LEAN HEALTHCARE: AN APPLICATION OF TPM WITHIN NEPHROLOGY COMPANIES IN BRAZIL

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ABSTRACT

The purpose of this paper is to present findings of how Lean Manufacturing was applied in Nephrology companies and its results. This research has an exploratory and descriptive character, a case study grounded by a literature review. The implementation of Lean Manufacturing in Brazilian Nephrology companies was conducted by content analysis of annual reports over two times periods, giving a detailed analysis of Lean's status in Brazilian healthcare. The study applies different Lean tools implementation in nephrology companies, at the operational level. These approaches were implemented considering the patient as the final customer. The findings suggest that isolated implementations can be very useful to a company that is not acquainted with continuous improvement philosophy. The data analysis demonstrates how much an isolated lean manufacturing tool could be considerable. Data were collected using a SAP system, which contents all service requests by each company, according to the defect found in the hemodialysis system. This research is the first to demonstrate how Lean Manufacturing tools were implemented, and what were the results generated by these applications, also is the first Brazilian implementation in Nephrology companies.

Keywords: Lean Manufacturing. Lean Healthcare. Nephrology. Healthcare.

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INTRODUCTION

The worldwide health system is getting unsustainable, while public hospitals lack of resources to improve their conditions, private companies develop new health technologies with higher costs, patient's access to the health system are harder than before (COSGROVE, 2013; KAPLAN; PORTER, 2012; PORTER; LEE, 2013).

In Brazil, the healthcare sector encounters itself in a very challenging situation. Fewer resources are being provided by the government, and inefficiency prevails in Brazilian hospitals. In a report released by the World Health Organization (WSO, 2010), Brazil's position is 55th in a ranking that measures efficiency, considering that the waste of resources is between 20% and 40%. In this same report, some actions are mentioned that can be taken to reduce the inefficiency of the sector, some of these points are: to improve hospital efficiency; to achieve maximum income from health technologies and services; to eliminate waste and corruption; to correct care in first contacts, with the intention of reducing medical errors; and critically assess what services are needed and how they are performed.

Considering the great evolution of productivity, improvement and efficiency achieved in the automotive sector, this study aims to propose the application of efficiency improvement processes applied in the automotive sector, to the health sector, aiming to eliminating waste, improving efficiency and, above all, meet the needs of the patient within Nephrology companies. Lean healthcare seems to be an effective way of improving healthcare organizations. The growing number of studies found by Souza (2009), in his literature review reinforces this view.

The objective of this project is to apply the practices of the lean philosophy within a Nephrology Company (Healthcare), based on continuous improvement's concept (quality tools and the cost of non-quality). The central question of this research is: "How to reduce wastes and improve quality applying lean principles in health services?". To accomplish this purpose a systematic literature review was conducted, aiming to identify the studies carried out in the health sector, specifically in Nephrology.

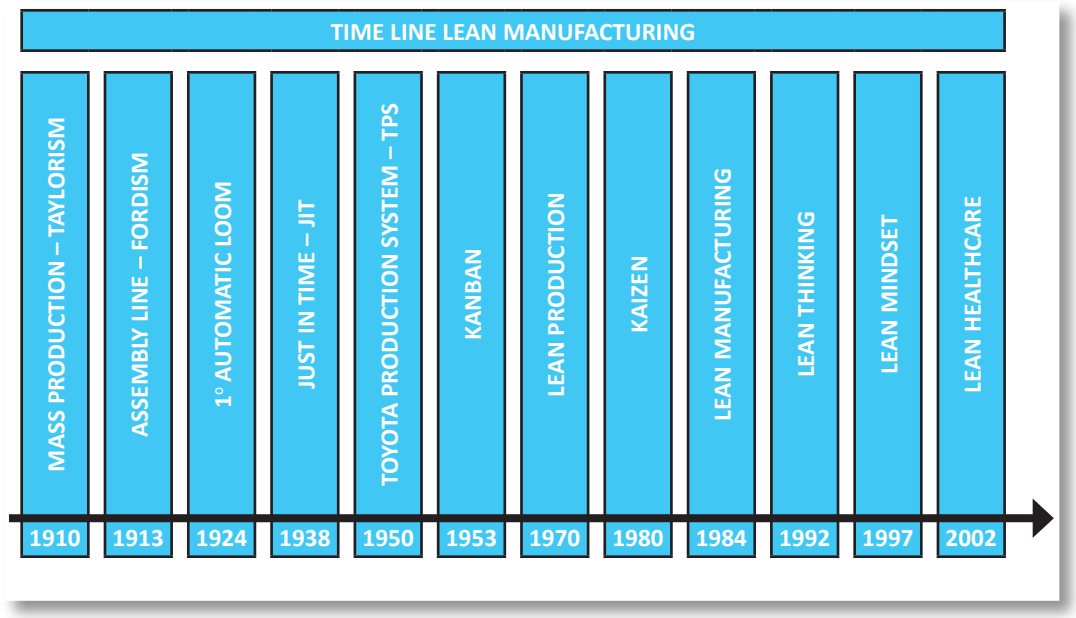
1 THEORETICAL FRAMEWORK

1.1 LEAN MANUFACTURING

In order to present the evolution of the Lean Manufacturing concept through time, this study will describe at different perspectives, productive phases since the era of craft production until the lean manufacturing system or lean production and this in turn will form a timeline (shown in figure 1) with the main ideas and authors.

To study and understand this Japanese philosophy very used by companies from various activities (from the distribution raw materials, services to manufacturing), called Lean Manufacturing (evolution of the Toyota Production System – TPS) is necessary to understand its foundation. Lean manufacturing is a management philosophy focused on eliminating waste, therefore reducing the time and cost of production, a result of continuous improvement. To eliminate the classical waste is necessary to focus on 7: defects, overproduction, waiting time, transport, handling operations, inappropriate processing (excess), excess inventory (loss) (GHINATO, 2000).

FIGURE 1 – Lean Manufacturing Timeline



SOURCE: Bertani (2012, Adapted)

The lean production system has undergone several changes and improvements over time, but before we get that Lean Production system we had several developments in recent centuries relating to production systems. The stages of evolution, took place according to the following production systems: it begin with the Artisanal Production

(until 1850), followed by the Mass Production (1850-1975) and the Lean Production or Flexible (from 1975 to the present day).

According to Ohno (1997), Martins (1993) and Shingo (1989), new concepts for manufacturing systems emerge in Europe and in Japan from 1950. The Toyota Production System (TPS) started in Japan after the 2nd Great War in order to be an example of reconstruction of industry, and a new approach of manufacturing.

Two major transitions in production systems were realized, the first was the change of Artisanal Production for Mass Production, and the second transition was of Mass Production for a modern Production System most modern, determined by Womack, Jones and Roos (1992) as Lean Production.

