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EXPERT REVIEW

Lean approach to improving performance and efficiency in a nuclear medicine department

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Abstract

Purpose Healthcare organizations using Lean Management have the potential to decrease the number of errors, reduce wait time and increase productivity. The aim of this review is to assess the literature with regard to the use and efficacy of Lean thinking and Lean methodologies within a Department of Nuclear Medicine.

Methods Several health departments have adopted lean thinking as a consistent approach to quality improvement. We considered studies that demonstrated improvements across a variety of outcomes: the common factor was the aim to improve services to the patient. Lean methodology was selected because it is widely used in the healthcare environment and many Lean tools (VSM, one-piece flow, 5S, spaghetti diagram, A3, cell design, SMED) were analyzed for different processes.

Results Many Lean studies have resulted in shortened queuing time, in cost-saving, in reducing defects, in increasing patient volume and in increasing staff and patient safety and satisfaction.

Conclusion Lean tools have the potential to reduce error and costs and improve quality. Because Radiology and Nuclear Medicine departments are similar concerning patient processes, they have plenty of potentials to benefit from systematic Lean adoption. We believe these principles can be applied to other health care delivery areas.

Keywords Lean management · Process improvement · Work analysis · Nuclear medicine · Value stream map · Cost-saving

Introduction

Lean thinking has been introduced in healthcare during the latest 3 decades in various areas of the world for the benefit of patients, employees and hospital organisation. The concept called "Lean management" or "Lean thinking" is commonly associated with Japanese manufacturing, particularly the Toyota Production System (TPS) [1–3]. In fact, Lean thinking is not associated with health care, where waste of time, money and supplies is typically a problem [4–6]. But the principles of Lean management can be applied in health care in much the same way they do in other industries. But is it possible to use a production system from industry in the hospital sector? In Italy, as in other European countries, health care costs are increasing more rapidly than costs for other products and services. Health care providers, particularly hospitals, are under significant pressure to reduce costs while at the same time improving service and patient safety, reducing patient waiting times, and minimizing errors and associated litigation. A possible way to achieve this result is by implementing Lean practice. However, the experiences of Lean projects in other industries have shown that Lean activities require time and perseverance associated to sponsor commitment combined with a bottom-up implementation. Lean interventions aim to improve quality, to reduce waste and to facilitate flow in the care processes of patients [7]. Recent studies have shown that patient outcomes can be improved by a Lean management system in healthcare institutions worldwide [8, 9]. Virginia Mason Medical Center believed the TPS would make "an excellent fit in health care" when they first began their Lean journey in 2001. This, which was the first consistent application of Lean thinking in healthcare, had a lot of media coverage, especially for

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the results obtained in a short time. After 20 years, even if the results were not as exciting as at the beginning, it is still necessary to recognize an epochal change in the ways of thinking and working in the health sector [10]. Because Lean transforms organizational culture from the inside out, it requires a major shift in roles: managers became facilitators, mentors, and teachers and allow front-line workers to make improvements. The entire staff must identify and solve problems with a continuous improvement attitude. For these reasons, the organization can achieve a number of benefits, which may include improved quality, increased operational flexibility, reduced cycle time within processes, more efficient use of space, consistent service delivery, reduced lead times, and reduced operating costs. Applying a Lean approach in diagnostic departments, such as Nuclear Medicine or Radiology, there are many opportunities for:

- Reduce clinical and technical errors and mistakes.
- Reduce patients and report waiting times.
- Improve patients outcomes.
- Increase staff productivity.
- Decrease costs.
- Improve employee and customer satisfaction.

Boyer states that the determinants of Lean success are the principles implemented, the actions taken and the changes made to the organization to achieve the desired performances [11]. Systematic studies have been conducted to investigate the effectiveness of Lean methodologies in various health care settings [12–16], but the real benefits within the field of Nuclear Medicine remain unclear. However, it implied a change in working culture, keeping up the flow in all steps of the production and minimizing every kind of waste in each step. Aim of our work is to demonstrate that the Lean approach may be applied to a Nuclear Medicine department improving performance and efficiency if we choose adequate tools.

Materials and methods

This review was conducted based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, as displayed in Fig. 1: first, identification; second, screening; third, eligibility; and fourth, inclusion [17]. In the first step, two research axes were defined, as follows: lean, and healthcare. Thus, the keywords: ("lean system" OR "lean thinking" OR "lean healthcare" OR "lean") AND ("healthcare" OR "health system" OR "hospital" OR "health care") were combined to retrieve posts in titles, abstracts, and keywords. Scientific articles were identified by keywords in the following databases: PubMed, Scopus and

