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Improving care efficiency in a radiotherapy center using Lean philosophy

A case study of the Proton Therapy Center of Institut Curie - Orsay

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Abstract— In the field of health care, as in production or services, there is a need for tailor made methodology to help managers improving quality of care as well as efficiency of the organization. Quality Improvement (QI) has become a major preoccupation in the current context where hospitals and health care services need to provide a high level of care and a welcoming environment for patients while reducing costs and maintaining a pleasant work atmosphere for staff. In this paper we present how, with very few adaptation to the local culture, the principles of Lean Thinking combined to the well known DMAIC from Six-Sigma can be applied to improve the efficiency of a French therapy center for cancer treatment. We then discuss how this methodology could be generalized to a larger structure such as a teaching hospital.

Keywords- Continuous quality improvement, Lean, care efficiency, radiotherapy, 5S, VSM, Kaizen workshop

I. INTRODUCTION

Current hospital context urges decision makers to reduce cost and treat more patients with a steady level of resources and a high level of quality. In the radiotherapy sector, these aspects are combined to a high need for security insurance. Lean management methods, whose main objectives are to maximize value and eliminate wastes, have proven to bring significant results in industry in the last decades [1]. There are still few empirical studies on the implementation of Lean in the public sector within both academic and practitioner literature [2]. In healthcare sector, and especially in hospitals, few initiatives have emerged so far. Some Lean projects have been deployed for histology laboratories workflow improvement [3], for the redesign of emergency departments [4], for a learning system in a hospital ward [5]. However in radiotherapy, the only evidence of such initiative was a poster presentation aiming to present ways to reduce waiting lists and improve quality of care [6]. Whereas Anglo-Saxon initiatives progressively appear [1][7], there is still little experiment of such transfer in France. If most Lean implementation efforts are aimed mainly at improving operational efficiency, they however often neglect to tackle the socio-technical effects of Lean interventions [8]. Taking into account such effects may bring major innovation compared to classical quality improvement methods:

adequately deployed, lean management should contribute to create an environment where team based improvements overcome individual actions.

Taking advantage of a collaboration started in 2007 with a radiotherapy center in France, part of the renowned Curie Institute, our goal is twofold: firstly to answer to the challenges faced by the team in terms of quality, security, delay and cost, and secondly to develop and validate a method for lean management implementation in medium size healthcare center. In this paper, our aim is to explain how lean thinking has been applied in a radiotherapy center and led to enhance the number of patients admitted for treatment. The case study is followed by a discussion that highlights the benefit of the socio-technical dynamics created. Finally, a conclusion gives tracks for future search.

II. CASE STUDY

A. Background and objectives

1) Context of radiotherapy

The proton therapy center of the Curie Institute in Orsay (CPO) is the only French center using high energy protons beams for medical purposes, whereas conventional radiation therapy uses beams of photon or electrons. The aim of radiation therapy is to destroy malignant cells and preserve healthy tissue surrounding the tumor site. Proton therapy is a high-precision radiation treatment that uses the advantageous ballistic properties of protons to deliver their energy within the target volume. This method is recommended especially to treat tumors located in critical area of the body close to radiosensitive organs.

The center is equipped with a circular accelerator. The beam lines are fixed and horizontal and can lead into two treatment rooms (room Y1 and room Y2). In these rooms, a six degrees freedom patient positioning system allows to set-up the patient in any required angle using a customized immobilization system. At the present time, the main clinical indications of the center are the eye melanomas and the base of skull tumors. In 2010, the CPO will have a new-generation accelerator, which will supply a new treatment room equipped with a gantry (i.e., rotating beam arm) for a wider range of tumors type.

Despite investment for the extension of the resources available for treatment, the capacity of treatment in the center stays far below the increasing demand. The proton therapy center faces the need to increase the number of patients that could benefit from proton therapy, while maintaining a submillimetric precision for each treatment. Recent dosimetric incidents that occurred in several centers led to a need for improved and controlled internal processes and also increased the pressure for quality.

2) Objectives

To contribute to the achievement of those multiple objectives (i.e., high quality of care, lower delay for treatment, low additional financial investment), Lean thinking has been deployed to the whole center, through the managers' initiative and thanks to the help of external support.

Since some auditing methods were settled by the management and some standards were already defined, the highly skilled personnel (i.e., radio-therapists, radio-physicists, medical secretaries, radiological technologists, technicians) had a certain sensibility to continuous improvement. Evolving in a high technical environment, they were happy to learn and use new quantitative and rational methods.