According to Womack et al., (1992), the Lean manufacturing should establish the maximum amount of responsibility and functions to employees that influence any value to the product that is on the production line, thus, enabling the introduction of a more efficient quality system that identifies in real time the defects in production and correct the errors in its root cause.

Between 1950 and 1980, the Toyota Production System has enabled Toyota manufacturer had a competitive advantage, making superior cars that were produced in terms of cost and quality in relation to American automobiles (WOMACK; JONES, 1992).

Lean Production includes benefits related to Artisanal Production and Mass Production, enabling flexibility and high productivity without the high costs of Artisanal Production and bureaucracy (excessive rigidity) of Mass Production (WOMACK, 1992).

1.2 LEAN HEALTHCARE

Within lean healthcare all the improvements are related to the health system, providing better results to the patients directly or indirectly. Although lean concepts were initially developed to improve vehicle production, nowadays, lean principles are reached beyond the production of goods to service and healthcare delivery (SOUZA, 2007; D'ANDREAMATTEO et al., 2015; SILBERSTEIN, 2006; MAZZOCATO et al., 2010; PERALTA, 2015; BENFIELD et al., 2015; BURGES; RADNOR, 2013).

The healthcare costs are increasingly expensive, some of this increase came by the development of new healthcare technologies and treatments. Since the 90's many countries started to share a concern that, the new urgent call is to invest in healthcare improvements, lowering costs, improving quality, but always looking for better conditions to the patients (COSGROVE, 2013; KAPLAN; PORTER, 2012; PORTER; LEE,

2013). Even with increases in healthcare spending, it seems there is a need to improve healthcare delivery considering that, sooner or later, healthcare will be about costs and patient outcomes, lower medical errors, lower broken medical devices (SOUZA, 2009; COSGROVE, 2013; KAPLAN; PORTER, 2012; PORTER; LEE, 2013).

Some aspects that make lean more adaptable to healthcare sector than other improvement strategies are: distinct levels of autonomy and the concept of gradual and continuous improvement intrinsic to employees (SOUZA, 2009; WOMACK; JONES, 1996). This is an important factor, considering the lack of understanding of healthcare employees about how much it costs to deliver patient the proper care (KAPLAN; PORTER, 2012; PORTER; LEE, 2013).

The literature made by Souza (2009) found that the potential first appearance of lean healthcare concept was published near to 2001, another study made by D'Andreamatteo et al., (2015) says this concept begin to be introduced since 2000.

After that, some books initiated to suggest the implementation of lean concepts in healthcare sector but they do not base their content on solid ground (SOUZA, 2009), being the GAP to this study case.

1.3 COST CRISIS IN HEALTHCARE

The worldwide health system is getting unsustainable, while public hospitals lack of resources to improve their conditions, private companies develop new health technologies with higher costs, patient's access to the health system are harder than before (COSGROVE, 2013; KAPLAN; PORTER, 2012; PORTER; LEE, 2013);

As mentioned by Kaplan and Porter (2012), in a management approach what is not measured cannot be improved. The caregivers are poorly educated about health inputs (materials used for care), reducing the effectiveness of any improvement attempt. The lack of awareness on the process induces waste (COSGROVE, 2013; PORTER; LEE, 2013).

Normally, providers analyze costs at each department level, and also establish their costs based on their reimbursements. Instead, the government considers as costs how much it is reimbursed to providers. This is a disagree between those parts, considering that costs are not just reimbursement values or product and services values, but how much it costs to delivery all health services (KAPLAN; PORTER, 2012; PORTER; LEE, 2013).

Kaplan and Porter (2011) suggest that both, healthcare providers and government, should consider costs of treating each conditions over their full cycle, or in other words, identify the value stream for each case (WOMACK; JONES, 2010; BURGES; RADNOR, 2013).

The complexity of healthcare system turns difficult the cost's analysis, mostly caused by a no linked system, a supply chain approach. A suggestion to this problem could be a different manner to analyze patient's costs, also connecting in a different manner the supplier and the customer (KAPLAN; PORTER, 2012; D'ANDREAMATTEO et al., 2015; SOUZA, 2009).

1.4 NEPHROLOGY

Currently, chronic kidney disease is considered a public health problem worldwide, with an estimated prevalence ranging from 8 to 16%. In Brazil in the year 2006 about 1.75 million people were diagnosed with chronic kidney disease. In 2012, the number was approximately 97,586 dialysis patients in Brazil (MENEZES et al., 2015).

The census report shows an increase in the number of patients on dialysis in the country in the last decade (84.14%) and in the year 2012, about 2 billion reais were spent on a hemodialysis procedure. Studies conducted in Brazil show costs associated with the disease ranging from R $ 19,950.00 to R $ 26,810.30 (MENEZES et al., 2015).

The number of people with chronic kidney disease (in its abbreviation known as CKD) is increasing more and more worldwide, and at a very fast pace. Options for the treatment of patients suffering from advanced chronic renal failure have been renal transplantation and dialysis. In most cases it can be said that the evolution of CKD depends on the quality of the care provided before the occurrence of functional failure of the kidneys (BASTOS et al., 2004).

The kidneys are very important organs in the maintenance of the human body, so when it begins to occur the constant drop in the rhythm of common glomerular filtration in chronic kidney disease, it has as a consequence the loss of the regulatory functions of the kidneys, causing all the others Organisms are overloaded and compromised. In order to be considered renal functional failure (FFR), the values of glomecular filtration rate must be lower than 15 mL/min. (BASTOS et al., 2004).

Hemodialysis is procedure performed by the clean equipment in which it performs the function of a healthy kidney which is to filter the blood. In this filtration process, all wastes that are harmful to health, such as excess salt and excess liquids, are eliminated from the body. Another function performed in hemodialysis is the control of blood pressure, helping the body to maintain the balance of substances such as creatinine, potassium, sodium and urea (SOCIEDADE BRASILEIRA DE NEFROLOGIA, 2017).

In 2017, according to the directorate of the nephrology institute, a session of hemodialysis costs for Brazil around R$ 250,00 per session, counting that the money

passed by the Ministry of Health is only R $ 179,03, that is, for the clinic (or hospital) each of the sessions performed generates a loss is $ 71.00. The damage does not appear to be very large, but considering that a patient performs on average 13 sessions per month, his monthly expenditure is R $ 3,250.00 per month, totaling a loss of R $ 923.00 per patient (the Federal Government pays only R $ 2,327.00 of this total).

2 METHODOLOGY

2.1 RESEARCH METHOD

The research methodology to develop this study will be the study case. Merriam (1998) considers the study case strategy especially suited to an empirical investigation that makes question about a contemporary set of events about which the researcher has little or no control." The central question of this research is: "How to reduce wastes and improve quality applying lean principles in health services?"