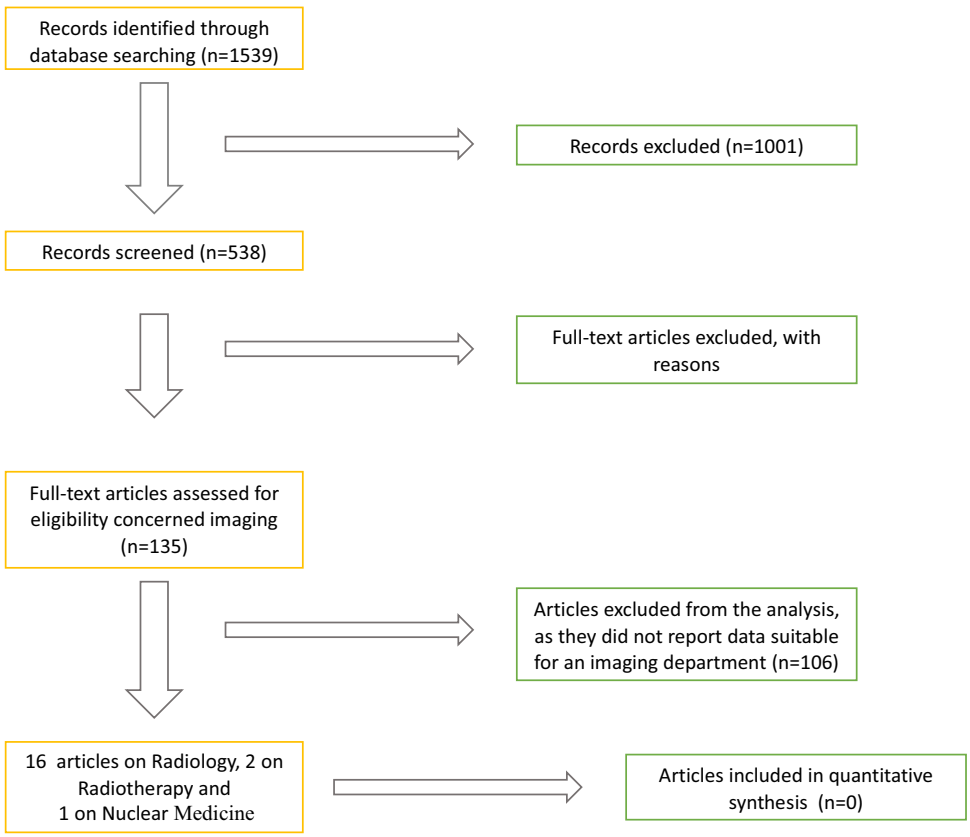

Fig. 1 Flowchart of information through the different phases of the systematic review [17]

Google Scholar. The second phase consists of the first filtering process, in which all publications have been thoroughly analyzed. There was no temporal delimitation of publications as it was included in the last 20 years. Thus, after the first filtering process from the 1539 articles identified by the databases (1143 in the last 10 years), 538 of them were screened to be assessed full text. Of these 135 concerned radiological imaging. The third step consists of eligibility. Of the 135 articles concerned radiological imaging, only 19 were adequate. Of the 21 publications that included the keyword "nuclear medicine", only two dealt with the topic but none of the significant relevance in terms of management and organization. In fact, of the two articles on nuclear medicine, one abstract [18] concerned software to optimize PET/CT acquisitions in oncology and the other concerned the improvement of the sentinel lymph node protocol [19]. Each study was independently screened by two reviewers to identify the title, abstract, and keywords: the disagreements were about 9% and were solved by means of discussion. Then we retrieved and assessed the full texts of the relevant studies. Given the heterogeneity of the studies in terms of their study designs (mainly observational and descriptive), settings, and outcomes, we were unable to pool the results and conduct a meta-analysis. Therefore, we provide comments and discussion for the main outcomes using the measures of effect in the same way as they were reported by authors.

There only a limited number of healthcare organizations who have published their efforts with Lean in the literature and even fewer in the imaging area. As there are currently no articles on lean healthcare in nuclear medicine, references to nuclear medicine in imaging or service articles have been considered. In particular, the articles on organization in radiology have been adapted due to the sharing of many processes between the two diagnostic areas. Since there are currently no scientific reviews on the applications of the Lean system in nuclear medicine, a concise explanation of the main tools that have been described in the articles with applications to the imaging departments appears necessary. Lean tools grew out of the need to have mechanisms in place to support the Lean way of thinking and to allow *flow* to permeate a process. Value Stream Mapping, Spaghetti Diagram, 5S, One Piece Flow, A3, Cell Design and Six Sigma are among the most popular Lean tools.

Value stream mapping

A Value Stream Mapping (VSM) is a basic lean technique used to document, analyze and improve the flow of information or materials needed to produce a product or service for a customer. This technique identifies the chain of processes involved in creating a service, thus helping workers to detect inefficiencies, workload variability and non-value-added activities (NVA) that lead to increased waste [20]. VSM is a demanding job because it requires analyzing a process as if each phase were not value-added but as if it cost the organization time and resources. A member of the Lean group, together with a member of the nuclear medicine team, follows the patient's activities step by step through the system from arrival until the report is returned. It is necessary to measure the time taken for each phase of the workflow and the waiting time between phases. Each step is analyzed and what creates value for the patient is identified. Problems in the workflow are identified, an effort is made to solve them, presenting the correct future flow. The 5 Whys is an easy way to eliminate as many non-value-added steps as possible. From the VSM analysis, it was possible to calculate the times and routes necessary for the manual administration of FDG-F18 to patients in a PET center; in one study, this evaluation was repeated after the installation of an automated infusion system. This study made it possible to calculate a reduction in the infusion time of approximately 50% and a reduction in the distance of approximately 14%. However, an increase in costs related to the purchase of consumables, such as infusion systems, remains to be considered [21].