The objectives were (1) to reduce the delay between the decision of treatment (during the multidisciplinary staff meeting) and the first treatment session; (2) to progressively increase the annual number of treatment sessions, in order to treat more patients; (3) to involve the whole staff in quality improvement and change, while incorporating existing auditing methods in a continuous improvement cycle.

3) Proton treatment process flow

Patients are sent to the Proton Therapy Center (CPO) by a radio-oncologist from an oncology partner center (CPO collaborates with 3 partner centers). The decision that the patient will be treated at the CPO is made during a multidisciplinary staff meeting involving radio-oncologists, radio-physicists and supervisors. Then, in the case of intra-cranial tumor, intracranial fiducial markers have to be implanted at the partner center. Those markers are references that will allow radiological technologists to position the patient in an identical manner each day during the whole treatment, with a one-millimeter precision. The next step consists in medical imaging (i.e., MRI imaging and CT scan), performed at the partner center. These imaging and scan enable the radio-oncologist to delimit the tumor and sensitive organs. Once the tumor is outlined begins the treatment planning performed by operators who determine the ballistic of irradiation, i.e. the number of irradiation fields required as well as the orientation and the dose of proton required for each field (the number of fields can range from 1 to 3 per day). The next step is to manufacture in the mechanical workshop custom accessories, which will give the right shape to the irradiation field so that the tumor will be perfectly covered (thanks to the collimator) and reached at the right depth (thanks to the compensator). Prior to the treatment, a simulation phase with X-rays ensures that the accessories and the restrain system will permit to verify that

the patient stays immobile during setup and treatment, and to irradiate diseased tissues without touching healthy cells. Finally, the treatment can begin. Each treatment session follows the same procedure: setup, treatment (and consultation at least once a week). The setup constitutes the critical part of the treatment session since it represents 90% of the session duration. Once the patient is correctly positioned, the operators leave the room for approximately 5 minutes, which is the time required to join the beam control desk, check the quality of the beam and deliver the irradiation. For each session, the patient needs to be maintained exactly in the same position in order to ensure a good matching between the deposit of dose and the target volume. The whole dose of radiation is administered to the patient through a set of proton treatment sessions over several weeks.



Figure 1. Main process

B. Methodology

Radiotherapy and proton therapy are fields in constant evolution and require continuous adaption and improvement of processes in place. Facing the very high quality requirement and the need to optimize the processes, quality improvement methodologies such as Lean and Six Sigma provide concepts, tools and philosophy appropriate to the culture of the CPO. Organized like a small and medium size enterprise (35 employees), CPO is reactive and able to put an action plan in place relatively quickly. A global "Lean project" has been conducted since the beginning of 2008 and still lasts.

In this section, we explain which methodology has been followed to supervise the project, i.e. how the project started with the creation of working groups, the identification of wastes and value added activities thanks to VSM (value stream mapping), the design of the future state which gives a vision on the target processes and organization (value stream design), the definition of improvement priorities and specific Kaizen working groups focusing on one step of the process. In the next section, we detail specifically the progression of three Kaizen workshops: "Positioning and patient treatment", "Accessories manufacturing" and "Simulation".

1) Initial training and kick-off

An initial working group, composed of representatives of each staff category (i.e. radio-therapist, radio-physicist, treatment planning operator, radiological technologist, supervisor), has been set up to initiate the project. Other personnel, such as medical secretaries, engineers and technicians from the mechanical workshop have been punctually mobilized and integrated to the discussions. Through periodical workshops lasting from 1 to 2 days, the main development lines have been identified:

- The training of the whole staff to continuous improvement principles and tools: 5S (Sort-Set-Shine-Standardize-Sustain), value stream mapping

(VSM), PDCA (plan-do-check-act) improvement cycle, defect analysis, problem solving toolbox and Jidoka transcription to the radiotherapy specificities and constraints.

- The necessity to map the process, identify the milestones, and to identify critical steps.
- The implementation of Lean on a well defined part of the process giving visible and quick results to instill dynamism and faith in the project.

2) VSM

The Lean methodology implementation started with the creation of a VSM of the existing situation. VSM is a process analysis tool to identify the key process characteristics such as the sequence of activities in the process, their speed or cycle time. VSM helps establishing a judgement as to whether or not the activities add value for the patient or customer [2]. “Current state” maps are used to capture the existing process and these are adapted to “future state” maps (value stream design) that suggest how the process may be changed to become Lean.