The application of lean principles in services is a recent issue in the literature and its application within the health services is in its initial stage. It is, therefore, a contemporary subject.

The incorporation of these principles into any operation whether of a good or a service is a complex phenomenon, admitting several degrees. The researcher has no control over the events that led to the adoption of these principles. It is up to the researcher to verify the degree of adherence of the processes that compose the operations of the health services to lean principles. Hence the choice of the study case methodology.

This study has an exploratory and descriptive character. It is exploratory due to lack of literature of previous works relating lean principles to Nephrology companies in Brazil. It is also descriptive because it seeks to understand how principles are applied in the operations of these organizations.

Four companies were selected for the study. In order to reach the organizations that would be the object of study, some interviews were carried out with people who combined knowledge in the health area, for the health training that they had or to have been working in this area for some years; And managerial knowledge, for having done some specialization in management or for having held management posts. These people were explained the purpose of the study and the principles to be analyzed.

Because this is a recent issue, one did not expect to find any health organization that explicitly uses lean principles to organize its operations.

The objective of the study is not to make comparisons between organizations neither to establish a kind of ranking in relation to lean practices. Since the purpose of the study is to verify how lean principles could be applied to health services in their various processes, in order to reduce wastes, different processes have been selected in each organization.

2.2 DATA COLECT

In order to analyze the effectiveness of lean tools applications, data will be collected via the SAP® system. In this system are inserted every day all the intercurrences generated by the clinics, attended by the company in which one of the authors works. The SAP system describes the types of maintenance requested (referring to hemodialysis machines), the date the maintenance performed, the duration of the service, the location and the time of travel to the place.

The main idea is to collect the data of maintenance numbers performed in each clinic before and after the application of the lean tools, and to verify the result of this implementation in terms of reduction of wasted time of machine stopped, inputs used, waiting time of patient, and other existing waste factors.

2.3 LIMITATIONS

With the intention of preserving the image of the company that provide maintenance services, as well as of the clinics, the name of all the companies involved will be kept confidential.

Some procedures will be described superficially, also with the intention of secrecy of the company that provides maintenance services, which limits the explanatory and descriptive level of this study.

The specific limitation to present clearly the TPM method is due to confidentiality of the companies.

3 METHOD

The main reason for this project is the few references specifically addressing the lean mentality in health services, and the lack of specific examples to illustrate all lean principles within healthcare demonstrate how the subject is recent. Thus, study references in Brazil are even difficult to find. Nevertheless, this study intends to offer a contribution.

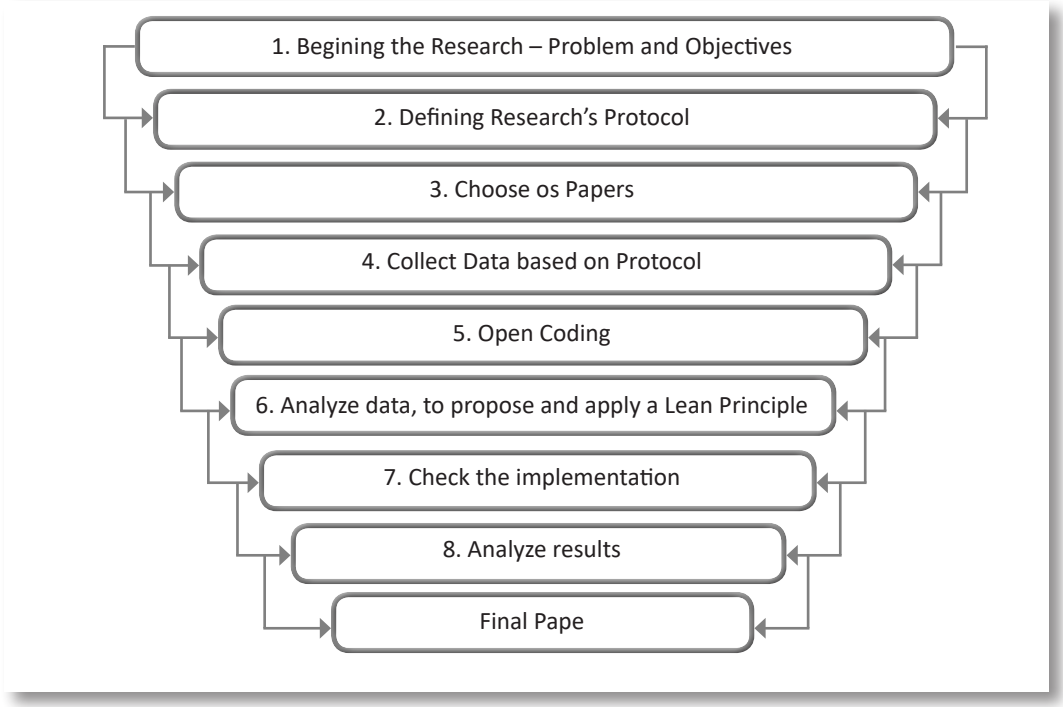
In terms of its objectives, this is a Case Study research grounded by a literature review, for it is identifies and present the already developed research on the above-mentioned fields, thus proposes a model based on the lack of studies and prove its efficiency.

The systematic literature review was conducted to develop this study due to its scientific method for an analytical research, which conducts it in a systematic and rigorous manner, contributes to the development of a solid structure of knowledge, facilitating the development of the theory in areas where there are already research, as well as by identifying areas where there are opportunities for further research (HART, 1998; CONBOY, 2009; WEBSTER; WATSON, 2002).

Cook et al. (1997) points out that the literature review can be narrative or systematic. The first type is based on a simplified description of studies and information about a particular subject.

The second is based on the application of methods with greater scientific rigor, supporting better results and reducing errors and tendency of the researcher. This allows the researcher to compile data, refine hypotheses, estimate sample sizes, better define the search method to be adopted for that problem, and finally set directions for future research (GLASER; STRAUS 1967; COOK; MULROW; HAYNES, 1997). Figure 2 demonstrates clearly the research protocol.

FIGURE 2 – Research Protocol



SOURCE: The authors (2016)

To initiate the papers search on CAPES database, the authors decided to use all available journals from all available databases. By accessing CAPES via PUC-PR, these were the databases available: Scopus (Elsevier); OneFile (GALE); MEDLINE/PubMed (NLM); Science Citation Index Expanded (Web of Science); ProQuest Advanced Technologies & Aerospace Collection; Social Sciences Citation Index (Web of Science); Technology Research Database; SciVerse ScienceDirect (Elsevier); Materials Research Database; Wiley Online Library; ASSIA: Applied Social Science Index and Abstracts; Engineering Research Database; Materials Business File; Advanced Technologies Database with Aerospace; Emerald Journals (Emerald Group Publishing); Mechanical & Transportation Engineering Abstracts; Computer and Information Systems Abstracts; ERIC (U.S. Dept. of Education); Civil Engineering Abstracts; ANTE: Abstracts in New Technology & Engineering.

