Improving performance of the hospitalization process by applying the principles of Lean Thinking

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Abstract

Purpose – The goal was to improve the quality of the hospitalization process and the management of patients, allowing the reduction of costs and the minimization of the preoperative Length of Hospital Stay (LOS).

Design/methodology/approach – The methodology used to improve the quality of the hospitalization process and patient management was Lean Thinking. Therefore, the Lean tools (Value stream map and Ishikawa diagram) were used to identify waste and inefficiencies, improving the process with the implementation of corrective actions. The data was collected through personal observations, patient interviews, brainstorming and from printed medical records of 151 patients undergoing oral cancer surgery in the period from 2006 to 2018.

Findings – The authors identified, through Value Stream Map, waste and inefficiencies during preoperative activities, consequently influencing preoperative LOS, considered the best performance indicator. The main causes were identified through the Ishikawa diagram, allowing reflection on possible solutions. The main corrective action was the introduction of the pre-hospitalization service. A comparative statistical analysis showed the significance of the solutions implemented. The average preoperative LOS decreased from 4.90 to 3.80 days (−22.40%) with a p-value of 0.001.

Originality/value – The methodology allowed to highlight the improvement of the patient hospitalization process with the introduction of the pre-hospitalization service. Therefore, by adopting the culture of continuous improvement, the flow of hospitalization was redrawn. The benefits of the solutions implemented are addressed to the patient in terms of lower LOS and greater service satisfaction and to the hospital for lower patient management costs and improved process quality. This article will be useful for those who need examples on how to apply Lean tools in healthcare.

Keywords Lean thinking, Quality improvement, Healthcare management, Maxillofacial surgery, Oral cancer

Paper type Research paper

1. Introduction

Oral cancer represents the sixth most common malignancy in the world. There are a lot of oral cancers depending on the histology: minor salivary gland cancers, odontogenic tumours, sarcomas, lymphomas and melanomas represent the 10% of the oral cancers (Kumar *et al.*, 2016). Squamous cell carcinoma alone represents the 90% of all the malignancies of the oral cavity (Chaturvedi *et al.*, 2013). The mouth also has an important aesthetic and communicative function that may be affected in case of big tumours and important surgical removal. It is often needed to operate and reconstruct to restore the anatomy and the function of the tissues affected (Wong and Wiesenfeld, 2018).

Data from the AIOM/AIRTUM Report "I numeri del cancro in Italia 2019" [1] indicate that around 9,400 new cases of head-neck cancer (lips, oral cavity, pharynx) are expected in 2019, 7.200 among men and 2.200 among women: they represent approximately 3% and 1% of all incident cancers respectively.

The incidence of health expenditure on the Italian economy is relevant in this context; at first glance, in absolute terms it has been growing steadily in recent years, in 2019 health expenditure of 118.560 billion is expected, equal to 6.6% of gross domestic product (Nota di aggiornamento del Documento di Economia e Finanza 2019) [2]. Healthcare spending has grown less than inflation, but the cuts have been justified with the need to maintain a balanced budget and to eliminate wastes and inefficiencies (Report GIMBE Observatory n. 7/2019).

The significant increase in healthcare costs has prompted hospital services to reinvent themselves to increase productivity, ensure quality of care and patient safety (Costa *et al.*, 2017; Lucchese *et al.*, 2020; Cabrera *et al.*, 2020). However, there are several excellence-oriented management models based on the use of methodologies developed in the industrial and manufacturing sectors (Nicolay *et al.*, 2012; Antony and Kumar, 2012; Amrani and Ducq, 2020) but also spread in the transactional and services sector, with the aim of assisting, supporting and advising health policymakers (Converso *et al.*, 2012; Ran *et al.*, 2020). Several methodologies have been used in the healthcare sector: health technology assessment between technologies (Ricciardi *et al.*, 2020a), machine learning algorithms to analyse data and improve clinical decision making (Ricciardi *et al.*, 2020b, c; Improta *et al.*, 2020; D'Addio *et al.*, 2019) and Six Sigma (SS) to introduce and analyse new clinical pathway (Improta *et al.*, 2019a, b).

Lean Thinking (LT) emerged in the 1940s in the Japanese automotive industry, Toyota. Toyota Production System (TPS) is based on the concept of eliminating waste or unnecessary interventions on the entire industrial process (Ohno, 1988; Costa and Filho, 2016; Östlund, 2020).

The term "lean" was first used by Womack *et al.* (1990) to describe TPS, which involves a series of methods and tools to continuously improve the efficiency and effectiveness of a system by eliminating waste. LT is implemented according to five principles: (Cruz and Leitner, 2010; Abdallah, 2020; Amaro *et al.*, 2020):

(1) Definition of value according to customer's perspective.

(2) Mapping the flow of value, or rather outlining the activities into which the process is divided, distinguishing those with added value and those non-added value.

(3) Create the flow: the value creation process must flow continually (no waiting and delay).

(4) Pull production: the value flow should be based on pull production, i.e. produce only when and what is requested by the customer.

(5) Pursuing perfection is the point to which we must strive through continual improvement and eliminating wastes.

Thus, LT focuses on reducing wastes (called Muda, in Japanese) and activities that absorb time and resources without adding value to the production process, synchronizing workflows (Womack and Jones, 1996). Toyota highlights two important techniques for reducing wastes and continual improvement of the process: "just-in-time" (production of goods when requested by a customer and in the necessary quantity) and "jidoka" (automation with a human touch, through equipment that automatically stops when quality problems are detected) (Mezzocato *et al.*, 2010; Östlund, 2020).

Among the numerous Lean tools, the most cited in the studies, are the Value Stream Map (VSM), Visual Management, Ishikawa diagram, Kanban, Standardization, Kaizen Process map (Cruz and Leitner, 2010; Babu Purushothaman *et al.*, 2020). Therefore, LT allows to carry out a qualitative evaluation and its strength lies in its series of standard solutions to common problems (George, 2003; De Koning *et al.*, 2006; Coelho *et al.*, 2015; Akmal *et al.*, 2020). Lean has spread to other sectors and organizations gradually moving to services, in fact, since the beginning of the twenty-first century, Lean tools have also been used in the healthcare sector (Young and McClean, 2008; Kelendar, 2020). Amaral *et al.* (2020) performed a systematic literature review to map how Lean tools are used in healthcare and what are their outcomes. VSM, 5S and Kaizen were the most widely used Lean tools.

The wastes indicated by LT in the production services are well described in the literature (Torielli *et al.*, 2011; El-namrouty and Abushaaban, 2013; Pavlović *et al.*, 2020) and they can be interpreted by researchers to address problems in the healthcare sector (Womack, 2005; Toussaint and Gerard, 2010; Kelendar and Mohammed, 2020).

According to Usman (2020), the seven categories of wastes from the TPS can be adapted to healthcare, as shown in Table 1, as well as including an eighth category talent (failure to train emergency technicians and doctors in new diagnostic techniques) (Catalyst, 2018). Reducing these wastes in healthcare facilities leads to faster service, fewer errors and less costs (Ricciardi *et al.*, 2019).

The aim of this work is to improve the performance of the hospitalization process of patients undergoing surgery to remove oral cancer. Therefore, a process analysis was carried out using Lean tools to identify wastes and its causes. Only some of the wastes in Table 1 are present in our case study, which were analysed both qualitatively and quantitatively. Then, Lean solutions to minimize wastes were defined and implemented.

Type of waste	Application to healthcare
Transportation	It takes account of those movements of materials and workers that does not add value to the merchandise: unnecessary movement of patients and staff
Inventory	It leads to higher financing and storage costs, higher defect rates and patients waiting (i.e. drugs with excessive or scarce supplies)
Motion	It consists of physical motions or walking by workers that distract them from actual processing work: staff searching for equipment, drugs and paperwork
Waiting	It is idle time that occurs when time is used ineffectively: excessive waiting for exams result, staff or medicines; waiting caused by schedule mistake
Over-production	Producing more than the customer demands or too early before there is the need is not necessary. It increases the time of lead and storage, i.e. unnecessary diagnostic, acting per schedule
Over-processing	It occurs when workers are unintentionally doing more processing work than the customer requires in terms of product quality or features: unnecessarily repeating tests, asking for patient's details several times
Defects	It may include errors in paperwork, late transport, production according to incorrect specifications, wastes of raw materials or generation of scrap, repeating tests because of errors, readmission because of failed discharge

Table 1.
Type of wastes in
healthcare

The Length of Hospital Stay (LOS), measured in days, was the hospitalization performance indicator used to quantify wastes minimization. The hypothesis to be verified, therefore, is the reduction of LOS. Some authors reported empirical evidence in previous scientific articles to support this hypothesis and the use of LOS as a performance indicator in Lean and Six Sigma studies.