The mapping phase is crucial to understand the process and to study the delays, from the decision of the treatment to the first treatment session. As in industry, prior to the mapping, it is necessary to select a family of treatment to focus on. Intra-cranial tumors have been chosen, since compared to the eye tumors, which follow repetitive and stable processes, they present certain variability both in the pre-treatment phase and in the treatment session.

Internally, the VSM was used to map the current situation, to identify major wastes along the value chain and to identify bottlenecks in the internal patient preparation process, from the reception of the imaging file to the first treatment session. The VSM was designed with a multi-competent group involving decision makers and experts of each process element. Figure 2 shows the VSM obtained. The squares represent the process box with data box below. Dotted arrows represent the patient flow. If two activities do not directly follow each other, e.g. if the patient has to wait for the resources to be available or the patient file has to wait for validation, then a triangle is used to represent the waiting time and the queue line. The three first activities have been put together because they are performed by the partner center.

Based on the analysis of the VSM, two different approaches were followed in parallel: the definition of the future state (Value Stream Design or VSD, see following section) and the continuous improvement of each local process step and of each interface. This preliminary study led to the identification of critical steps and to the creation of Kaizen workshops for the treatment session, the simulation, the accessories’ manufacturing, the treatment planning and the medical imaging file transfer. Details for three of the steps will be given further (see section C. Kaizen workshop).

3) VSD

With VSM in hand, the working group had a view of the existing processes and flows, with the knowledge of the processing time (value added time) but also the time during

which the patient or the patient file waits (waiting time). The design of the future state includes deep reconfiguration of the value stream. These changes go beyond the identification of the origins of the wastes leading to non-value added activities and excessive lead time and their eradication handled by the Kaizen workshops.

The main questions were: which performed activities could be reduced or deleted in the value stream? Why are there such long waiting times before some activities? How could we synchronize the preparation of the treatment and the production of the accessories so that the waiting times are reduced? The discussion around those interrogations led to the proposal of substantial changes helping to reach the objectives: maintain a high quality level, reduce the delays and enhance the number of treatments.

The first thought is to seek for non-value added activities, which are performed, but do not add any transformation that contribute to the patient treatment. It has been the case of the simulation step, which aims to verify the good position of the patient before treatment and to anticipate collision between the nozzle (collimator and/or compensator) and the patient. What is at stake is the capacity to maintain the patient immobile during the future treatment session. The simulation requires occupying the treatment room, whereas this step does not provide any treatment to the patient. We will see in the next sub-section (Kaizen workshop), how this activity could be removed only for cases that do not require any adjustment of accessories and restrain system before treatment. For those cases, the simulation would be incorporated in the first treatment session.

In the book “Making hospitals work” [7], experts in Lean Healthcare recommend that, after having mapped the process, one should focus on answering the following questions in order to draw the future state map: (1) What is the takt time, giving that the takt time is the available working time per day divided by the demand rate? (2) Where can we remove triangles (waiting times), i.e. install a continuous flow? (3) How to reduce delays where we cannot remove triangles? (4) What process should we make our single point of schedule (the pacemaker process)?

This whole methodology has not been conducted yet for the CPO, however some questions have been studied and here are some response elements. The takt time is an interesting concept that expresses the pace of the customer demand in the manufacturing world and can be transposed to qualify the patient care demand. However some adaptations are required: in the case of CPO, several takt times could be calculated for each process step, depending on the demand rate and the availability of resources considered. On one hand, to calculate the takt time felt by the treatment room, it is necessary to consider the total number of treatments. The takt time for this step, which corresponds to the interval between two treatment sessions, could be calculated with the following formula:

$$\text{Takt Time}_{\text{Treatment room}} = \frac{\text{working time in treatment room}}{\text{total number of individual treatment sessions}} = 38 \text{ min}$$