The main limitation found by the authors regarding journals' availability was related to crossed referenced searches, that were done all the times it was decided to include in the research a paper that was cited in another one. Most of times the papers found by this method were out of reach due to database limitations. Due to this fact, some important references might have been left out of this study. The paper search focused on the period comprehended from 1995 to 2016.

The strategy to optimize searching was to apply the defined variables and their equivalent keywords to find as many results as possible simultaneously. A string's model was structured to help on the research. As an example, the "Lean Healthcare" variable gave birth to the following string: "Lean Healthcare" OR "Healthcare Continuous Improvement" OR "Lean Pathway" OR "Lean Saúde" OR "Melhoria Contínua em Hospitais" OR "Hospital Continuous Improvement".

At the beginning of the search process, all possible filters (period, language, and article) were used to refine journals findings, focusing exactly in the research questions. For example, in the search for "lean healthcare", the category "Robotics" was disabled, because this issue wasn't related to the research questions presented in the study. This sort of action diminished the numbers of papers to 4.345 papers, considering the main subject: Lean Healthcare.

Using these criteria, the authors evaluated titles and abstracts in order to make sure they were related to research objectives, and chose 4 systematic literature reviews as the main references to construct the theoretical framework.

These Systematic Literature Reviews were used due to their vast and solid content, also because summed they construct a content of 243 papers, which would demand a lot of time to analyze all of them.

The exhibit 1 shows these 4 literature reviews, nevertheless these papers guided to other researches which improved the content of this paper. The exhibit 2 shows the main contribution of these 4 systematic reviews.

EXHIBIT 1 – Literature Reviews found

Author	Methodology	Title
Souza (2009)	Literature Review	Trends and approaches in lean healthcare;
Mazzocato et al. (2010)	Literature Review	Lean thinking in healthcare: a realist review of the literature;
Andreamatteo et al. (2013)	Literature Review	Lean in healthcare: A comprehensive review
Da Luz Peralta et al. (2015)	Literature Review	Lean healthcare: uma análise da literatura.

Source: The authors (2016).

EXHIBIT 2 – Literature Reviews Contribution

Souza (2009) – Trends and approaches in lean healthcare
The study shows that there seems to be a consensus about the potential of lean healthcare and it is surprising that no work firmly criticizing the use of lean healthcare was found in the literature. For this reason, it remains a challenge for academics and practitioners to e valuate lean healthcare under a more critical perspective and decide if it is just a management fashion or a valuable improvement philosophy.
Mazzocato et al. (2010) – Lean thinking in healthcare: a realist review of the literature
The authors found some unclear studies design and/or outcome measures. Also, The few number of studies specific to a certain setting, the limited data on contexts, and the variation in terminology, tools and methods used, made it hard to identify which aspects of lean worked best, in which settings, and in what way. Very few of the articles discuss any limitations to the application described, to the study design or to the generalizability of the study findings. The authors suggests for a future researches to focus on particular aspects, such as the role of management to improve implementation and sustainability, also demonstrate clearly the evaluations which could help practitioners and researchers to better understand how lean principles work in interaction with each local context.
Andreamatteo et al. (2013) – Lean in healthcare: A comprehensive review
The authors describes that Hospital is the more explored setting, with emergency and surgery as the pioneer departments. USA appears to be the leading country for number of applications. The theoretical works have been focused mainly on barriers, challenges and success factors. Sustainability, framework for measurement and critical appraisal remain underestimated themes. Evaluations of “system wide approach” are still low in number. Lean results appear to be promising, but findings so far do not allow to conclude on its positive impacts or challenges in healthcare sector. Researchers should explore further the potentiality and the weaknesses of Lean, enabling to health professionals, managers and policy makers to learn from research how to play a pivotal role for a more effective implementation of lean in different health contexts.
Da Luz Peralta et al. (2015) – Lean healthcare: Uma Análise da Literatura
Note that most of papers were practical, but these did not show in detail how the Lean philosophy was implemented the in the healthcare industry. It was noticed that Lean thinking has been successfully applied in a wide variety of services targeted to health. To better understand the potential benefits, health organizations need to directly involve management, work in functional divisions, continue to create value for patients and other customers and sustain a long-term vision of continuous improvement.

SOURCE: The authors (2016)

Lean healthcare is still in an early stage of development if compared to the same process in the auto industry. It is very hard to compare lean in the auto industry with lean in healthcare since the chronological developments are so large.

However, it is certain that lean healthcare is learning with some of the mistakes made in the auto industry, as this issue is amply discussed in Brandao de Souza and Pidd (2008). Souza (2009) did not found any report describing the use of lean healthcare crossing organizational boundaries, neither any work firmly criticizing the use of lean healthcare.

Very few of the articles discuss any limitations to the lean applications, to the study design or to the generalizability of the study; also they are unclear with their measures or with the study design (MAZZOCATO et al., 2010).

Lean results appear to be promising, but findings so far do not allow to conclude on its positive impacts or challenges in healthcare sector. Researchers should explore further the potentiality and the weaknesses of Lean (ANDREAMATTEO et al., 2015).

Most of papers analyzed were practical ones, but these did not show in detail how the Lean philosophy was implemented the in the healthcare industry (PERALTA; FORCELLINI, 2015). Exhibit 3 presents lean interventions proposed to healthcare:

EXHIBIT 3 – Lean Interventions proposed to Healthcare

Lean Interventions proposed to Healthcare
• Methods to identify, analyze and solve problems, on each specific area, in order to follow a defined process and maintain a correct documentation. • Methods to organize processes. • Methods to prevent errors that could cause harm to the patient. • Methods to manage change. • Methods to documentation's control. • Specific indicators to measure continuous improvement. • Methods to improve the relationship with patients.

SOURCE: Adapted from Silberstein (2009)

In order to define clearly which Lean tool will be used for each organization, the authors adapted the exhibit 4, which contains the most kinds of wastes in Healthcare, considering these as "No Value Adding activities".