Improta *et al.* (2015, 2017) applied the Lean Six Sigma (LSS) methodology to the prosthetic hip and knee replacement surgery processes, in fact they adopted pre-hospitalization as a corrective action to improve the quality of the services provided and to reduce LOS and hospital costs. Subsequently, Improta *et al.* (2019b) and Ricciardi *et al.* (2020d) introduced Fast Truck surgery, compared to previous works. Through rigorous LSS analysis, they allowed patients stable medical conditions and adequate pain relief, reducing the inappropriate lengthening of LOS. Again, Ricciardi *et al.* (2019) and Scala *et al.* (2020, 2021) analysed the introduction of the diagnostic-therapeutic-care pathway (DTAP), using the LSS methodology. They reported a statistically significant reduction in LOS (Ricciardi *et al.*, 2019; Scala *et al.*, 2021) and in preoperative-LOS (Scala *et al.*, 2020); therefore the implementation of DTAP has brought advantages for both hospitals and patients.

The paper is structured as follows: in the *Introduction*, a description of the healthcare sector and methodology is performed to support the research. Next, in *Literature review*, the most recent studies using LT in the healthcare context are reported. This is followed by *Materials and Methods*, which describes the context where the study takes place, the data collected and the phases of the applied methodology. In the *Results,* the authors present the results of the statistical analyses obtained with the implementation of Lean management. Finally, the discussion of the findings is presented step by step, followed by the conclusions.

2. Literature review: Lean thinking
Literature review about Lean applied in the healthcare is relatively recent. However, there are documents in a wide range of clinical situations, according to which Lean tools have been successful (Al-Araidah *et al.*, 2010; Montella *et al.*, 2017; Improta *et al.*, 2018a; Akmal *et al.*, 2020).

Fantola *et al.* (2020) analysed the clinical and logistical aspects of the operating room in the Enhanced recovery after bariatric surgery protocol. Through LT method, the operating room was reorganized and logistical efficiency was achieved, which contributed to reducing all operating room times and related to the improvement of LOS and post-operative complications.

Blouin-Delisle *et al.* (2020) followed the approach of a collaborative Lean methodology that involved various health professionals. The goal was to improve interprofessional work and coordination of care during patients' hospitalization to reduce the LOS. The study demonstrated a reduction in the average LOS in the geriatric care unit and optimized flow in the Emergency Room.

Peynetti Velázquez *et al.* (2020) applied the Lean methodology by transforming all non-urgent outpatient mental health appointments into telemedicine in days, at the Cambridge Health Alliance's psychiatry department. The system redesign process involved a customer-centric approach and continual improvement through monitoring operational data. The authors demonstrated a reduction in no-shows, stability in the volume of visits and strategies that will improve the provision of equitable and quality care for all.

Morales-Contreras *et al.* (2020) used Lean principles to identify wastes and an evaluation of applying an innovative approach in the hip fracture surgery process. This research stated that wastes identification and process redesign help continue to improve operations, increase efficiency, reduce costs and improve services while providing benefits to patients, families, hospital employees and healthcare systems.

Improta *et al.* (2018b) applied a LT approach at Emergency Department (ED) of Cardarelli Hospital Naples with the aim of increasing patient flow, improving the processes that contribute to facilitating the flow of patients through the various stages of medical treatment and eliminating all bottlenecks (queue) as well as all non-added value activities. They demonstrated the applicability of LT to ED processes and shown a positive increase in the performance of the ED, improving the efficiency of services and reducing waiting times.

Lot *et al.* (2018) opted for the application of LT tools to address problems in patient flow and identify the reasons behind long waiting times at a public liver transplant outpatient clinic in an education and research hospital. The solutions implemented reduced patient waiting times by improving patient flow.

Salam and Khan (2016) analysed a health service facility through the LT to improve system-wide process and greater patient satisfaction. The results show that by adopting the Lean process the system can become more efficient by providing a better, faster and safer healthcare system that contributes to patient satisfaction.

Haddad *et al.* (2016) used LT to map and model the hospitalization process of patients to improve patient flow and reduce unnecessary waiting and manipulation by patients and staff. The result was to reduce total time of the patient in the system up to 43%, without incurring additional costs or using more resources.

Furthermore, new studies emerged in the context of the COVID-19 pandemic. Pellini *et al.* (2021) assessed the impact on patient flow of organizational and logistical changes (key interventions) based on LT implemented after the COVID-19 outbreak. Indeed, they highlight that LT could prove useful for optimizing preoperative and postoperative time during the current pandemic, minimizing the exposure of healthcare professionals and patients to COVID-19 and promoting the rational use of limited resources, in compliance with oncological principles. Furthermore, the authors stated that LT strategies need to be monitored closely and for long time as they can lead to significant improvements in clinical practice, even beyond the current pandemic.

As a result of the literature review it can be claimed that Lean can be implemented in a public healthcare system to help improve the quality of processes and avoid wastes. The most important indicator for measuring the performance of a healthcare process is LOS, the number of days between the patient's hospitalization date and the date of his discharge. In some cases, LOS is influenced by several factors related to the clinical diagnosis of the patient, but also by the inappropriate organization of the process. Indeed, in most cases, an inappropriate prolongation of LOS is associated with a lack of standardization of the healthcare process (Mosè *et al.*, 2012; McKenry, 2012; Gayed *et al.*, 2013 Daultani *et al.*, 2015; Alfaro *et al.*, 2020).

3. Material and methods

3.1 Context

This study was performed at the Maxillofacial Surgery Department at building 14 of the University of Naples "Federico II" and is divided over two floors. On the ground floor there are: consultancy with two desks and the possibility of visiting two different patients simultaneously; the Day Hospital surgery where oral surgery is performed every day, the management office, medical offices, the acceptance office and a library. On the first floor there are: the hospital ward, the waiting room, two operating rooms, the infirmary, the pharmacy and the rooms for the medical and nursing team. The hospital ward consists of 9 rooms with 22 beds for patients and some rooms for doctors and nurses.

The multidisciplinary team of research was composed of an economist, an engineer, a specialized doctor, a physician, nurses and the health management. In accordance with the literature (Improta *et al.*, 2018b; Abdallah, 2020; Morales-Contreras *et al.*, 2020; Amaral *et al.*, 2020), the research framework is divided into two phases:

(1) In the first phase, the analysis of the hospitalization process included:

- Qualitative analysis through Lean tools, i.e. representation of the process with basic VSM and identification of wastes; discover the causes of the wastes effect with the Ishikawa diagram.

- Quantitative analysis carried out to support the definition of Lean solutions. Statistical tests were used to investigate which independent clinical variables could effectively influence LOS.

Thanks to the findings of the first phase, the research team designed and implemented Lean solutions to reduce wastes.

(2) In the second phase, quantitative analyses were carried out to measure the improvement of the hospitalization process by analysing LOS: that is, performance indicators before and after improvement; descriptive statistical analysis of LOS; statistical tests to verify the hypothesis of reduction in LOS after the implementation of Lean solutions.

3.2 Collection data
To get more information on the patient's hospitalization process, the research team explored with personal observations at the department, patient interviews and brainstorming with nurses and doctors. This information is not measurable but was useful for the qualitative analysis of the process. Then, they studied two groups of hospitalized patients who were operated due to an oral cancer before and after improvement. Data were collected from printed medical records consecutively and punctually from 2006 to 2018 without exclusion criteria (there are no missing values). The sample size of the pre-improvement analysed patients is 65 (2006–2008), while post-improvement is 86 (2009–2018).

3.3 Process as is
At the Maxillofacial Surgery Department, prior to Lean management, the hospitalization process of patients undergoing oral cancer surgery is described as follows.