5S

The implementation of this method allows to organize the workplace basically in its existing configuration and is generally the first Lean method that organizations implement to improve the warehouse. The 5S (Sort, Set in Order, Sweep, Standardize and Sustain) provide a methodology for organizing, cleaning, developing and sustaining a productive work environment. 5S is a system for reducing waste and maximizing productivity by maintaining an orderly workplace and using visual cues to achieve more consistent operational results. In the daily work of a company, routine activities that ensure organization and order are essential for a smooth and efficient flow of activities. This lean method encourages workers to improve their working conditions and helps them learn how to reduce waste, unplanned downtime and in-process inventory. It would be critical in organizing tools and materials in labeled and color-coded storage locations, as well as "kits" that contain exactly what is needed to perform a task (Fig. 2). Most organizations report an efficiency improvement of at least 10% in the first few months, which is sustainable over time. This tool is particularly useful for organizing the radiopharmaceutical preparation and patient injection rooms. Arranging drugs in cabinets and refrigerators also requires a 5S-type organization.

Fig. 2 Organization of the emergency trolley with 5S method: on the drawers are glued the labels of the drugs on which the drug package must be placed. From a quick glance, you can see if the emergency trolley is complete: everything in the right place

A3

The problem solver records survey and planning findings in a concise two-page document (the A3 Report, also adapted by Toyota) that facilitates knowledge sharing and collaboration. The term "A3" comes from the paper size used for the report, which is the metric equivalent of 11 "$\times$17" (or B) paper. Toyota currently uses several styles of A3 reporting to troubleshoot, report project status and propose policy changes, each with their own "storyline". We focused on the troubleshooting report simply because it is the simplest style, making it the best place to start. An A3 is a powerful tool that establishes a concrete framework for implementing PDSA (Plan, Do, Study, Act) management, leading the report author to a deeper understanding or resolution of the problem. An A3 is an opportunity for improvement and allows anyone in the organization to view the status of the improvement work or problem resolution. It is generally shared between operators and placed where everyone can see it, like a whiteboard. The actors of the process are included in the title, where the problem to be solved is described. On the left side of the sheet is accurately described the current state of the problem and the breakdown of the process into steps. On the right side,

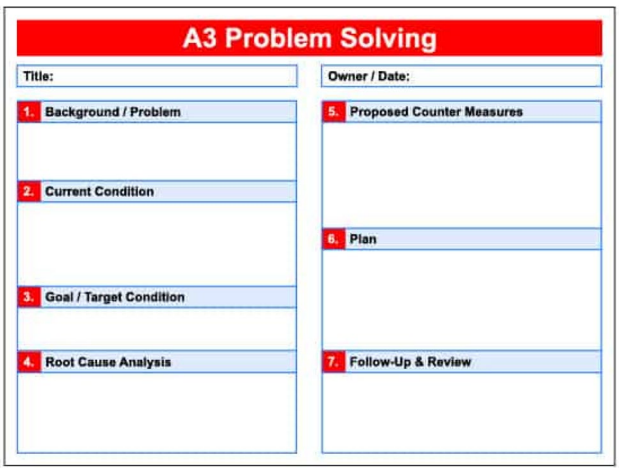

Fig. 3 The A3 tool allows us to describe the problem, study and then implement the solutions through a clear and logical path, by means of a standard that uses the principles of visual management to make it intuitive and simple to perform

the improvement plan with execution and follow-up times must be entered (Fig. 3).

Spaghetti diagram

The spaghetti diagram is an adequate tool for establishing the optimal layout for a department based on observations of the distances traveled by patients, staff or products, e.g., in radiology or nuclear medicine. Spaghetti diagrams detect inefficient layouts and identify large distances traveled between key steps. It is used to visually represent the physical flow of healthcare workers for a process. Three steps are required to create a spaghetti diagram: (a) create a workspace diagram. (b) Observe the process, noting the physical location of the worker at the start of the process. (c) Draw lines that follow the path the worker takes as he completes the process; the lines can be numbered to reflect the steps on the process map (Fig. 4). The lines can be of different colors for different healthcare professionals. By analyzing the lines, you can identify any areas with unnecessary movement. This helps staff decide whether to bring two workspaces together and how to optimize the flow. The construction of the spaghetti diagram on the layout allows considering the pathways of healthcare professionals and patients [22]. In terms of radiation protection, pathways should be separated as much as possible between radioactive patients and healthcare professionals. In this regard, it is also necessary to calculate the transit and rest times of patients in the various areas of the ward (waiting rooms, corridors).

One-piece flow

Patient waiting times in the hospital today are long. Anyone who has experienced sitting in a waiting room, exam room, or hospital bed can attest that there is a distinct lack of flow in the way healthcare is delivered today. One of the key ideas in Lean is to increase speed by examining the revenue-generating sequence of activities called VSM. When wastes like delays, errors, unnecessary transport and movement and so on are eliminated from these operations, what remains is the ability to deliver the same service in less time. Therefore, flow is the key to increasing speed. Because we cannot add resources without spending money and we cannot increase the amount of time we have available in a workday, we need to increase the speed by accelerating the flow of value through the system. This is done by examining and eliminating the non-value-added elements of the care process. With the reduction of waiting times, health experience teaches that the time of illness is reduced, increasing the possibility of recovery. Since hospital stays are shorter, more patients can be treated. The first step is to identify the health care value streams that are the goal of converting to the fastest and most appropriate stream. Therefore, it is necessary to program a "just in time" system through a one-piece pull employment relationship (patients, scans, X-rays, etc.) at the pace of the customer's demand (Takt time).