EXHIBIT 4 – Definition of "no value adding" activities

Waste Source in Healthcare
• Accumulation of patients in the waiting room. • Long waiting time associated to the preparation time for each patient on each step of the diagnostic and/or treatment process. • Duplication of exams by distrust. • Carrying out unnecessary exams for lack of team's preparation. • Excessive movement of hospital personnel and transport of patients. • Excessive treatment times caused by difficulties while establishing procedures between distinct departments. • Incorrect information or information not available. • Wrong/inappropriate tools and devices. • Correction , rework , inspection • Excess or lack of materials and drugs • Human potential waste • Inefficient communication • Lack of training • Lack of experience • Lack of knowledge in operating devices correctly

SOURCE: Adapted from Silberstein (2006), Bhat et al. (2014)

Lean paradigm proposes a philosophy which the main principle is continue improvement, consequently turning into an action of analyzing internal operations and the value stream, identifying those activities which add value or don't add value. This systemic approach improves (gradually) the system in which it operates.

The Brazilian health sector has been a critical problem long time ago, due to lack of investments and attention on its operational sector (exhibit 5 describes the main difficulties encountered in most Brazilian hospitals).

EXHIBIT 5 – Main difficulties found in Brazilian Hospitals

Operational problems within Brazilian Hospitals	
Problem	Consequences
Difficulties in access the healthcare system;	Delay in diagnosis of diseases, resulting in a worsening of symptoms or even patient's death;
Long Queue;	Patients die waiting for treatment or even for diagnosis;
Unnecessary Exams;	Increase of requested unnecessary exams, demanding more money from patients;
Inefficient stock control;	Missing materials for treatments;
Missing equipment;	Patients are wasting time searching another hospital which possesses the appropriate device to the treatment or diagnosis.
Responsibilities badly divided between managers;	Poor management of hospital departments

SOURCE: Adapted from Silberstein (2009)

4 ANALISYS

The main idea to apply and measure the results of any lean tool implemented within the companies, was, before everything, to define what could be called as the "production line" of these companies (clinics) and in this case the considered production line is the hemodialysis. Considering that those clinics provide the same service, the authors chose to apply lean techniques related to the operational level.

According to the aspects that do not add value to the system a defective hemodialysis machine affects directly the provision of this service causing:

- Accumulation of patients in the waiting room;
- Long waiting time associated to the preparation time for each patient on each step of the diagnostic and/or treatment process;
- Excessive movement of hospital personnel and transport of patients;
- Incorrect information or information not available;
- Wrong/inappropriate tools and devices;
- Correction , rework , inspection;
- Waste of materials;
- Inefficient communication;
- Lack of training;
- Lack of experience;
- Lack of knowledge in operating devices correctly.

As World Health Organization (WSO, 2010) reported in 2010, the main problem in the Brazilian healthcare sector is the system's inefficiency, thus, the purpose of applying lean techniques on levels which impacts directly the hemodialysis machine park is to reduce this inefficiency, eliminating those aspects which do not add value to the service neither to the customer (in this case, the patient), consequently improving quality.

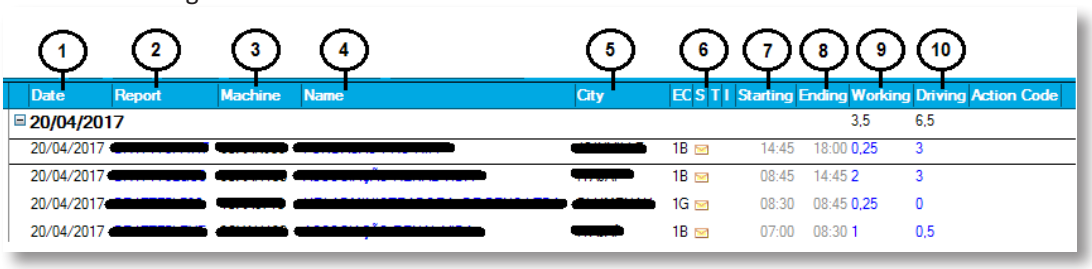
This study started at March 2016, the period between March 2016 and August 2016 was considered Pre-Lean it means, in this period the Lean tools were not applied yet, but an analysis of what could be applied were already happening. The period between September 2016 and February 2017 was considered Post-Lean, which lean manufacturing tools were already applied within companies and the results started to be analyzed. In the next chapters.

4.1 DATA COLLECT

The data collection was done using a TI system (SAP) which one of the authors works with. This system controls machinery serial numbers and all services provided to the customers (clinics), in these cases, maintenances to the hemodialysis systems.

The manner which the system categorizes the services are shown below (Figure 3 – Categorization of Maintenance) with the categories numbered.

FIGURE 3 – Categorization of Maintenance



SOURCE: The authors (2017)

1. **Date:** The date of the maintenance;
2. **Report:** The number of the report;
3. **Machine:** Machine's serial number;
4. **Name:** Customer's name;
5. **City:** City where the clients are;
6. **EC/S/T/I:** Maintenance code;
7. **Starting:** Time which the service starts;
8. **Ending:** Time which the services ends;
9. **Working:** Time working;
10. **Driving:** Time driving.

Using these information provided by the system, the authors collected all maintenance reports in the period of March 2016 till March 2017. Due to higher occurrence factors (and the most important to this research), the types of service: corrective maintenance and operational error were chosen; since from these it is possible to carry out a clearer and more objective analysis of the results of the applications of lean practices. Within the system SAP used to collect these data, those kinds of services are classified as 1B and 1G to control all provided services to the customers, meaning: Corrective Maintenance – 1B and Operational Error – 1G;

4.2 NEPHROLOGY COMPANY 1

The Company number 1 actually is the most careful among all companies attended by the authors. From all 10 companies attended, this one was chosen due to the proximity with the Administrator, considering the openness and facility to showing problems and proposing new solutions.

An interesting factor is that this company already has a lean thinking very intrinsic on its routines, but not called as "lean manufacturing" concept. Many internal controls are already realized everyday, for example: Cleaning control, input control, IT system to fulfill patients' information and avoid medications' error, stock's organization, patient's safety control, environment safety control etc.

The main problem within this organization is that technicians (machine operators) did not dominate the machine functions and basics necessary care (good practices) causing defects on machines which needed maintenance, consequently wasting time, wasting productivity, slowing patients time waiting, and all those factors already mentioned above.

The authors considered an opportunity to apply some improvements, aiming to reduce those "bad or incorrect utilization (operational error)", lack of good practices and introduce the Kaizen mentality to the employees. Together with the Company's administrator, after looking the main occurrences, the authors suggested the following Lean Manufacturing techniques:

1. Introduce the Kaizen method to the team, explaining its advantages and how to apply it.
2. To realize TPM training, improving users' knowledge about the systems.
3. Introduce PDCA method.

The first step was to training employees in Lean Manufacturing concepts (superficially), only to introduce them what is lean manufacturing, how it works, what the benefits are and what techniques will be developed with them. The authors developed a simple presentation (10 minutes) with the main lean concepts.