The biopsy of the neoplasm represents the first step to characterize the suspect of an oral malignancy; moreover, it is important to frame the clinical health status of the patients and the stage of the cancer. Pre-operative imaging is important. There are some instrumental exams that should be practiced to understand the size and the stage of the pathology and to define the surgical and/or the medical therapy (Nae *et al.*, 2019). Sometimes of these exams may require long times to be practiced because long waiting lists in the hospitals.

Before 2009, at the Department of Maxillofacial Surgery the normal procedure to treat an oncologic patient previewed the first visit in the ambulatory and then his hospitalization to run each needed exam. This situation could cause long period of hospitalization because of the lack of availability to run these exams. During this time the patients are submitted to many other exams, comprehending ultrasound and echo-colour-Doppler of the neck to evaluate lymph nodal stations involvement, contrast CT and/or contrast MR to stage the primary tumour, lymph nodes and metastasis, PET-CT, to evaluate distant metastasis, and orthopantomogram to have a clear vision of teeth and bone (Sureshkannan and Vijayprabhu, 2011; Moreira *et al.*, 2017; Karam *et al.*, 2017). The anaesthesiologist, having read the exams and consultations practiced, assigns the patient an anaesthesiologic risk category (American Society of Anaesthesiologists Score) that allows surgery. Typically, the preoperative LOS is on mean about 5 days to run diagnostic exams.

The surgery for oncological operations lasts a mean of 5 h and it needs basically two steps. The first step is represented by the removal of the tumour and other structures involved in the

disease. The second step is represented by the reconstruction of the removed tissues. Sometimes, the first step can be demolitive, requiring the removal of big part of the face or the mouth. The reconstruction aims at restoring the anatomy and the physiological functions of the area (Montero and Patel, 2015). The post-operative LOS may vary according to the type of surgery performed and the specific needs required by each patient. On average, it can take around 15 days to cure. The clinical evolution of the patient is not always predictable. Discharge is deliberated by the doctor and generally takes one hour.

3.4 Process analysis

The first phase of the study was a qualitative analysis of the hospitalization process, using Lean tools. However, looking at the hospital ward's dynamics over a period and from patient interviews showed that, although the patients were satisfied of the medical team care, prolonged waiting times were bothering them the most. Additionally, medical team's perception of patient dissatisfaction with waiting times has led to increased stress and frustration for medical team.

Therefore, to evaluate and represent the patient hospitalization process, previously described, a basic Value Stream Map was drawn and shown in Figure 1. This tool allowed to identify the main activities, non-added value activities, that is, wastes, delays and inefficiencies of the process (Alkaabi et al., 2021; Marin-Garcia et al., 2021; Ricciardi et al., 2019). In fact, it was possible to frame delays and wastes during the preoperative phase of hospitalization.

Subsequently, nurses and physicians were involved in a brainstorming session to investigate influencing factors of prolonged preoperative LOS. However, a cause and effect diagram, or Ishikawa fishbone (root cause) diagram, was developed to determine the main sources of preoperative LOS prolongation, shown in Figure 2. This diagram represents the relationship between a problem and its potential causes. Four major causes were identified: patient, healthcare staff, system, process and related secondary causes. Of course, the causes (Figure 2) correspond to some of the wastes mentioned by Usman (2020) in Table 1.

As highlighted in the Ishikawa diagram, the causes that prolong patients' LOS affected by oral cancer are mainly related to the following wastes: long waits before providing the service of a test/exam or specialist consultancy (system); over production of services due to patients' co-morbidities and social factors (due to patients); defects in the service offered, i.e. errors in the paperwork, due to the difficulties encountered by the healthcare staff with an information system (healthcare staff) and thus over processing of healthcare activities due to a lack of organization of the staff and complex bureaucratic procedures (process).
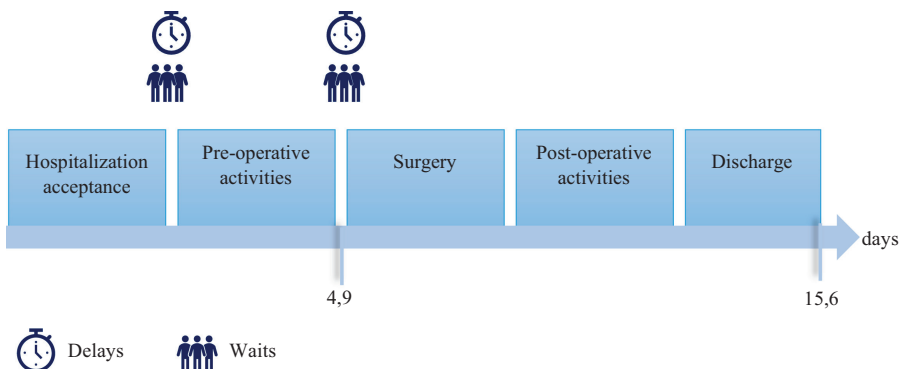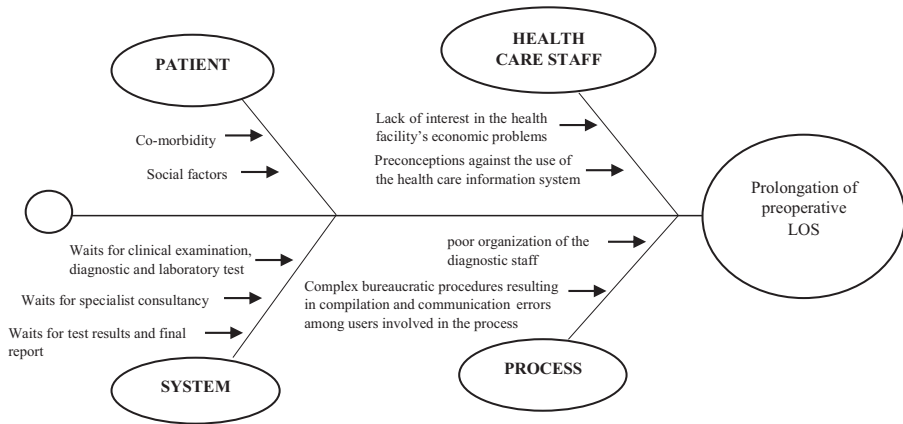

Figure 1.
A basic value stream map of process performance, pre-improvement (2006–2008)

Figure 2.
Ishikawa diagram of process performance

Since previous wastes and their causes generated a prolongation of preoperative LOS, they are measured by analysing LOS. In fact, to support planning of Lean solutions, we considered interesting to understand which clinical characteristics of the patients could influence preoperative LOS (Improta *et al.*, 2019c; Manyam *et al.*, 2020). Statistical tests were conducted to investigate which independent clinical variables could effectively influence preoperative LOS. The variables considered were gender, age, American Society of Anaesthesiologists Score (ASA score), oral hygiene, diabetes, cardiovascular diseases. To test the normality of the data distribution, the Kolmogorov–Smirnov test was performed, with a significance level 0.05. So, the data did not follow a normal distribution. The Mann–Whitney test was used to compare the mean of the categories related to each single dichotomous variable, while the Kruskal–Wallis test for the non-dichotomous variable (age only). The results, in Table 2, show that the variable age has a weak influence on preoperative LOS, the presence of cardiovascular disease and diabetes in patients significantly influence, while the other variables have no influence it. However, patients with cardiovascular disease or diabetes need to be strictly monitored because of their blood pressure, their cardiovascular symptoms and their glycaemia. Sometimes, medical team, following the anaesthesiologic visit and prescriptions, needs to change cardiac and/or diabetes therapy before major surgery. In fact, in most cases, these patients included specialized non-routine and unscheduled tests that required long waits for their booking and execution, inevitably elongate time of hospitalization.

3.5 Lean solutions
From previous analyses, the research team planned and implemented solutions in close collaboration with physicians, nurses and management staff. The goal was to improve the performance of the hospitalization, so is important to reduce wastes and inefficiencies detected, thus reducing LOS. Therefore, the solutions are described below.