The rules to follow for a regular flow of patients are similar to those of the Toyota Production System (TPS):

- Specify the times, the sequence and the result of the diagnostic procedure.

Fig. 4 The "spaghetti" diagram consists of a graphic representation of the movements and paths made by a product along the production flow or by people in the workplace. The tool visually shows the linearity or dispersion of the flows [16]

- Link all relationships between different health professionals.
- Process one patient at a time, without queues.
- Report problems in each path.
- Solve problems using a scientific method.

There are three main problems that may be encountered when analyzing hospital patient flow: planning, hospital layout rigidity, and rigid functional mindset across departments. An example of a flow barrier is a shortage of beds or places to book services. Root cause can be resolved by scheduling discharge times based on the pace of customer demand and/or a target delivery time for beds.

Not having a seat available for a diagnostic test or hospitalization creates wasted waiting for the patient, unnecessary movement for nurses to search for an available bed or list, transport for the patient to be transferred, and extra processing to guaranteeing records, drugs and resources. A common goal must be set to improve patient flow and increase the speed of processes. Compared to an automotive factory layout where equipment and bulkheads can be easily moved to allow for better flow, nuclear medicine wards are located in multi-story hospitals with complex infrastructure and unsuitable for quick reorganizations to accommodate the flow of patients. While the best opportunities are new builds or renovations, work is needed in old hospital facilities to remove physical walls and convert offices and spaces to improve patient flow. As in any industry, hospitals have a strong staff mentality to try to optimize the business of providing care without considering the patient's point of view.

Patient flow is an exciting area of Lean Healthcare, as it promises to reduce costs, better quality of care, and better patient satisfaction.

Cell design

Cellular design and work cells are at the heart of lean manufacturing. Cells simplify patient flow, management and even accounting systems. Each element must match the others in smooth, self-regulating and self-improving functioning. A work cell is a unit of work that is larger than a single machine or workstation but smaller than the normal department. Typically, it has 3–7 people and 5–15 workstations in a compact layout. An ideal cell produces a narrow range of highly similar products. Such an ideal cell is autonomous with all the necessary equipment and resources. Cellular layouts organize departments around a product or a narrow range of similar products [23]. Materials are in an initial queue when they enter the department. Once processing begins, they jump directly from one process to another (or sit in mini-code). The result is very fast throughput. Communication is easy as each operator is close to the others: this improves the quality and coordination of teamwork. Simplicity is the underlying theme throughout mobile design. An imaging department could be divided into many working cells, represented by the diagnostic rooms. Each diagnostic room works independently with its own staff from the beginning of the process (validation of the exam) to the end (delivery of the report). The management of the individual cells is governed by the times set by the patient reception secretariat.

Takt time

Takt time represents the available production time divided by the rate of customer demand. Takt time is the rate at which you need to complete a product to meet customer demand. For example, if you receive a new product order every two days, your team needs to finish a product in 2 days or less. Takt time is your sell rate and can be categorized as the heartbeat of your work process; it allows to optimize the capacity in the most appropriate way to meet demand without keeping too much inventory in reserve. Defining Takt time is crucial for optimizing the team's capacity in performing examinations in Nuclear Medicine. Takt time can help you maintain a continuous flow of work and reduce waste in the workflow, especially in PET/CT diagnostics. Nonetheless, Takt time is useful for reducing storage costs as it will help to avoid overproduction. Some patients are complex and require more time for care, and some are less complex and move through their care delivery steps rapidly. To achieve synchronized flow and a quality result, patient care must be sequenced at just the right time.

Lean six sigma (LSS)

Six sigma is a data-driven methodology that provides tools and techniques to define and evaluate each step of a process. It provides methods to improve efficiencies in a business structure, improve the quality of the process and increase the bottom-line profit. The Six Sigma methodology calls for bringing operations to a "six sigma" level, which essentially means 3.4 defects for every one million possibilities. The goal is to use continuous process improvement and refine processes until they produce stable and predictable results. The Lean Six Sigma is a method for process standardization, waste reduction and image quality consistency. The application of LSS method is demonstrated to continuously improve processes in a nuclear medicine environment while strategic data registration, monitoring and assessment are achievable using specific imaging information systems. Lean Six Sigma method requires specific staff training and data collection in the application of the methodology and in

statistical analysis. Thus, for Lean, LSS studies are the ideal choice because it is both practical and has a fair degree of methodologic strength [24–26].

SMED

SMED (Single-Minute Exchange of Die) is used to reduce the exchange time between patients. Setup reduction is the process of reducing changeover time (i.e., from the last good part of the previous run to the first good part of the next run, in diagnostics the change between one patient and another with the reset of the equipment). Because configuration activities do not add any form, fit or marketable function to the product, they by definition add no value. By reducing the setup time to SMED, you can complete more setups every day. SMED is a systematic approach to reduce changeover times to less than ten minutes. This allows the reduction of the overall time taken, which is critical for the flow and improves production flexibility. The total examination time was found to be too long compared to the imaging time [27]. Since a lot of time has been spent informing the patient and inserting a cannula, one of the solutions is to organize a preparation room and establish a workflow. In Lean implementation, setup reduction will help to:

- Reduce the total examination time, leading to a higher production frequency.
- Reduce waiting times and report delivery times, with a consequent improvement in patient satisfaction.
- Improve configuration processes, leading to better quality.

