valid and real data, and the application of corrective actions, since the medical staff felt part of the project and was highly motivated. We can conclude that LSS is a tool that can really guarantee the improvement of the effectiveness and efficiency of health care delivery and provides an impetus for establishing best practice within the organization.

Therefore, the advantages of this new process are multiple:

- for patients, there is a reduction of length of stay and increase of satisfaction with the health service; and
- for hospitals, there is a reduction of costs for each admission, an optimization of the waiting lists, better planning of operating lists and an increase of the annual activity of the department.

We did not monitor patient satisfaction and patient outcomes. However, we expect that the significant reduction in length of stay, an increase in admissions and in beds available will have a substantial and positive influence on patient outcomes.

The first dataset showed that the age and clinical factors, as the American Society of Anesthesiologists (ASA) score and the presence of cardiovascular disease, in agreement to Collins et al. [55], generate the highest risk for a prolonged LOS.

The second dataset showed that the average LOS of the patients with a hip fracture at the department reduced with an impressive 44%. Through the application of the corrective actions, there has been a significant reduction (P-value < 0.05) and a lower variability of length of stay (Table 4). Considering that the average cost of 1 day of hospital stay at the national level is around €674 [56], the implementation of our project results in annual cost savings of more than €260 000.

There are several limitations in this study. The sample size was relatively small and the study was conducted in the specific context of the Italian University Medical Center. Contextual factors such as the Italian Healthcare System may have influenced the results. However, the general features of this approach make it widely applicable as a basic framework for possible future developments.

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