Since 2009 Maxillofacial Surgery Unit of the University Hospital "Federico II" of Naples started to use the pre-hospitalization to reduce the period of hospitalization and guarantee a timely treatment to the patients. The timeline previews the first visit in the ambulatory where a first suspect of diagnosis is made. In the ambulatory the patient is addressed to practice a biopsy of the neoplasm and diagnostic tests are required. When the patient is registered for the biopsy the medical team assigns a priority for the protocol to guarantee a fast treatment. Often, due to the long waiting list to practice some diagnostic exam in the hospital, patients

Variable	Category	N	Preoperative LOS mean ± Std. Dev pre-improvement	p-value
Gender	Man	37	4.70 ± 4.40	0.415
	Women	28	5.18 ± 4.57	
Age	<55	25	3.80 ± 4.01	0.051
	55 ≤ Age ≥ 70	24	4.54 ± 3.03	
	>70	16	7.19 ± 6.08	
ASA score	Low	46	4.67 ± 4.13	0.919
	High	19	5.47 ± 5.23	
Oral hygiene	Low	17	6.41 ± 5.54	0.136
	High	48	4.38 ± 3.92	
Diabetes	No	61	4.46 ± 3.99	0.008**
	Yes	4	11.75 ± 6.13	
Cardiovascular	No	50	3.88 ± 3.21	0.003**
diseases	Yes	15	8.33 ± 6.17	

Note(s): *significance at 0.05; **significance at 0.01; *** significance at 0.001

Table 2.
Variables influencing
preoperative LOS

are invited to practice it externally. This assures the possibility to get the diagnostic report in time and start to plan the treatment. During this time, patients are not obliged to stay in the hospital. Once the histological report is ready, patients are claimed to come to the ambulatory to get it. If the histological report shows a situation that need to treat, the patient is admitted in the waiting list for the hospitalization with a priority.

The pre-hospitalization previews a first access to the department to open the medical record and practice last exams (blood tests, electrocardiogram, x-ray) required for the anaesthesiologic evaluation. Once the medical record is opened and exams are ready, the patient is visited by the anaesthesiologic team, which assigns the American Society of Anaesthesiologists (ASA) risk score. The anaesthesiologist analyses the clinical background of the patients and his associated diseases. After the surgical planning, the patient is ready for hospitalization and to the surgery.

However, a simplification of complex bureaucratic procedures was recommended to reduce compilation and communication errors between users involved in the process. Procedures for an optimization of the waiting lists and work shift planning were introduced to ensure greater availability of diagnostic staff in handling cases.

Information and training meetings were held in which the medical staff were invited to overcome the preconceptions against the information system, showing the advantages in terms of speed, sharing and process optimization. In addition, other meetings were organized between healthcare managers and medical staff with the aim of informing them about the financial problems of the healthcare facility and the economic implications that could derive from non-compliance.

Unlike the implementation of pre-hospitalization, the latter solutions proposed will not apply immediately but will be adopted gradually over time.

As of 2009, the proposed solutions were implemented, and the results were observed. The solutions are summarized in Table 3.

4. Results
The Lean solutions described above were implemented. The most important Lean solution was the pre-hospitalization service. The other solutions will apply gradually over time.

To evaluate the improvement of the hospitalization process, the minimization of wastes was verified by analysing the LOS. In fact, the findings, discussed below, verify the reduction of preoperative LOS after the implementation of Lean solutions.

Cause	Solution
Waits for clinical examination, diagnostic and laboratory tests	Pre-hospitalization service
Waits for specialist consultancy	
Waits for test results and final report	
Complex bureaucratic procedures resulting in compilation and communication errors among users involved in the process	The simplification of bureaucratic procedures
Poor organization of diagnostic staff	Work shift planning
Preconceptions against the use of the healthcare information system	Promotion of the healthcare information system
Lack of interest in the health facility's economic problems	Planning of information and training activities

Table 3.
Causes and solutions

Therefore, the performance indicators of preoperative LOS before and after the introduction of pre-hospitalization were calculated and showed in Table 4, (Improta *et al.*, 2018b). They indicate from 2006 to 2008 (pre-improvement) 40% of patients had preoperative LOS $\geq$ 5 days, instead only 60% of patients had preoperative LOS <5 days. While, from 2009 to 2018 (post-improvement) a reduction in the percentage of patients with preoperative LOS $\geq$ 5 days (−6.28%) was observed.

Furthermore, in Table 5 the total LOS' mean was about 11.77 days compared to 15.60 days calculated without pre-hospitalization while the standard deviation indicates a greater variability of LOS compared to the mean value.

However, the Mann–Whitney test was performed to verify the significance of the difference in preoperative LOS between two independent samples (pre- and post-improvement) overall and for each category related to clinical variables. The null hypothesis is H$_0$: $M_1 = M_2$; instead the alternative hypothesis is H$_1$: $M_1 \neq M_2$; where M_1 indicates the mean of pre-improvement preoperative LOS and M_2 indicates the mean of post-improvement preoperative LOS. The difference in preoperative LOS for each category related to clinical variables is statistically significant when the p-value is < 0.05, so the null hypothesis is rejected.

The results of hypothesis tested, in Table 6, show that the overall mean of preoperative LOS of patients hospitalized decreased from 4.90 to 3.80 days (−22.40%), resulting statistically significant (p-value 0.001). All categories have a statistically significant difference before and after Lean solutions, except for the category of patients aged 55 to

Table 4.
Performance measurements

	Pre-improvement %	Post-improvement %
Percentage of patients with preoperative LOS < 5 days	60	66.28
Percentage of patients with preoperative LOS $\geq$ 5 days	40	33.72

Table 5.
Descriptive statistical analysis

	Mean ± Std. Dev pre-improvement	Mean ± Std. Dev post-improvement
Total length of stay (days)	15.60 ± 12.07	11.77 ± 17.64
Preoperative length of stay (days)	4.90 ± 4.45	3.80 ± 5.30
Post-operative length of stay (days)	10.68 ± 11.68	7.99 ± 14.37

Variables	Category	Preoperative LOS mean ± Std. Dev pre-improvement	Preoperative LOS mean ± Std. Dev post-improvement	Difference [%]	p-value
Overall		4.90 ± 4.45	3.80 ± 5.30	−22.40	0.001**
Gender	Man	4.70 ± 4.40	3.33 ± 4.42	−29.10	0.010*
	Women	5.18 ± 4.57	4.20 ± 6.03	−18.90	0.039*
Age	<55	3.80 ± 4.01	2.56 ± 4.21	−32.60	0.004**
	55 ≤ Age ≥ 70	4.54 ± 3.03	4.51 ± 6.54	−0.70	0.107
	>70	7.19 ± 6.08	5.71 ± 4.42	−20.60	0.728
ASA score	Low	4.67 ± 4.13	1.51 ± 3.12	−67.70	≤0.001***
	High	5.47 ± 5.23	8.00 ± 5.94	46.30	0.117
Oral hygiene	Low	6.41 ± 5.54	6.00 ± 5.55	−6.40	0.635
	High	4.38 ± 3.92	2.81 ± 4.91	−35.80	≤0.001***
Diabetes	No	4.46 ± 3.99	3.25 ± 4.77	−27.1	0.001**
	Yes	11.75 ± 6.13	8.22 ± 7.52	−30	0.503
Cardiovascular disease	No	3.88 ± 3.21	3.46 ± 5.44	−10.80	0.006**
	Yes	8.33 ± 6.17	4.22 ± 5.12	−49.30	0.012*
Note(s): *significance at 0.05; **significance at 0.01; *** significance at 0.001					

Table 6.
Statistical analysis of
LOS related to each
variable and category

70 and those over 70, patients with a high ASA score, poor oral hygiene and with diabetes. Among the statistically significant variables, patients with low ASA score show the most significant decrease, approximately 67.70% in terms of mean values.

Finally, a run chart for the preoperative LOS of both periods is shown in Figure 3, it is simple to verify the result of our study.

5. Discussion and conclusion

Lean approaches had been originally developed for the automotive and manufacturing industry. Today, the service industry, especially the hospitals have been wise to adapt to Lean transformation by applying similar Lean techniques to their processes (Yu *et al.*, 2021; Ahn *et al.*, 2021). Lean is an approach which improves healthcare service quality by eliminating faults and decreasing patient waiting times through effective use of available resources (Graban, 2011; Godley and Jenkins, 2019; Sales and De Castro, 2021). Many authors have implemented Lean applications in healthcare through case studies confirming the validity of the methodology (Chiarini, 2014; Jorma *et al.*, 2016; Yurtkuran *et al.*, 2017; Sánchez *et al.*, 2018; Bharsakade *et al.*, 2021).