Gemba walk

In Lean manufacturing, the visit to the workplace is called the "gemba walk". It is the best way to see, firsthand and unmediated, what works and does not. It is the best way to get the information you need to make the best possible decisions, usually in the most efficient possible manner.

In a non-profit-making hospital, if Lean tools could increase production, only 45% of this output should go towards more scans, and 55% should go towards other activities, such as courses, conferences, education and (why not?) physical activities. It became realistic the slogan for Lean "work smarter, not harder". This could be the way of demonstrating to the doubters and the opponents that Lean was having a benefic effect [28]. Resistance to change is a well know reaction [29, 30]. The strategy for organizing the Lean group was to make broad information about Lean available to all the employees. The Lean group consists of one Team Leader and other employees of the Department of Nuclear Medicine Department. Despite the Leader, all members of the group started without any previous knowledge of Lean thinking. The group has to adjust the Lean tools and methods to the world of Nuclear Medicine Department and the best way to understand the working situations is represented by periodic visits ("gemba walk") of the working group.

Results

In the first analysis, we noted that the adoption of Lean principles and practices in healthcare is very recent (first studies date 2007), with a significant increase of number of publications from 2013, indicating an increasing interest in this theme. Most of the studies focused on certain sectors, specifying only one type of services family, such as preoperative, emergency, nursing and outpatient surgical procedures. The most positive results of the Lean implementation were reported in logistic functions, in departments with limited complexity and managed by a specialized team. The specific outcomes of working with Lean were decreasing waiting time for the patients, optimized workflow and an increased number of examinations during a working day. However, there are no systematic scientific articles on the implementation of Lean in Nuclear Medicine that can allow a complete review or meta-analysis. Papers must be evaluated individually by making specific evaluations, pending a greater number of implementations that we hope for. At Department of Radiological Sciences of the Odense University Hospital (OUH), the run-through time for the patients with the longest waiting times was 3 months from start to finish, of which only 133 min were of value to the patient—a shocking result for everybody in the section. Having worked through this problem, the result of the group's great efforts decreased the total run-through time for these patients to 4 weeks (Fig. 5).

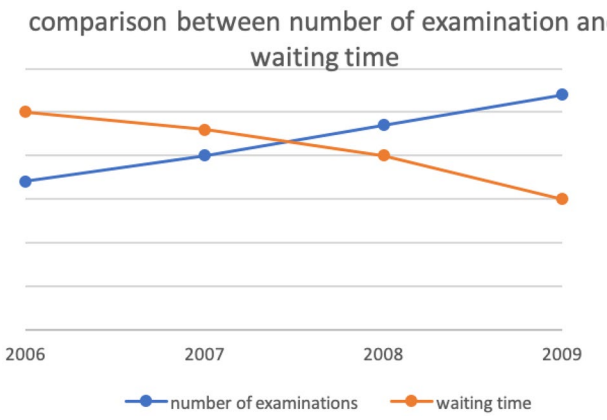

Fig. 5 Efforts of Lean in a diagnostic section in Odense University Hospital: increasing number of examinations and a drop in waiting time, adapted from Karstoft and Tarp [28]

It was measured that the total examination time was too long compared with the imaging time. To find the reason for this, it was considered a number of examinations and found out that it was spending a lot of time informing the patient and inserting a cannula with the patient lying in the PET/CT or CT device. One of the solutions was to establish a preparation room. Now a doctor takes in the first patient—prepares him/her for imaging outside the diagnostic room and then the same doctor takes the patient in to carry out imaging. Meanwhile, another doctor takes the next patient into the preparation room and so on. This gives up to 50% reduction in in-room time [28].