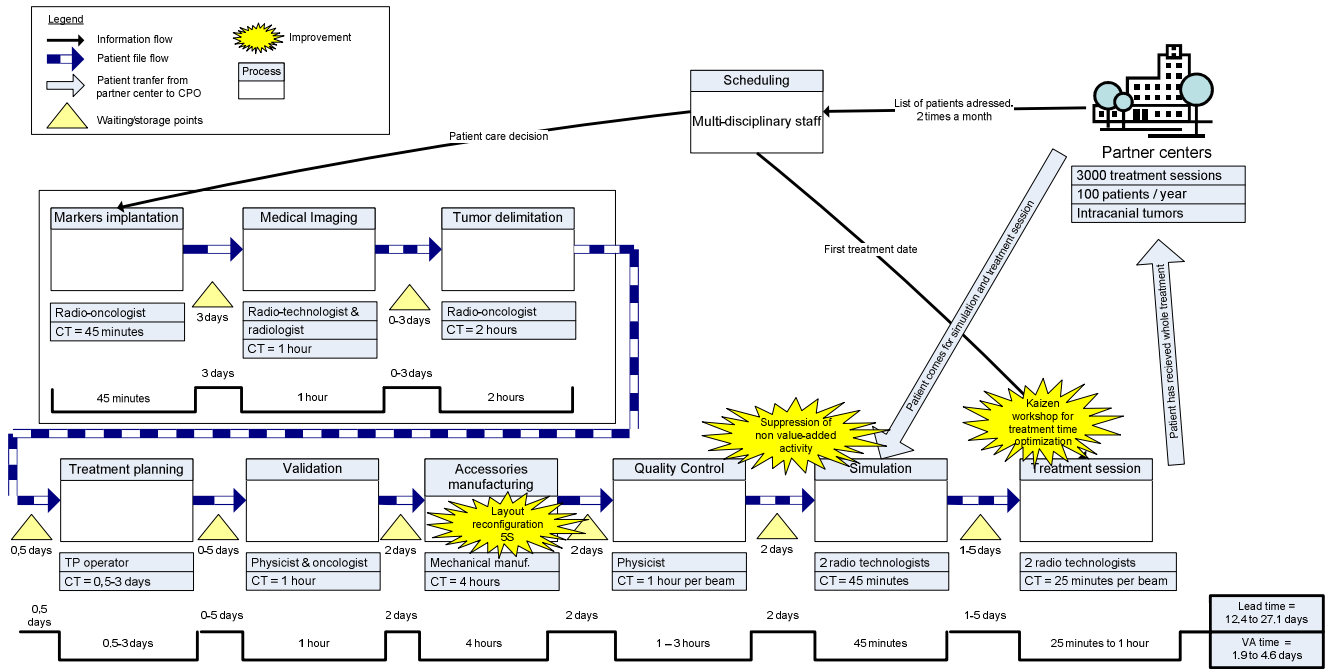


Figure 2. Current state CPO value stream map (VSM) for intracranial tumors

On the other hand, the demand for medical imaging corresponds to the total number of patients admitted to receive the whole treatment (including about 20 treatment sessions in average). For this step, the available working hours (WH) are limited to the time slot of medical imaging service (MIS) dedicated to the patient sent to CPO which are limited to one time slot per week. The takt time can be calculated as:

$$\text{Takt Time}_{\text{Medical imaging}} = \frac{\text{WH in MIS dedicated to CPO patients}}{\text{total number of patients admitted to CPO}} = 50 \text{ min}$$

Finally the takt time of 50 minutes felt by the medical imaging step is greater than the cycle time of 1 hour. Therefore, queue lines will be created before the medical imaging step. This represents waiting points either for the patient or the patient file (triangles in the VSM).

The next question is how we can remove those triangles. It is possible to act on the process capacity or in the process work content to reduce most of the waiting times, but it appears difficult to completely remove them. Let's take for example the triangle between "Markers implantation" and "Medical imaging". This queue is due to the very limited medical imaging services time slot allocated in partner center for the patients treated in CPO. One improvement line could be to work on the medical imaging process to reduce the execution time. Since this process is performed by a partner center, it is however difficult to have influence on this work content. Another option could be to find other imaging slots to divert patient flow out of those critical resources. This will increase the working hours and thus increase the takt time allowing aligning takt time with processing time. Nevertheless, it is a long way to completely remove the waiting time in this process.

The last issue concerning the pacemaker process has not been tackled yet and requires further discussions in working groups. However this question constitutes the core of a significant improvement since through it, the patient flow could be regulated from one single point.

Finally, the future state value stream has not been designed in full, but the reflections on where wastes could be eliminated and where waiting times could be reduced along the value stream have progressed a lot. The next section explains how Kaizen projects have been conducted on some steps of the value stream to remove wastes and variability.

C. Kaizen workshops

Starting from the final process step (patient treatment in treatment room), the objective was to progressively improve the process and to identify the difficulties due to former process steps. For each process step, the methodology used has been the same, very close to the DMAIC (define-measure-analyse-improve-control) of the Six Sigma methodology: (1) Identify root causes of major difficulties raised during the value stream mapping; (2) Set up a specific measurement protocol to quantify more precisely a given issue; (3) Analyse the data and find the causes of the problems; (4) Define the corrective action and implement solutions during a pilot phase, and deploy the defined solution; (5) Measure the obtained results and control their stability through standardization.