The objective of this study was to improve the performance of the hospitalization process by implementing Lean solutions according to a culture of continual improvement. The research team, to support the planning of Lean solutions, in addition to using Lean tools (basic VSM and Ishikawa diagram) also studied the influence of clinical variables on preoperative LOS, the results were reported in Table 2. Practical implementation of Lean solutions, and especially pre-hospitalization, improved hospitalization performance. Indeed, there was a significant reduction in the overall preoperative mean LOS of patients undergoing oral cancer surgery.

Table 6 shows the results of the comparison of mean preoperative LOS between pre-improvement (without Lean solutions) and post-improvement situations (with Lean solutions) for each category related to clinical variables. Analysing the overall patients, we registered a diminishing of the preoperative LOS for the 22.40%, with a *p*-value of 0.001. Regarding the variations for each category of clinical variables, statistically significant differences were noted when we refer to the age, ASA score, oral hygiene, cardiovascular disease and diabetes.
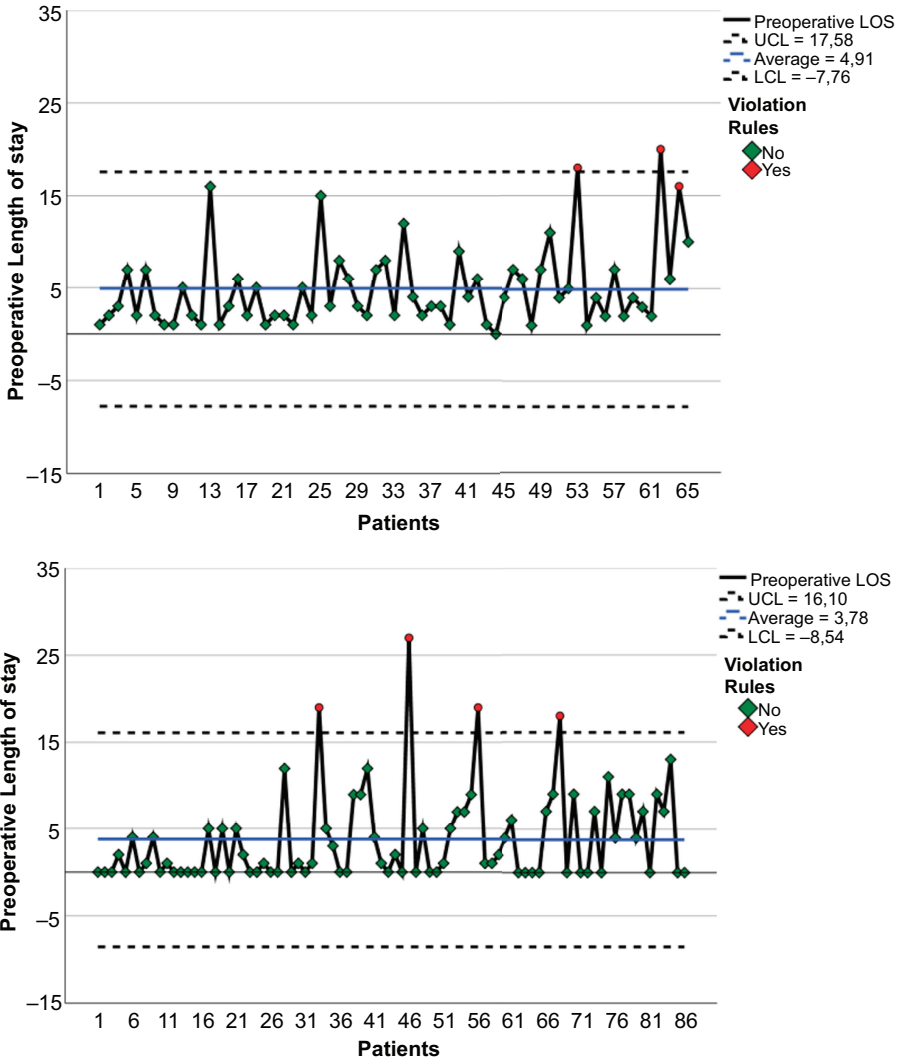
Figure 3.
Run chart before (left side) and after (right side) pre-hospitalization

The most important reduction of preoperative LOS about 67.70%, in terms of mean values, is recorded for patients with a low ASA score (p-value ≤ 0.001). This can be explained because patients with a low ASA score, generally, have less comorbidities and need easier management than those with more comorbidities and their LOS is generally shorter. For the same reason, patients with high oral hygiene have a lower preoperative LOS with a difference of -35.80% (p-value 0.001). Non-diabetics and patients without cardiovascular disease have respectively -27.10% and -10.80% of preoperative LOS after improvement. Their difference is statistically significant with a p-value of 0.001 and 0.006, respectively, as these patients require fewer diagnostic tests and a simple preparation for surgery. In addition, even patients with cardiovascular disease, after improvement, benefited from a statistically significant improvement (p-value 0.012) in preoperative LOS (-49.30%), mainly due to better planning

of diagnostic tests and therapies. Finally, lower preoperative LOS (-32.60%) statistically significant (p-value 0.004) is shown for patients under the age of 55, mainly because they have a relatively good health status and fewer clinical aspects to manage.

However, the improvement in the hospitalization process was verified through the significant reduction in LOS. In addition to this finding, patients, hospital employees and healthcare management involved in the process received benefits from Lean management, as also justified in the literature (Sunder *et al.*, 2020; Salam and Khan, 2016; Rosas-Hernandez *et al.*, 2019; Qin *et al.*, 2019).

For patients, a reduction in LOS improves patient satisfaction and experience, as they receive quality and faster service. In fact, Sunder *et al.* (2020) demonstrate how LSS improved patient satisfaction in a mobile hospital in India by reducing turnaround times by providing healthcare services. While Salam and Khan (2016) through the LT improved the system-wide process by becoming more efficient, faster and safer, and consequently helped to increase patient satisfaction.

For hospital employees, the reduction of wastes (time, overworking, potential errors, etc.) and simplification of bureaucratic procedures reduce workload, stress and fatigue, increasing their motivation and commitment. However, in the study of Rosas-Hernandez *et al.* (2019) show that the implementation of LT provides an effective approach to reduce wastes improving process efficiency. The results had a direct effect on cost reduction, better resource utilization and reduction of staff processing time, which can lead to a better work climate.

For healthcare management, an increase in efficiency and better planning of the process implies more availability of beds, potentially increasing the capacity and activities of the process, but also a reduction in hospital costs linked to fewer days of hospitalization. In fact, Qin *et al.* (2019) applied Lean principles to standardize the patient management process in a stroke centre. The results were the effective use of medical resources, improved quality of care and consequently the reduction of management costs.

In conclusion, this article has demonstrated the validity of the principles and tools of the LT in the healthcare context. The findings, as discussed earlier, showed that it was possible to verify the hypothesis underlying the study, that is, to improve the performance of the hospitalization process by reducing LOS after the implementation of Lean solutions. A similar research to our work was that of Cifone *et al.* (2019), they implemented a healthcare process improvement project following the principles of the LT. The results were a minimization of the wastes and then reduction in the LOS.

Finally, there is a limitation and a future development. The sample size was relatively small because the study was conducted only at the Maxillofacial Surgery Department and refers to the specific context of oral cancer removal surgery. In the future, this type of analysis can be performed on a larger sample of hospital departments to improve the overall healthcare system.

5.1 Practical implications

Implementing Lean solutions through this methodology has implications. The management implication is framed by the positive impact on society of the previous benefits for hospitals and patients. More interesting is the practical implication, that is the substantial reduction of hospital costs from the reduction of LOS. However, the daily hospitalization fee for surgery or medical treatment of oral cancer is € 201.42. Thus, considering the reduction in LOS from 15.60 days to 11.77 days, on average, the hospital saves € 771.44 for each individual patient. Multiplying this amount by the number of patients hospitalized in a year, it promises great economic savings. Finally, the contribution of the authors to the part of the practical and managerial implications consists in providing management support in organizing health processes in quality.