The results obtained from various studies have indicated that some variables are able to guarantee the success of the Lean transformation: development of teams as a support structure of the hospital, calculation and communication of paths and times, communication between all members of the organization overcoming organizational barriers, communicating to employees about their specific role in Lean transformation, acknowledging and celebrating the successes achieved through Lean transformation [31]. As Lean was implemented and rolled out in the department, it became evident that some of the staff got involved enthusiastically working with Lean, while someone was critical. According to the Lean method, the top-down commands had changed and the ideas and the proposals of the youngest staff were just valuable as those of the senior consultants. Additionally, one hospital in the United States reported that Lean management techniques led to the timely launch of nearly all of its operations, while another managed to reduce total care costs by 25% and improve patient satisfaction by almost 100% [32]. Several studies measured the appointment wait time (time elapsed between the day the request for examination was sent and the examination took place) before and after Lean implementation. Reduced appointment wait times for imaging were found from 25 to 2 days and access to MRI scans within 24 h increased from 53 to 90% [33, 34]. In a study conducted at the Department of Radiology, Medical College of Wisconsin, patient waiting time was surprisingly reduced by 70%, total visit duration was reduced by 32%, and reading time for mammography screening of the 40% [35]. The lean approach has been used for several years at the radiology department, Beth Israel Deaconess Medical Center to improve performance and efficiency. The goal of the implementation was primarily to improve patient flow with uninterrupted equipment function, as well as a lean transformation of work philosophy and workplace culture [36]. Many studies measured cost savings. Cherry achieved the greatest gross cost reduction [37]; Karstoft and Tarp increase examinations and treatments at their hospital without significant increasing costs [28]. Reducing the time spent performing a nuclear medicine examination is defined as reducing cycle time. The reduction of patient cycle time was measured and the time saved ranged until 13 min in a MRI study [34]. Moreover, staff and patient satisfaction was measured with an improvement in patient satisfaction was revealed from 60 to 88% [38]. At the Helsinki University Central Hospital, sentinel node gamma imaging procedure was analyzed using VSM, 5S and spaghetti diagram. Lean Team implemented eleven changes, including four new guides, more free camera time and reduced injection doses. A recent case report showed how the use of two tools such as the spaghetti diagram and the VSM were able to improve patient flow in an X-rays department. This case study identified options for increasing efficiency, improving patient workflow and decreasing wait times during peak hours in Diagnostic Imaging, and walk-in X-ray in particular [22]. However, the greatest success was the continuous improvement holds strong even after the project was finished [19]. The utilization of diagnostic examinations, especially CT, PET/CT and MRI, has been increasing in the last several decades. In addition, it has been estimated that 30% of such examinations, especially CT scans, may be unnecessary [39]. The VU University Medical Center Amsterdam estimated the costs for all diagnostic tests from 2006 to 2008 and declared 2009 the year reduction of unnecessary diagnostic costs. From 2006 to 2009 the expenses of the internal medicine department for nuclear medicine exams went from 239,178 to 127,803 euros with a reduction of 47%. The expenses of the entire hospital, except internal medicine, for nuclear medicine have instead increased from 1,882,726 to 2,150,789 euros. The introduction of few cost control measures from a Lean perspective has in fact made it possible to bring about a significant reduction in costs for radiological and nuclear medicine diagnostic examinations Although the word “Lean” is mentioned in the title, this study does not use suitable tools but is based exclusively on cost control by reducing the number of unnecessary examinations: this cannot be a result obtained with Lean management [4]. Even in a radiation oncology department satisfactory results have been obtained with the application of Lean methods [40]. University of Michigan Health System has adopted Lean thinking as a consistent approach to quality and process improvement by cutting the number of individual steps to begin treatment from 27 to 16 and minimize variability by applying standardization [41]. The Lean Six Sigma method was applied to analyze, monitor and improve processes in a nuclear medicine department using a dedicated nuclear medicine software to manage processes. After implementation, the average noise level was preserved and all patients had accettable image noise with significant decrease in F18-FDG dosage [18]. The practice quality improvement in an abdominal imaging Department increased communication and documentation from 17 to 93% over a period of almost a year [42]. Using the Lean management approach, a musculoskeletal radiology division introduced beneficial changes to

facilitate clinical workflow efficiency, reduced moonlighting costs and improved radiologist satisfaction. The average of turnaround time for radiographic examination to final report submission decreased from 40 to 12 h with moonlighting expenses reduced from $26,000 to $5000 in one year [43]. In a study, a kaizen event was held over a 2-day period involving associates from the nuclear medicine department and the cardiology department. A process engineer led the group in mapping out each step of the procedure, measure the time at each interval and countless observations. The group then plotted all the information on a VSM and identified areas of non-value-added time. The VSM and action plan were posted in the department with weekly updates on progress. Customer satisfaction scores specific to the test and treatment category rose from 74th percentile to the 99th percentile in 6 weeks. Scores for personal issues category rose from the 65th percentile to the 91st percentile [44].