1) Treatment session and treatment room optimization

The treatment rooms are the critical resources or bottlenecks of the CPO and are also used in last process at the end of the value stream. Currently two rooms (Y1 and Y2) are into service, and a third room is under construction. The number of treatments delivered to the patients is limited by

the capacity of the treatment rooms, which are open to patient treatment 9.5 hours per day (2 additional hours are dedicated to maintenance and quality controls), 5 days per week, 50 weeks per year. The main objective of this kaizen workshop was to optimize the use of treatment rooms.

As explained above in the description of the process, more than 90% of the treatment session is dedicated to the set-up. The set up consists in installing and maintaining the patient in the position required for the treatment, so that the beam of proton irradiates the target volume and preserves the healthy tissue.

Verification of the right position is done by two technologists, using X-Rays. On the images, the contour of the skull and the markers are clearly visible. For each treatment session, the technologist compares the X-Ray images with the referenced images printed from the treatment planning system. If the matching between the two sets of images is under the tolerance values the proton beam is sent. If not it is necessary to move the patient using the patient positioning system and to repeat the cycle of X-Ray images till the tolerance values are reached. This set-up phase can last if the positioning and verification have to be repeated.

The kaizen working group involves 2 radio-physicists (responsible for the whole technical setup and dose dispensation management), 1 treatment planning operator, 2 radiological technologists, and 1 radio-therapist. Prior to the workshop, the members of this team have been trained to the tools and methods required to identify the problems, put the measures in place, analyse the data collected, identify the causes and design potential solutions.

Three complementary approaches have been imagined to improve the efficiency of the treatment rooms: (1) standardization of the treatment session length, which presents a high variability depending on multiple parameters; (2) reduction of the standard treatment session duration; (3) reduction of the time between two treatment sessions. Before trying to reduce the treatment time, which is the time between the patient entrance and the patient exit of the room, it is first necessary to measure this time in real and to observe whether it is steady or not. Here the DMAIC method from the Six Sigma methodology has been selected since it is the most appropriate to study processes with variability. Data measured in treatment room Y1 over one week showed that, for treatments including one single beam, one third of the treatment time exceed 30 minutes, whereas the standard time has been set to 25 minutes. For treatments including two or three beams, 20 minutes are added to the standard time for each subsequent beam. This standard includes one X-Ray positioning cycle (i.e., 25 minutes for a single beam treatment, 45 minutes for a two beams treatment, and so on), with a tolerance of one additional X-Ray repositioning cycle for each irradiation beam. The causes of this deviation are diverse: the mask is not adapted, the beam is not available, the patient moves, an operator mistake occurs, etc. For each cause, a FMECA (failure mode, effects and criticality analysis) has been drawn up in order to assess the criticality of each problem and to classify them. After the search for

root cause using to Ishikawa (fish bone diagram) and 5 Whys tool, actions to solve the main problems have been defined. Table 1 presents an extract of the action plan for treatment room Y1.

TABLE I. PART OF ACTION PLAN FOR Y1 TREATMENT ROOM OPTIMIZATION

Improvement axis	Action carried out
Ensure reproducibility of a treatment session of 25' for the first treatment beam, of 20' for subsequent treatment beams.	Review the whole hardware setup to ensure patient comfort, limit patient movements and ensure precision in the positioning after only 2 imaging controls (new chair, new restraint set up, new lead impregnated apron)
	Define a standard tasks' distribution between the 2 technologists.
	Create a paramedical consultation to inform the patient about operational aspects of the treatment and therefore limit stress
Ensure security and quality check of the treatment session	Personalized treatment follow-up for most stressed patients, creation of a "referent" role for patients (a technologist responsible for patient's information and for the rest of the team information).
	Kaizen workshop on the control room organization.

2) Simulation

To optimize the time available in the treatment room it is highly important to allow simulations only when it really adds value, i.e. it leads to a modification in the patient treatment process. To identify and classify those treatments, a retrospective study on a one-year treatment period has been conducted by a member of the team. This was done in order to identify among treatment simulations, which ones led to a modification in the treatment parameters or configuration. The treatments are classified depending on the position of the patient (horizontal or seated position), the restraint system, the mask type, the beam type and the beam orientation. This analytical work is completed by a workshop to define which simulations are unavoidable from a more qualitative point of view. A specific decision making tool has been defined as a result of this work, in order to determine among all potential simulations which ones still need to be carried out. For the moment simulation can be avoided for 20% of the treatments, but in the future this rate could reach 50%. However, the simulation is still necessary if the radio-oncologist asks for it. This usually depends on the physical or mental condition and the age of the patient.