Abbreviations

AIOM	Associazione Italiana di Oncologia Medica
AIRTUM	Associazione Italiana dei Registri Tumori
LT	Lean Thinking
SS	Six Sigma
LSS	Lean Six Sigma
TPS	Toyota Production System
ED	Emergency Department
DTAP	diagnostic-therapeutic-care pathway
LOS	Length of Hospital Stay
VSM	Value Stream Map
ASA Score	American Society of Anaesthesiologists Score

Notes

1. I numeri del cancro in Italia - Report 2019 AIOM/AIRTUM - https://www.aiom.it/wp-content/uploads/2019/09/2019_Numeri_Cancro-operatori-web.pdf

2. Nota di aggiornamento del Documento di Economia e Finanza 2019 - http://www.dt.mef.gov.it/modules/documenti_it/analisi_progammazione/documenti_programmatici/def_2019/NADEF_2019__FINALE.pdf

References

Abdallah, A.A. (2020), "Healthcare engineering: a lean management approach", *Journal of Healthcare Engineering*, Vol. 2020, p. 17, doi: 10.1155/2020/8875902.

Ahn, C.M.P.H., Rundall, T.G., Shortell, S.M., Blodgett, J.C. and Reponen, E.M.D. (2021), "Lean management and breakthrough performance improvement in health care", *Quality Management in Health Care*, Vol. 30 No. 1, pp. 6-12, doi: 10.1097/QMH.0000000000000282.

Akmal, A., Greatbanks, R. and Foote, J. (2020), "Lean thinking in healthcare – findings from a systematic literature network and bibliometric analysis", *Health Policy*, Elsevier Ireland, Vol. 124 No. 6, pp. 615-627, doi: 10.1016/j.healthpol.2020.04.008.

Alfaro, C.R., Madrigal, G.B. and Hernández, M.C. (2020), "Improving forensic processes performance: a Lean Six Sigma approach", *Forensic Science International: Synergy*, Vol. 2, pp. 90-94.

Alkaabi, M., Simsekler, M., Jayaraman, R., Al Kaf, A., Ghalib, H., Quraini, D., Ellahham, S., Tuzcu, E.M. and Demirli, K. (2021), "Evaluation of system modelling techniques for waste identification in lean healthcare applications", *Risk Management and Healthcare Policy*, Vol. 13, pp. 3235-3243, doi: 10.2147/RMHP.S283189.

Al-Araidah, O., Momani, A., Khasawneh, M. and Momani, M. (2010), "Lead-time reduction utilizing lean tools applied to healthcare: the inpatient pharmacy at a local hospital", *Journal for Healthcare Quality*, Vol. 32 No. 1, pp. 59-66.

Amaral, L.C., Calado, R.D., Teixeira, A.M., Silva, M.H.T.D., Bourguignon, S.C. and Costa, H.G. (2020), "Systematic review and meta-analysis of the use of lean methods and tools in healthcare services: an alternative to improve care during the pandemic", *Research Square*. doi: 10.21203/rs.3.rs-53743/v1.

Amaro, P., Alves, A.C. and Sousa, R.M. (2020), "Lean thinking: from the shop floor to an organizational culture", *IFIP International Conference on Advances in Production Management Systems*, Springer, Cham, pp. 406-414.

Amrani, A. and Ducq, Y. (2020), "Lean practices implementation in aerospace based on sector characteristics: methodology and case study", *Production Planning and Control*, Vol. 31 No. 16, pp. 1313-1335.

Antony, J. and Kumar, M. (2012), "Lean and six sigma methodologies in NHS Scotland: an empirical study and directions for future research", *Quality Innovation Prosperity*, Vol. 16 No. 2, pp. 19-34.

Babu Purushothaman, M., Seadon, J. and Moore, D. (2020), "Waste reduction using lean tools in a multicultural environment", *Journal of Cleaner Production*, Vol. 265, 121681, doi: 10.1016/j.jclepro.2020.121681.

Bharsakade, R.S., Acharya, P., Ganapathy, L. and Tiwari, M.K. (2021), "A lean approach to healthcare management using multi criteria decision making", *Opsearch*, pp. 1-26.

Blouin-Delisle, C.H., Drolet, R., Hains, M., Tailleur, L., Allaire, N., Martin, C. and Vézo, A. (2020), "Improving interprofessional approach using a collaborative lean methodology in two geriatric care units for a better patient flow", *Journal of Interprofessional Education and Practice*, Vol. 19, doi: 10.1016/j.xjep.2020.100332.

Cabrera, C.I., Ning, A.Y., Cai, Y. and D'Anza, B. (2020), "Systematic review of telehealth cost minimization for patients and health systems in otolaryngology", *The Laryngoscope*.

Catalyst, N.E.J.M. (2018), *What is Lean Healthcare?*, NEJM Catalyst.

Chaturvedi, A.K., Anderson, W.F., Lortet-Tieulent, J., Curado, M.P., Ferlay, J., Franceschi, S. and Gillison, M.L. (2013), "Worldwide trends in incidence rates for oral cavity and oropharyngeal cancers", *Journal of Clinical Oncology*, Vol. 31 No. 36, pp. 4550-4559.

Chiarini, A. (2014), "Lean thinking implementation in the public healthcare: results from Italy", *17th Toulon-Verona International Conference 'Excellence in Services', Toulon-Verona International Conference*.

Cifone, F.D., Portioli-Staudacher, A. and Silla, A. (2019), "Lean healthcare: how to start the lean journey", *European Lean Educator Conference*, Springer, Cham, pp. 321-329.

Coelho, S.M., Pinto, C.F., Calado, R.D., Marotta, E.A., Romano, E. and Silva, M.B. (2015), "Lean healthcare", *Journal of Innovation and Healthcare Management*, Vol. 1 No. 1, pp. 1-9.

Converso, G., De Carlini, R., Santillo, L.C. and Improta, G. (2012), "Project Management implementation for healthcare activities organization", *Advances in Computer Science*, Vol. 8, pp. 436-443.

Costa, L.B.M. and Filho, M.G. (2016), "Lean healthcare: review, classification and analysis of literature", *Production Planning and Control*, Vol. 27 No. 10, pp. 823-836.

Costa, L.B.M., Rentes, A.F., Bertani, T.M. and Mardegan, R. (2017), "Lean healthcare in developing countries: evidence from Brazilian hospitals", *The International Journal of Health Planning and Management*, Vol. 32 No. 1, pp. 99-120.

Cruz Machado, V. and Leitner, U. (2010), "Lean tools and lean transformation process in health care", *International Journal of Management Science and Engineering Management*, Vol. 5 No. 5, pp. 383-392.

Daultani, Y., Chaudhuri, A. and Kumar, S. (2015), "A decade of lean in healthcare: current state and future directions", *Global Business Review*, Vol. 16 No. 6, pp. 1082-1099.

De Koning, H., Verver, J.P., van den Heuvel, J., Bisgaard, S. and Does, R.J. (2006), "Lean six sigma in healthcare", *Journal for Healthcare Quality*, Vol. 28 No. 2, pp. 4-11.

D'Addio, G., Ricciardi, C., Improta, G., Bifulco, P. and Cesarelli, M. (2019), "Feasibility of machine learning in predicting features related to congenital nystagmus", *Mediterranean Conference on Medical and Biological Engineering and Computing*, Springer, Cham, pp. 907-913, doi: 10.1007/978-3-030-31635-8_110.

El-namrouty, K. and Abushaaban, M.S. (2013), "Seven wastes elimination targeted by lean manufacturing case study 'Gaza strip manufacturing firms'", *International Journal of Economics, Finance and Management Sciences*, Vol. 1 No. 2, pp. 68-80.

Fantola, G., Agus, M., Runfola, M., Podda, C., Sanna, D., Fortunato, F., Pintus, S. and Moroni, R. (2020), "How can lean thinking improve ERAS program in bariatric surgery?", *Surgical Endoscopy*, pp. 1-11.

Gayed, B., Black, S., Daggy, J. and Munshi, I.A. (2013), "Redesigning a joint replacement program using lean six sigma in a veterans affairs hospital", *JAMA Surgery*, Vol. 148 No. 11, pp. 1050-1056.

George, M.L. (2003), *Lean Six Sigma for Services*, McGraw-Hill, New York, NY.

Godley, M. and Jenkins, J.B. (2019), "Decreasing wait times and increasing patient satisfaction: a lean six sigma approach", *Journal of Nursing Care Quality*, Vol. 34 No. 1, pp. 61-65.