Discussion

Lean is an innovative management approach that has proven successful in health care organizations. It is not a new concept, but it is relatively new to health care. Lean principles hold the promise of reducing or eliminating wasted time, money, and energy in health care, creating a system that is efficient, effective, and truly responsive to the needs of patients. Although Lean implementation in healthcare is widespread in the literature, the challenges inherent in its implementation are scarce or superficially reported, making it difficult to understand the factors that inhibit such implementation. In a recent systematic review, the implementation times of Lean management in emergency hospital units were assessed; the shortest implementation time was 1 month, the longest 40 months, with an average lead time of 10 months. The activities of the Emergency Departments in the literature period between 2006 and 2015 were compared, with particular attention to waiting times, visit times, pathways and patient satisfaction [45]. Furthermore, the most frequently described method was the "case study" and there is a paucity of studies that address the barriers for a successful Lean implementation in healthcare [46]. Healthcare workers perceive problems from the perspective of their functions, which does not permit to understand the real opportunities of the value stream as a whole [47]. Among the different indicators found in many studies, the length of stay and the timing of the examinations had the highest frequency. Lean thinking was felt to focus more on time-related indicators, such as time of first service offer, waiting time, hospitalization time, and patient circulation time. Therefore, time indicators can be good examples of intervention and improvement. However, we cannot ignore the importance of other social indicators relating to costs, patient satisfaction and efficiency. Lean Management brings a big change in the offering of services and styles in every department: however, any change requires the senior manager of the organization the responsibility and motivation to implement Lean. One of the barriers to implementing Lean management is resistance to change; another obstacle is that the origin of Lean thinking is in the industry without sufficient compatibility with healthcare, as well as lack of knowledge in this system. On the other hand, the 5S method constitutes a relatively simple, rapid, low-cost and low-tech way of finding more time for the staff. The underlying goal of Lean is to improve value for the patient. It promises an improvement of quality and efficiency while controlling costs in the provision of optimum patient care. As a part of any improvements, it is important that they do not stop after the original implementation. The staff must embrace the changes, and make them their own to ensure continued success. Understanding the theoretical concept and learning how to use the different methods is one thing, but the real challenge is undoubtedly managing change in culture. Since normal top-down commands can be overturned, Lean not only creates a change in culture, it can also create a change in work influence and personal authority, a challenge that must be considered [29]. In fact, today Lean thinking is about more than 5S and U-shaped cells; it is also about people, culture and leadership. Lean methodologies to improve the quality require consistent staff training and data collection not only in the application of the methodology but in statistical analysis. Seven steps are described: train involved staff members, determine the study protocol, measure a diverse set of outcomes, collect data, avoid before-and-after study designs, conduct a statistical analysis of the data, conduct follow-up studies [48]. This systematic review indicates that benefits can be derived through the application of Lean thinking within the field of imaging, particularly Nuclear Medicine. Lean management involves a long-term cultural shift that needs to be adopted by all personnel in a particular setting to be effective and produce positive results [49]. Similar conclusions were reached on the applications of Lean tools within various aspects of health care in the clinical setting. Because of the standardization in the work, Lean might reduce the creativity of the consultants. However, standardization helped improve the ability to provide care. Without standardization, there is likely to be great variability in how work is done, and leads to rework and reduce the quality of care provided. It is necessary that all the information needed be available for the physicians early in the process with a high degree of accuracy to improve quality and efficiency. The involvement of physicians in the quality improvement process is necessary for the advancement of patient-centered mission and helping to define the value proposition [42]. Decreasing inventory and costs, Lean provided higher productivity-increasing capacity, as well as extra time for education and meetings.

In conclusion, in health care facilities, Lean management techniques have been documented to reduce costs, errors and time wastage as well as improve patient and staff satisfaction. The rational usage of resources and process optimization allows to reduce waste and improve quality in Nuclear Medicine departments.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animal subjects performed by any of the authors.