3) Accessories manufacturing

A specific kaizen workshop has been set up with the engineers responsible for the mechanical workshop. The first part of the workshop was dedicated to the identification of areas for improvement in the organization of the mechanical workshop in its current configuration. The goal was to set up and apply a set of rules for workshop management, cleaning, etc.. The second workshop led to redesign the mechanical workshop layout in accordance with the increasing demand for accessories (collimators and compensators).

Different actions have been carried out at the mechanical workshop level. First, some interface issues, before and after mechanical workshop, have been identified and corrected:

treatment planning, quality control, treatment room. In that framework, in between mechanical workshop and treatment room, Kanban cards have been set up for new masks' supplies: re-order point, lot size, and standard delay to deliver the masks have been defined for each mask type. Then layout has been redesigned, following a flow orientation. 5S in the mechanical workshop has been carried out (cleaning, storage area definition, acquisition of additional cupboard and storage box to complete equipment, cleaning, zoning and labeling, audit...).

D. Results

The Lean project has been deployed since the beginning of 2008. The results obtained regarding the improvement of delays and the number of treatments are measured in comparison with the defined strategic objectives and they show the evolution since 2007. Delay between the multi-disciplinary staff meeting and the first treatment session was reduced to 8 weeks whatever the addressing partner center (instead of 13.1 weeks average for center 1 in 2007, = 12.4 weeks average for center 2, 12 weeks average for center 3). Daily number of intracranial treatment sessions performed in room Y1 progressively increased from 8 in 2007 to 10 in 2009. This improvement has allowed to push the annual number of treatment sessions from 4000 (intracranial and ophthalmology both included) treatment sessions in 2007 to 4500 treatment sessions in 2009.

III. DISCUSSION

In this section we discuss the benefits and the limits of applying Lean in a radiotherapy center such as the Proton Therapy Center in Orsay. The main added value of the experiment was that the project brought an improvement in the overall process management, contributing to reduce the number of emergency situations leading to the degradation of attention given to the patient. Moreover, through the experience of CPO, we were able to verify and demonstrate that the lean approach was actually transferable to the radiotherapy context, at least to a certain extent. The threefold problematic quality/cost/delay is equally important in the radiotherapy context and in other sectors. The co-construction of tools and methods with healthcare professionals leading the project is a successful and key approach that constitutes one of the project's strengths. We showed that the portability and the sustainability of lean management approach calls for increased professionals training rather than intensive "consulting". In addition to the improvement of performance, the main benefit was to create an environment where professionals working in care processes have adopted lean thinking and systematic problem solving for their daily work, because they are convinced that this attitude reduces their stress and improves their efficiency.

To some extent, one should not consider the patient as the only customer. Indeed social insurance offices and radio-oncologist should be considered as customers as well, which changes the way the processes are managed. Besides, the competitiveness and attractiveness of the health structure are

highly conditioned by the extent to which well known physicians are willing to address patients since this demonstrates a certain confidence in the center. On another aspect, standardization has to be approached with caution in healthcare context. Indeed, it can be badly interpreted as a degradation of the unique relationship between imaging technologists and patients. One of the challenges in the application of Lean in hospital or healthcare services lies in the responsibility given to management on continuous improvement issues. Some government initiatives by the National Health Authority (HAS) are henceforth working towards the same objective and intend to increase the awareness of such approaches. Besides, some major hospitals in France start implementing Lean in their structures. To perpetuate this improvement cycle, it is necessary to find a training model based on training & action, which could encourage managers to develop their workforce and to enter in a continuous search for efficiency without landing up in an awkward position toward the hierarchy.

IV. CONCLUSION

In this paper, we presented how Lean has been applied to a radiotherapy center and how this methodology, if adequately transferred from industry to healthcare could bring an improvement in the quality of care and delays before treatment as well as contributing to the increase of the number of patients treated. This implies that some tools are adapted cautiously to the healthcare domain. The Lean concepts, methodology and tools have been effectively accepted and adopted by the professionals that have been leading the continuous improvement actions. After one year, the approach is still being followed thanks to the involvements of the senior physicist and of the supervisor. Following this project, in order to go one step further in Lean deployment in healthcare institutions, it also becomes evident that generalization to larger structures, as well as top to middle management training, are necessary.

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