A Kaizen training was oriented in how employees could seek for an opportunity of improvement (in any area they want to) and how they could describe it. The main idea was to give them the responsibility to make their work better each day; conscious of the work they perform everyday aiming a better care to the patients. The method was oriented to improvement of treatment conditions (any variable which could impact directly in the patient's treatment, already presented in Aspects which do not add value in Hemodialysis Treatment) given the orientations mentioned in exhibit 6:

EXHIBIT 6 – Kaizen questionnaire

Kaizen's framework		
Orientation	Complement	Requirement
1. What is the suggestion of improvement?	Here the employee defines what the suggestion is.	The suggestion needs to be related to improve any condition to the patient's treatment.
2. Does it affect directly non value adding conditions?	Related to the framework of no value adding in hemodialysis treatments.	Only low costs suggestions will be accepted (the financial conditions need to be analyzed by the administrator).
3. What does this improvement aim for?	The employee needs to describe what he is aiming with his suggestion.	
4. Does it could be applied with low costs?	Explain how the suggestion will provide better conditions to the patients.	The suggestion need to improve working conditions.
5. Does this suggestion improve patients' treatment conditions? How?	Explain how the suggestion will improve working conditions.	
6. Does this suggestion improve working conditions? How?		

SOURCE: The authors (2017)

The purpose of the kaizen questionnaire is to filter the suggestions made by the employees, assuring the basic conditions to continue with the improvement application. After that, when a suggestion of improvement is done by any employee, the administrator analyzes if all conditions (presented in Exhibit 6 – Kaizen questionnaire) fills the necessary requirements to be developed (including financial requirements).

When a suggestion is considered good by the administrator, the team uses the PDCA cycle to implement the improvement (results of some suggestions will be shown in the next chapters).

The third technique presented to the company was TPM. This technique was introduced to the company members to avoid bad use of hemodialysis devices, assuring the correct use, functioning, and patients' safety. The operators were trained in how to clean correctly the surface of the machines and how to operate the machine correctly avoiding the breaking of parts. The operators were also trained in how to react correctly to the most common machine's warnings.

4.2.1 Findings

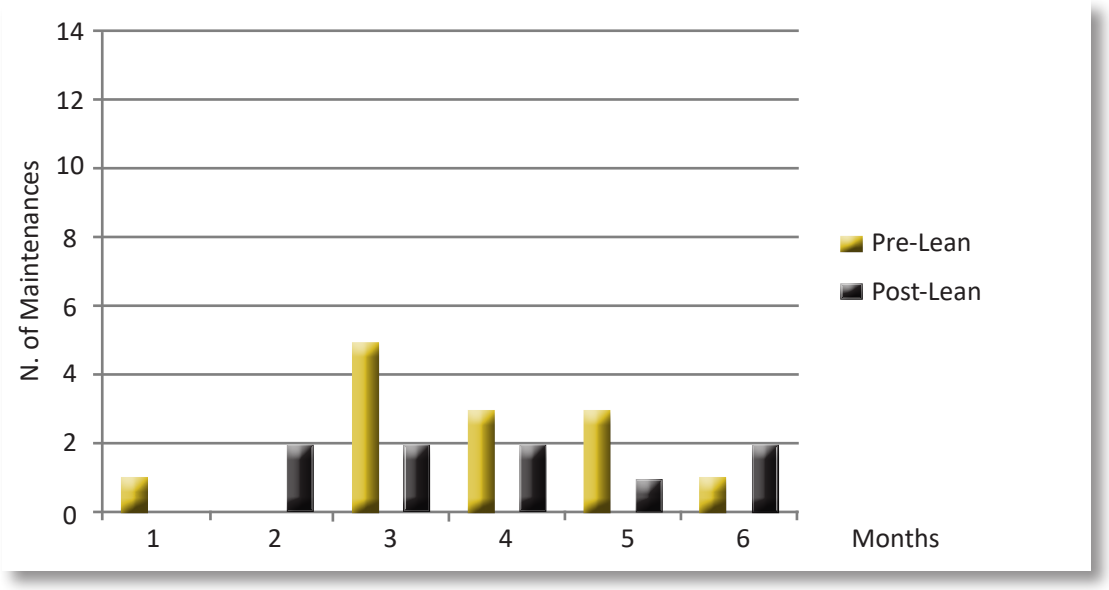
The company number 1 was and still being the company with the lower maintenance rates of all companies, exhibit 7 shows the maintenance rate comparison between pre and post lean implementation.

On the first semester there were a total of 6 corrective maintenances and 7 operational errors (that needed maintenances). On the second semester there were a total of 8 corrective maintenances and 1 operational error.

Is possible to find out that the numbers of corrective maintenance increased (from 6 to 8), but the numbers of operational errors decreased (from 7 to 1). It demonstrates the effectiveness of training employees in TPM and also in good practices, avoiding to brake machines for badly use. In this case, the increase of corrective maintenance is a consequence of defective internal parts, and it is not directly related to operational errors.

Each time when maintenance is required, the hemodialysis machine stays out of productivity for at least 48 hours. Decreasing a rate from 7 to 1 is very expressive in terms of productivity, because in 24 hours a hemodialysis system can provide 3 treatments (almost 4 hours each treatment), table 2 shows how much this is considerable.

EXHIBIT 7 – Data comparison – Company 1



SOURCE: The authors (2017)

To calculate how much the lean implementation was effective, the authors considered the difference of numbers of maintenances between the first and the second semester (caused by defective parts + operational errors). The calculation was considered in this way because does not matter if the machine was broken by an internal problem or an operational problem, both problems causes waste.

TABLE 1 – Financial Saving – Company 1

Cost of Opportunity per Treatment			
179,03			
Number of Machines	Machine Not Available (Hours)	Number of Lost Treatments	Lost Incoming
1	48	6	R$ 1.074,18
4	192	24	R$ 4.296,72
		Saving	R$ 4.296,72

SOURCE: The authors (2017).

The difference between first and second semesters resulted in 4 fewer maintenances, in financial terms R$4.296,72 was saving value. For a company that has almost 80% of patients' treatment paid by the government, this is a huge saving.

Each time an intervention is required, the use of 3 components are necessary to test the functioning of machine and to make available to use: Acid (Canister), Bicarbonate (Canister), Peracetic Acid (ml). The reduction rate of interventions also reduced the inputs wastes, as shown in table 2.

TABLE 2 – Inputs Saving – Company 1

Material Saving		
Acid (Canister)	Bicarbonate (Canister)	Peracetic Acid (ml)
4	4	264

SOURCE: The authors (2017)

The lean techniques in Company 1 were very well integrated by the employees and also provided very good results.