References

1. Womack J, Jones D (2007) The machine that changed the world. The story of Lean production. Free Press, New York
2. Womack JP, Jones DT (2003) Lean thinking: banish waste and create wealth in your corporation, revised and updated. Simon & Schuster, London
3. Liker JK (2004) The Toyota Way: 14 management principles from the world's greatest manufacturer. McGraw-Hill, New York
4. Vegting IL, Van Beneden M, Kramer MHH et al (2012) How to save costs by reducing unnecessary testing: lean thinking in clinical practice. Eur J Intern Med 23:70–75
5. Shrank WH, Rogstad TL, Parekh N (2019) Waste in the US health care system: estimated costs and potential for savings. JAMA 322(15):1501–1509
6. Schwartz A, Chernew ME, Landon BE et al (2015) Changes in low-value services in year 1 of the medicare pioneer accountable care organization program. JAMA Intern Med 175:1815–1825
7. Pyzdek T (2017) The lean healthcare handbook: a complete guide to creating healthcare workplaces that maximize flow and minimize waste, Paperback. Atlantis Publishing, Tucson USA
8. Mazzocato P, Savage C, Brommels M et al (2010) Lean thinking in healthcare: a realistic review of the literature. Qual Saf Health Care 19:376–382
9. McConnell KJ, Lindrooth RC, Wholey DR et al (2013) Management practices and the quality of care in cardiac units. JAMA Intern Med 173:684–692
10. Kenney C (2012) Transforming health care: Virginia Mason Medical Center's pursuit of the perfect patient experience. CRC Press, Boca Raton
11. Boyer KK (1996) An assessment of managerial commitment to Lean production. Int J Oper Prod Manag 19:48–59
12. Schultz SR, Ruter RL, Tibor LC (2016) Lean management systems in Radiology: elements for success. Radiol Manag 38:28–30
13. Nicolay CR, Purkayastha S, Greenhalgh A et al (2012) Systematic review of the application of quality improvement methodologies from the manufacturing industry to surgical healthcare. Br J Surg 99:324–335
14. Mason SE, Nicolay CR, Darzi A (2015) The use of Lean and Six Sigma methodologies in surgery: a systematic review. Surgeon 13:91–100
15. Olisemeke B, Chen YF, Hemming K et al (2014) The effectiveness of service delivery initiatives at improving patients' waiting times in clinical radiology departments: a systematic review. J Digit Imaging 27:751–778
16. Bianciardi C, Bracci L, Burroni L et al (2014) Lean thinking in sanità (it). Esculapio Press, Bologna
17. Liberati A, Altman DG, Tetziaff J et al (2009) The PRISMA statement for reporting systematic reviews and meta-analyses that evaluate health care interventions: explanation and elaboration. Plos Med 6:e1000100. https://doi.org/10.1471/journal.pmed.10000100
18. Menezes V, Machado M, Queiroz C et al (2018) How does Lean Six Sigma method improve healthcare practice in nuclear medicine departments? A successful case of dedicated software applications in oncological PET/CT. J Nucl Med 59(Suppl 1):1013
19. Lahdeniemi H (2014) Improving Sentinel Node gamma Imaging Workflow with Lean Methodology: a developmental project at the Helsinki University Central Hospital, Medical Imaging Center, Department of Nuclear Medicine. J Clin Radiography Radiotherapy 8:21–25
20. Ramaswamy R, Rothschild C, Alabi F et al (2017) Using value stream mapping to improve quality of care in low-resource facility settings. Int J Qual Health Care 29:961–965
21. Rico F, Yalcin A, Eikman EA (2015) Technology Integration Performance assessment using Lean principles in Health Care. Am J Med Qual 30:374–381
22. Jessome R (2020) Improving patient flow in diagnostic imaging: a case report. J Med Imaging Rad Sci. https://doi.org/10.1016/j.jmir.2020.08.014
23. White BA, Yun BJ, Lev MH et al (2017) Applying systems engineering reduces radiology transport cycle times in the emergency department. West J Emerg Med 18:410–418
24. Godley M, Jenkins JB (2019) Decreasing wait times and increasing patient satisfaction: a lean six sigma approach. J Nurs Care Qual 34:61–65
25. Dowell JD, Makary MS, Brocone M et al (2017) Lean six sigma approach to improving interventional radiology scheduling. J Am Coll Radiol 14:1316–1321
26. Klein D, Khan V (2017) Utilizing six sigma Lean strategies to expedite emergency department CT scan throughput in a tertiary care facility. J Am Coll Radiol 14:78–81
27. Verbano C, Crema M (2019) Applying Lean management to reduce radiology turnaround times for emergency department. Int J Health Plann Manag 34:1711–1722
28. Karstoft J, Tarp L (2011) Is Lean Management implementable in a department of radiology? Insights Imaging 2:267–273
29. Krantz J (2001) Dilemmas of organizational change: a systems psychodynamical perspective. In: Gould L, Stapley LF, Stein M (eds) The systems psychodynamics of organizations. Karnac Books, London
30. Hirschorn L (2000) Changing structure is not enough: the moral meaning of organization design. In: Beer M, Nohria N (eds) Breaking the code of change. Harvard Business School Press, Boston
31. Tracey MW, Flinchbaugh JW (2006) How Human resource departments can help Lean transformation. Target 22(3):5–10
32. Toussaint JS, Berry LL (2013) The promise of Lean in health care. Mayo Clin Proc 88:74–82
33. Bucci RV, Musitano A (2011) A Lean Six Sigma journey in Radiology. Radiol Manag 33:27–33
34. Zhang L, Hefke A, Figiel J et al (2011) Enhancing same-day access to magnetic resonance imaging. J Am Coll Radiol 8:649–656
35. Shah CJ, Sullivan JR, Gonyo MB, Wadhwa A, DuBois MS (2013) Using Lean principles to improve screening mammography workflow. Radiographics 33:1505–1517
36. Kruscal JB, Reedy A, Rosen MP, Boiselle PM (2012) Lean Approach to improving performance and efficiency in a radioloigical department. Radiographics 32:573–587

37. Cherry BJ, Fache MS, Seshadri S (2000) Six Sigma: using statistics to reduce process variability and costs in radiology. Radiol Manag 22:42–45
38. McDonald AP, Kirk R (2013) Using Lean Six Sigma to improve hospital based outpatient imaging satisfaction. Radiol Manag 35:38–45
39. Davies HE, Wathen CG, Gleeson FV (2011) Risk of exposure to radiologic imaging and how to minimize them. Clinical review. BMJ 342:589–593
40. Al-Balushi MM, Al-Mandhari Z (2018) Implementing Lean management techniques at a radiation oncology department. SQU Med J 18:362–366
41. Kim CS, Hayman JA, Billi JF (2007) The application of Lean Thinking to the care of patients with bone and brain metastasis with radiation therapy. J Oncol Pract 3:189–193
42. Paushter DM, Thomas S (2016) Quality assurance methodology and applications to abdominal imaging PQI. Abdom Radiol 41:395–404
43. Baccei SJ, Henderson SR, Lo HS et al (2020) Using quality improvement methodology to reduce costs while improving efficiency and provider satisfaction in a busy, academic musculoskeletal radiology division. J Med Syst 44:104
44. Fry J (2011) Using process excellence to improve patient satisfaction in nuclear medicine. J Nucl Med 52(suppl 1):2329
45. Isfahani HM, Tourani S, Seyedin H (2019) Features and results of conducted studies using a LKean Management approach in Emergency Department in Hospital: a systematic review. Bull Emerg Trauma 7:9–20
46. Borges GA, Tortorella G, Rossini M et al (2019) Lean implementation in healthcare supply chain: a scoping review. J Health Org Manag 33:304–322
47. Tortorella G, Fogliatto F, Anzanello M et al (2017) Making the value flow: application of value stream mapping in a Brazilian public healthcare organization. Total Quality Manag Business Excellence 28:1544–1558
48. Amaratunga T, Dobranowski J (2016) Systemic review of the application of Lean and Six Sigma Quality improvement methodologies in Radiology. J Am Coll Radiol 13:1088–1095
49. Simon RW, Canacari EG (2012) A practical guide to applying Lean tools and management principles to health care improvement projects. AORN J 95:85–100