Graban, M. (2011), *Lean Hospitals: Improving Quality, Patient Safety, and Employee Engagement*, CRC Press.

Haddad, M.G., Zouein, P.P., Salem, J. and Otayek, R. (2016), "Case study of lean in hospital admissions to inspire culture change", *Engineering Management Journal*, Vol. 28 No. 4, pp. 209-223.

Improta, G., Balato, G., Romano, M., Carpentieri, F., Bifulco, P., Alessandro Russo, M., Rosa, D., Triassi, M. and Cesarelli, M. (2015), "Lean six sigma: a new approach to the management of patients undergoing prosthetic hip replacement surgery", *Journal of Evaluation in Clinical Practice*, Vol. 21 No. 4, pp. 662-672, doi: 10.1111/jep.12361.

Improta, G., Balato, G., Romano, M., Ponsiglione, A.M., Raiola, E., Russo, M.A., Cuccaro, P., Santillo, L.C. and Cesarelli, M. (2017), "Improving performances of the knee replacement surgery process by applying DMAIC principles", *Journal of Evaluation in Clinical Practice*, Vol. 23 No. 6, pp. 1401-1407, doi: 10.1111/jep.12810.

Improta, G., Cesarelli, M., Montuori, P., Santillo, L.C. and Triassi, M. (2018a), "Reducing the risk of healthcare-associated infections through lean six sigma: the case of the medicine areas at the Federico II university hospital in Naples (Italy)", *Journal of Evaluation in Clinical Practice*, Vol. 24 No. 2, pp. 338-346, doi: 10.1111/jep.12844.

Improta, G., Romano, M., Di Cicco, M.V., Ferraro, A., Borrelli, A., Verdoliva, C., Triassi, M. and Cesarelli, M. (2018b), "Lean thinking to improve emergency department throughput at AORN Cardarelli hospital", *BMC Health Services Research*, Vol. 18 No. 1, p. 914, doi: 10.1186/s12913-018-3654-0.

Improta, G., Ricciardi, C., Borrelli, A., D'alessandro, A., Verdoliva, C. and Cesarelli, M. (2019a), "The application of six sigma to reduce the pre-operative length of hospital stay at the hospital Antonio Cardarelli", *International Journal of Lean Six Sigma*, Vol. 11 No. 3, pp. 555-576, doi: 10.1108/IJLSS-02-2019-0014.

Improta, G., Balato, G., Ricciardi, C., Russo, M.A., Santalucia, I., Triassi, M. and Cesarelli, M. (2019b), "Lean Six Sigma in healthcare: fast track surgery for patients undergoing prosthetic hip replacement surgery", *The TQM Journal*, Vol. 31 No. 4, pp. 526-540, doi: 10.1108/TQM-10-2018-0142.

Improta, G., Ricciardi, C., Amato, F., D'Addio, G., Cesarelli, M. and Romano, M. (2019c), "Efficacy of machine learning in predicting the kind of delivery by cardiotocography", *Mediterranean Conference on Medical and Biological Engineering and Computing*, Springer, Cham, pp. 793-799, doi: 10.1007/978-3-030-31635-8_95.

Improta, G., Guizzi, G., Ricciardi, C., Giordano, V., Ponsiglione, A.M., Converso, G. and Triassi, M. (2020), "Agile six sigma in healthcare: case study at Santobono Pediatric hospital", *International Journal of Environmental Research and Public Health*, Vol. 17 No. 3, p. 1052, doi: 10.3390/ijerph17031052.

Jorma, T., Tiirinki, H., Bloigu, R. and Turkki, L. (2016), "LEAN thinking in Finnish healthcare", *Leadership in Health Services*, Vol. 29 No. 1, pp. 9-36, doi: 10.1108/LHS-08-2015-0021.

Karam, M.B., Doroudinia, A., Nainee, A.S., Kaghazchi, F., Koma, A.Y., Mehrian, P. and Hossein, F.A. (2017), "Role of FDG PET/CT scan in head and neck cancer patients", *Archives of Iranian Medicine*, Vol. 20 No. 7, pp. 452-458.

Kelendar, H. (2020), "Lean thinking from Toyota manufacturing to the healthcare sector", *Research in Medical and Engineering*, Vol. 8 No. 5, RMES.000697, doi: 10.31031/RMES.2020.08.000697.

Kelendar, H. and Mohammed, M.A. (2020), "Lean and the ECRS principle: developing a framework to minimise waste in healthcare sectors", *International Journal of Public Health and Clinical Sciences*, Vol. 7 No. 3, pp. 98-110.

Kumar, M., Nanavati, R., Modi, T.G. and Dobariya, C. (2016), "Oral cancer: etiology and risk factors: a review", *Journal of Cancer Research and Therapeutics*, Vol. 12, pp. 458-63.

Lot, L.T., Sarantopoulos, A., Min, L.L., Perales, S.R., Boin, I.D.F.S.F. and Ataide, E.C.D. (2018), "Using Lean tools to reduce patient waiting time", *Leadership in Health Services*, Vol. 31 No. 3, pp. 343-351.

Lucchese, A., Marino, A. and Ranieri, L. (2020), "Minimization of the Logistic Costs in Healthcare supply chain: a hybrid model", *Procedia Manufacturing*, Vol. 42, pp. 76-83.

Manyam, R., Zhang, Y., Carter, S., Binongo, J.N., Rosenblum, J.M. and Keeling, W.B. (2020), "Unraveling the impact of time-dependent perioperative variables on 30-day readmission after coronary artery bypass surgery", *The Journal of Thoracic and Cardiovascular Surgery*.

Marin-Garcia, J.A., Vidal-Carreras, P.I., Garcia-Sabater, J.J. (2021), "The role of value stream mapping in healthcare services: a scoping review", *International Journal of Environmental Research and Public Health*, Vol. 18 No. 3, p. 951, doi: 10.3390/ijerph18030951.

Mazzocato, P., Savage, C., Brommels, M., Aronsson, H. and Thor, J. (2010), "Lean thinking in healthcare: a realist review of the literature", *BMJ Quality and Safety*, Vol. 19 No. 5, pp. 376-382.

McKenry, M.C. (2012), *Deming-based Lean-Six Sigma Applied to the Length of Stay in an Urban Emergency Department*, University of Miami.

Montella, E., Di Cicco, M.V., Ferraro, A., Centobelli, P., Raiola, E., Triassi, M. and Improta, G. (2017), "The application of Lean Six Sigma methodology to reduce the risk of healthcare–associated infections in surgery departments", *Journal of Evaluation in Clinical Practice*, Vol. 23 No. 3, pp. 530-539, doi: 10.1111/jep.12662.

Montero, P.H. and Patel, S.G. (2015), "Cancer of the oral cavity", *Surgical Oncology Clinics of North America*, Vol. 24 No. 3, pp. 491-508, doi: 10.1016/j.soc.2015.03.006.

Morales-Contreras, M.F., Chana-Valero, P., Suárez-Barraza, M.F., Saldaña Díaz, A. and García García, E. (2020), "Applying lean in process innovation in healthcare: the case of hip fracture", *International Journal of Environmental Research and Public Health*, Vol. 17 No. 15, p. 5273.

Moreira, M.A., Lessa, L.S., Bortoli, F.R., Lopes, A., Xavier, E.P., Ceretta, R.A., Sônego, F.G.F., Tomasi, C.D., Pires, P.D.S., Ceretta, L.B., Perry, I.D.S. and Waleska Simões, P. (2017), "Meta-analysis of magnetic resonance imaging accuracy for diagnosis of oral cancer", *PLoS One*, Vol. 12 No. 5, e0177462, doi: 10.1371/journal.pone.0177462 (accessed 24 May 2017).

Mosè, G., Mario, D., Murino, T. and Carmela, S. (2012), "A simulation based approach for improving healthcare systems", *Proceedings of the 6th WSEAS European Computing Conference*, WSEAS, pp. 387-393.

Nae, A., O'Leary, G., Feeley, L., Fives, C., Fitzgerald, B., Chiriac, E. and Sheahan, P. (2019), "Utility of CT and MRI in assessment of mandibular involvement in oral cavity cancer", *World Journal Otorhinolaryngol Head Neck Surgery*, Vol. 5 No. 2, pp. 71-75, doi: 10.1016/j.wjorl.2019.02.001.