Kaizen philosophy instigates people to work better with lower resources, always seeking for productivity and to simplify working conditions. The company 1 clearly focused on better conditions to patients (consequently to workers), applying techniques to organize and control operations, also to avoid operational errors.

4.3 NEPHROLOGY COMPANY 2

The Company number 2 had one of the highest rates of broken machines among all companies. This company was chosen to this study due to the proximity with the administrator and head nurse, but with less openness and opportunities to develop lean manufacturing philosophy.

The main problem within this organization is that the machine operators did not dominate the machine functions (even with some years of experience) and do

not perform the basics necessary care (good practices) causing the same encountered problems in company 1: defects on machines which needed maintenance, consequently wasting time, wasting productivity, slowing patients time waiting.

The authors considered a good opportunity to apply some improvements, aiming to reduce those operational and broken machines rate.

The lack of openness (from the Company's owner) to apply any method and the lack of time to training technicians restricted the options of operational improvement. So, considering these factors, the authors chose:

1. To realize TPM training, improving users' knowledge about the systems.

This is because the operators already know something about the machines, and all its routines, so the main objective is to improve their knowledge and their practices.

To training the technicians in TPM concepts, the authors used the same presentation model used in company 1. This training focused on the weaknesses of these operators to avoid bad use of hemodialysis devices, functioning, and patients' safety (assuring the correct use).

The operators were trained in how to clean correctly the surface of the machines, how to operate the machine correctly avoiding the breaking of parts, and also trained in how to react correctly to the most common machine's warning.

All of them were pointed out about their mistakes and induced to repeat the most common mistakes during the training, making possible their comprehension about those and letting easily to correct.

4.3.1 Findings

The exhibit 13 shows the maintenance rate comparison, between pre and post lean implementation.

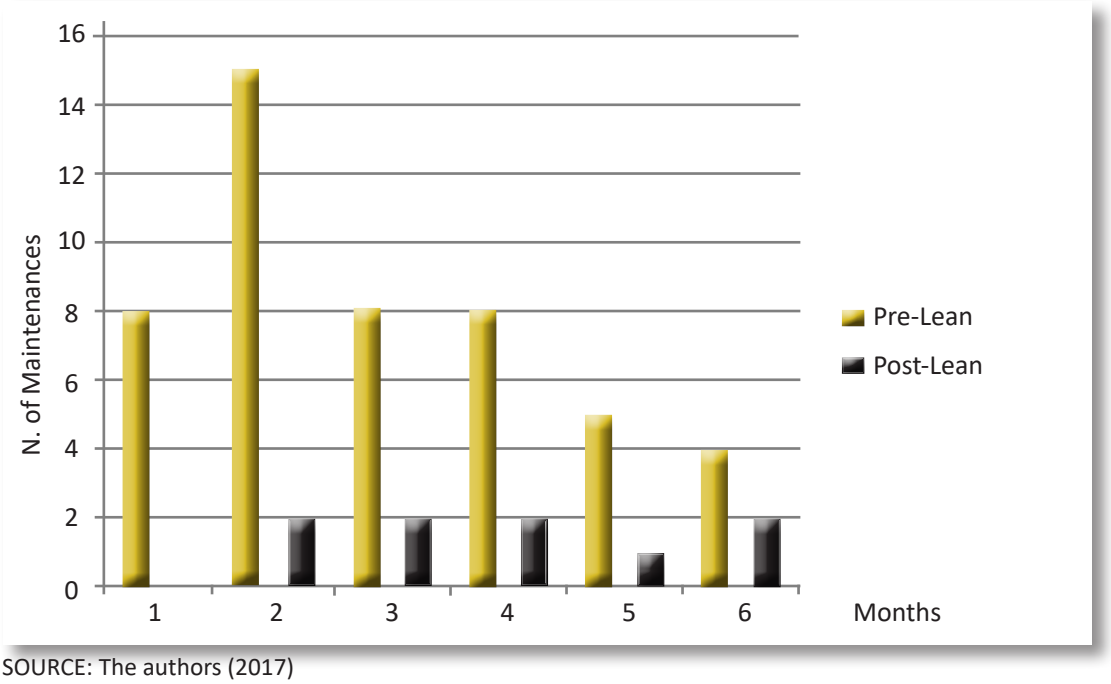
There was urgency in applying any proposal of improvement due to the high index of required maintenances. During the visitations to this company many problems were detected, the most worrisome was the patient's waiting time. Many of them come from another city, and had to wait until a machine was available to the treatment. Considering this, reducing the rate of broken machines, the waiting time consequently is reduced.

The first semester presented 38 corrective maintenances and 10 operational errors.

The second semester, after TPM already being applied, presented 13 corrective maintenances and 1 operational error. Comparing the two phases of lean implementation is very clear to see that was possible to reduce operational errors and corrective

maintenances. This fall on the maintenances numbers impacts directly on quality of the patients' treatment turning the whole system more reliable.

EXHIBIT 8 – Data comparison – Company 2



SOURCE: The authors (2017)

Applying TPM technique was possible to reduce the maintenance rate in 70,84%. Company 2 had a rate of 90% of patients treatments paid by government (SUS), it means that the obtained saving (demonstrated in table 3) is very expressive. This company also reduced the inputs wastes, as shown in table 4.

TABLE 3 – Saving – Company 2

Cost of Opportunity per Treatment			
179,03			
Number of Machines	Machine Not Available (Hours)	Number of Lost Treatments	Lost Incoming
1	48	6	R$ 1.074,18
34	1632	204	R$ 36.522,12
		Saving	R$ 36.522,12

SOURCE: The authors (2017)

TABLE 4 – Inputs Saving – Company 2

Material Saving		
Acid (Canister)	Bicarbonate (Canister)	Peracetic Acid (ml)
34	34	2244

SOURCE: The authors (2017)

4.4 NEPHROLOGY COMPANY 3

Company number 3 (in the same way as company 2) had one of the highest rates of broken machines among all companies. This company was chosen due to the high rate of maintenances required.

The main problem within this organization is the same encountered in the other companies, the machine operators did not dominate the machine functions (as they should) causing the same problems in company 1 and 2: defects on machines which needed maintenance, consequently wasting time, wasting productivity, slowing patients time waiting.

The lack of openness (from the Company's owner) to apply any method and the lack of time to training technicians restricted the options of operational improvement. So, considering these factors, the authors chose:

1. To realize TPM training, improving users' knowledge about the systems and proposing to them avoid abnormalities to the systems, taking better care of their work tool and anticipating defect detection.
2. To introduce and apply Andon within patients' rooms, aiming that the operators control any variation or warnings in machines (it is being analyzed by the administrators, not applied yet).