Nicolay, C.R., Purkayastha, S., Greenhalgh, A., Benn, J., Chaturvedi, S., Phillips, N. and Darzi, A. (2012), "Systematic review of the application of quality improvement methodologies from the manufacturing industry to surgical healthcare", *British Journal of Surgery*, Vol. 99 No. 3, pp. 324-335.

Ohno, T. (1988), *Toyota Production System: Beyond Large-Scale Production*, CRC Press.

Östlund, P. (2020), *Improving Materials Supply Processes to Assembly Lines through Toyota Production System and Lean Manufacturing*, LUND University Libraries.

Pavlović, D., Milosavljević, P. and Mladenović, S. (2020), "Synergy between industry 4.0 and lean methodology", *Journal of Mechatronics, Automation and Identification Technology*, Vol. 5 No. 4, pp. 17-20.

Pellini, F., Di Filippo, G., Mirandola, S., Deguidi, G., Filippi, E. and Pollini, G.P. (2021), "Effects of lean thinking and emerging technologies on breast cancer patients' therapeutic process during COVID-19 pandemic: a case-control matched study", *Frontiers in Surgery*, Vol. 8, p. 30.

Peynetti Velázquez, P., Gupta, G., Gupte, G., Carson, N.J. and Venter, J. (2020), "Rapid implementation of telepsychiatry in a safety-net health system during covid-19 using lean", *NEJM Catalyst Innovations in Care Delivery*, Vol. 1 No. 4.

Qin, C., Pan, L., Chen, Q., Lin, Q. and Zhang, D. (2019), "Application of lean management in cost control of cerebral infarction single disease in stroke center", *Zhonghua Wei Zhong Bing Ji Jiu Yi Xue*, Vol. 31 No. 5, pp. 637-640.

Ran, X., Zhou, F., Zhong, M., Liu, Y. and Zhang, J. (2020), "Innovative applications of patient experience big data in modern hospital management improve healthcare quality", *Chinese Medical Sciences Journal*, Vol. 35 No. 4, pp. 366-370.

Report Osservatorio GIMBE n 7/2019 (2019), *Il definanziamento 2010-2019 del Servizio Sanitario Nazionale*, Fondazione GIMBE, Bologna, available at: www.gimbe.org/definanziamento-SSN.

Ricciardi, C., Fiorillo, A., Valente, A.S., Borrelli, A., Verdoliva, C., Triassi, M. and Improta, G. (2019), "Lean Six Sigma approach to reduce LOS through a diagnostic-therapeutic-assistance path at A.O.R.N. A. Cardarelli", *The TQM Journal*, Vol. 31 No. 5, pp. 657-672, doi: 10.1108/TQM-02-2019-0065.

Ricciardi, C., Sorrentino, A., Improta, G., Abbate, V., Latessa, I, Perrone, A., Triassi, M. and Dell'aversana Orabona, G. (2020a), "A health technology assessment between two pharmacological therapies through Six Sigma: the case study of bone cancer", *The TQM Journal*. doi: 10.1108/TQM-01-2020-0013.

Ricciardi, C., Edmunds, K.J., Recenti, M., Sigurdsson, S., Gudnason, V., Carraro, U. and Gargiulo, P. (2020b), "Assessing cardiovascular risks from a mid-thigh CT image: a tree-based machine learning approach using radiodensitometric distributions", *Scientific Reports*, Vol. 10 No. 1, pp. 1-13, doi: 10.1038/s41598-020-59873-9.

Ricciardi, C., Cantoni, V., Improta, G., Iuppariello, L., Latessa, I., Cesarelli, M., . . . and Cuocolo, A. (2020c), "Application of data mining in a cohort of Italian subjects undergoing myocardial perfusion imaging at an academic medical center", *Computer Methods and Programs in Biomedicine*, Vol. 189, 105343, doi: 10.1016/j.cmpb.2020.105343.

Ricciardi, C., Balato, G., Romano, M., Santalucia, I., Cesarelli, M. and Improta, G. (2020d), "Fast track surgery for knee replacement surgery: a lean six sigma approach", *The TQM Journal*, Vol. 32 No. 3, pp. 461-474, doi: 10.1108/TQM-06-2019-0159.

Rosas-Hernandez, L., Tlapa, D., Baez-Lopez, Y., Limon-Romero, J. and Perez-Sanchez, A. (2019), *Use of Lean Healthcare and DMAIC to Reduce Waste in a Public Hospital*, Preprints.

Sánchez, M., Suarez, M., Asenjo, M. and Bragulat, E. (2018), "Improvement of emergency department patient flow using lean thinking", *International Journal for Quality in Health Care*, Vol. 30 No. 4, pp. 250-256.

Salam, M.A. and Khan, S.A. (2016), "Value creation through lean management: a case study of healthcare service operations", *International Journal of Services and Operations Management*, Vol. 25 No. 3, pp. 275-293.

Sales, M. and De Castro, R. (2021), "Value-based lean implementation in a surgical unit: the impact of the methodology", *The TQM Journal*.

Scala, A., Trunfio, T.A., Della Vecchia, A., Marra, A. and Borrelli, A. (2020), "Lean six sigma approach to implement a femur fracture care pathway at 'San Giovanni di Dio e Ruggi d'Aragona' University Hospital", *European Medical and Biological Engineering Conference*, Springer, Cham, pp. 740-749.

Scala, A., Ponsiglione, A.M., Loperto, I., Della Vecchia, A., Borrelli, A., Russo, G., . . . and Improta, G. (2021), "Lean six sigma approach for reducing length of hospital stay for patients with femur fracture in a university hospital", *International Journal of Environmental Research and Public Health*, Vol. 18 No. 6, p. 2843.

Sunder, M.V., Mahalingam, S. and Krishna, M.S.N. (2020), "Improving patients' satisfaction in a mobile hospital using Lean Six Sigma–a design-thinking intervention", *Production Planning and Control*, Vol. 31 No. 6, pp. 512-526.

Sureshkannan, P. and Vijayprabhu, J.R. (2011), "Role of ultrasound in detection of metastatic neck nodes in patients with oral cancer", *Indian Journal of Dental Research*, Vol. 22 No. 3, pp. 419-423, doi: 10.4103/0970-9290.87064.

Torielli, R.M., Abrahams, R.A., Smillie, R.W. and Voigt, R.C. (2011), "Using lean methodologies for economically and environmentally sustainable foundries", *China Foundry*, Vol. 8 No. 1, pp. 74-88.

Toussaint, J. and Gerard, R.A. (2010), *On the Mend – Revolutionizing Healthcare to Save Lives and Transform the Industry*, Lean Enterprise Institute, Cambridge, MA.

Usman, I. (2020), "Lean hospital management implementation in health care service: a multicase study", *Systematic Reviews in Pharmacy*, Vol. 11 No. 3, pp. 361-371.

Womack, J.P. (2005), *Going Lean in Health Care*, IHI Innovation Series White Paper, Institute for Healthcare Improvement, Cambridge, MA.

Womack, J.P. and Jones, D.T. (1996), "Lean thinking—banish waste and create wealth in your corporation", *Journal of the Operational Research Society*, Vol. 48 No. 11, p. 1148.

Womack, J.P., Jones, D.T. and Roos, D. (1990), *The Machine that Changed the World: The Story of Lean Production*, 1st ed., HarperCollins, Philadelphia, PA.

Wong, T. and Wiesenfeld, D. (2018), "Oral cancer", *Australian Dental Journal*, Vol. 63 No. 1, doi: 10. 1111/adj.12594.

Young, T. and McClean, S. (2008), "A critical look at Lean Thinking in healthcare", *Quality and Safety in Health Care*, Vol. 17 No. 5, pp. 382-386, doi: 10.1136/qshc.2006.020131.

Yu, T., Demirli, K. and Bhuiyan, N. (2021), "Lean transformation framework for treatment-oriented outpatient departments", *International Journal of Production Research*, pp. 1-15.

Yurtkuran, A., Özdemir, D., Yurtkuran, D.M. and Emel, E. (2017), "Lean transformation to reduce costs in healthcare: a public hospital case in Turkey", *Journal of Hospital Administration*, Vol. 6 No. 4, p. 10.

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