As the same described for Company 2, to training the technicians in the Company 3 in TPM concepts, the authors used the same presentation model used in company 1 and 2. This training focused on the weaknesses of these operators to avoid bad use of hemodialysis devices, functioning, and patients' safety (assuring the correct use), also to detecting external malfunctions.

The operators were trained in how to clean correctly the surface of the machines, how to operate the machine correctly avoiding the breaking of parts, and also trained in how to react correctly to the most common machine's warning.

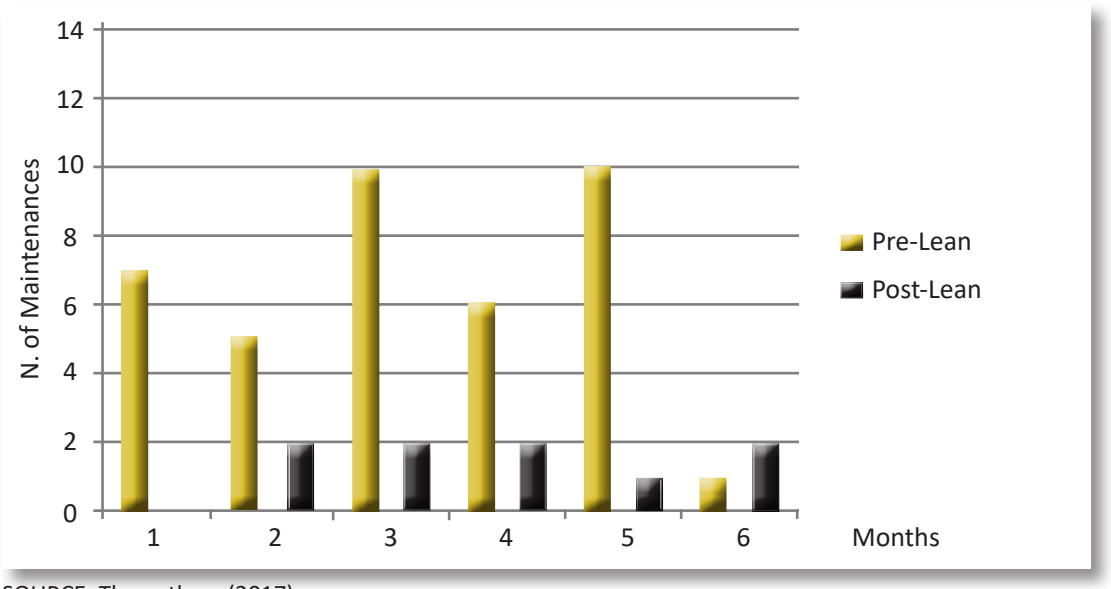
All of them were pointed out about their mistakes and induced to repeat the most common mistakes during the training, making possible their comprehension about those and letting easily to correct (as the same mentioned to the Company 2).

4.4.1 Findings

The exhibit 9 shows the maintenance rate comparison, between pre and post lean implementation. The first semester of the analysis, presented 34 corrective maintenances and 5 operational errors.

On the second semester, the result of TPM application was the decrease of maintenances: 13 corrective maintenances and 0 operational errors. Comparing the two phases (table 13) of lean implementation is very clear to see that TPM was effective to reduce operational errors and corrective maintenances. This decrease on the maintenances numbers, impacts directly on reducing of wastes (no value adding activities).

EXHIBIT 9 – Data comparison – Company 3



SOURCE: The authors (2017)

As demonstrated in exhibit 9, the rate of maintenances within Company 3 decreased in 66,66%, which is a considerable reduction, since only TPM technique was applied and only operational improvements could be applied.

In a semester, this company saved a waste calculated in R$27.928,68, which is a lot of expressive (as shown in table 5). This value could be reinvested in any other improvement which requires a higher investment to be started. The reduction rate of interventions also reduced the inputs wastes, as shown in table 6.

TABLE 5 – Saving – Company 3

Cost of Opportunity per Treatment			
179,03			
Number of Machines	Machine Not Available (Hours)	Number of Lost Treatments	Lost Incoming
1	48	6	R$ 1.074,18
26	1248	156	R$ 27.928,68
		Saving	R$ 27.928,68

SOURCE: The authors (2017)

TABLE 6 – Saving – Company 3

Material Saving		
Acid (Canister)	Bicarbonate (Canister)	Peracetic Acid (ml)
26	26	1716

SOURCE: The authors (2017)

4.5 NEPHROLOGY COMPANY 4

The Company number 4, the same way of Company 1, had one of the lowest rates of broken machines among all companies. This company was chosen to this study due to the proximity with the head nurse, but with less openness to apply any improvement in administrations levels. Within this company the operators have more experience and knowledge about the systems, they already perform good practices operations and are very careful with external parts.

The authors found a good opportunity to apply techniques that could anticipate defects, avoiding long periods of standing machinery, consequently eliminating wastes.

The lack of openness to apply any method at the administrations levels, and the low rate of broken machines due to the expertise of technicians restricted the options of operational improvement. So, considering these factors, the authors chose:

1. To realize TPM training, improving users' knowledge about the systems and proposing to them avoid abnormalities to the systems, taking better care of their work tool and anticipating defect detection.
2. To introduce and apply Andon system of manufacturing, aiming that the operators control any variation or warnings in machines, calling the maintenance as soon as possible to prevent any problem within machines.
3. Develop a check-list to be used in changing patient's shifting, aiming to ensure all basics operations are done correctly and ensure the integrity of machine. This check list also could provide the information about the responsible person of some bad utilization of machine's parts.

To training the operators of the 4th Company in TPM concepts, the authors used the same presentation model used for all other trainings. This training (as all other performed before) focused on the weaknesses of these operators to avoid bad use of hemodialysis devices, functioning, and patients' safety (assuring the correct use), also to detecting external malfunctions.

The operators were trained in how to clean correctly the surface of the machines, how to operate the machine correctly avoiding the breaking of parts, and also trained in how to react correctly to the most common machine's warning.

All of them were pointed out about their mistakes and induced to repeat the most common mistakes during the training, making possible their comprehension about those and letting easily to correct (as the same mentioned to the Company 2 and 3).

After the TPM training, the employees were introduced to Andon technique (visual panel control). This training was basically explaining how the operators should fill the data on the control sheet (exhibit 10). After that, all responsible Nurses were trained in how to act when any advertisement was marked by any employee:

1. Check the advertisement on the pointed machine.
2. Follow up at what time the problem occurs.
3. Call the maintenance service and program when the corrective action will be performed.
4. When the problem has been solved, erase the advertising from the control sheet.

EXHIBIT 10 – Andon Control Sheet – Company 4

Serial Number	Responsible	Occurrence	Shit / Maintenance Run
		STAND BY MACHINE	
		MACHINE IN USE	

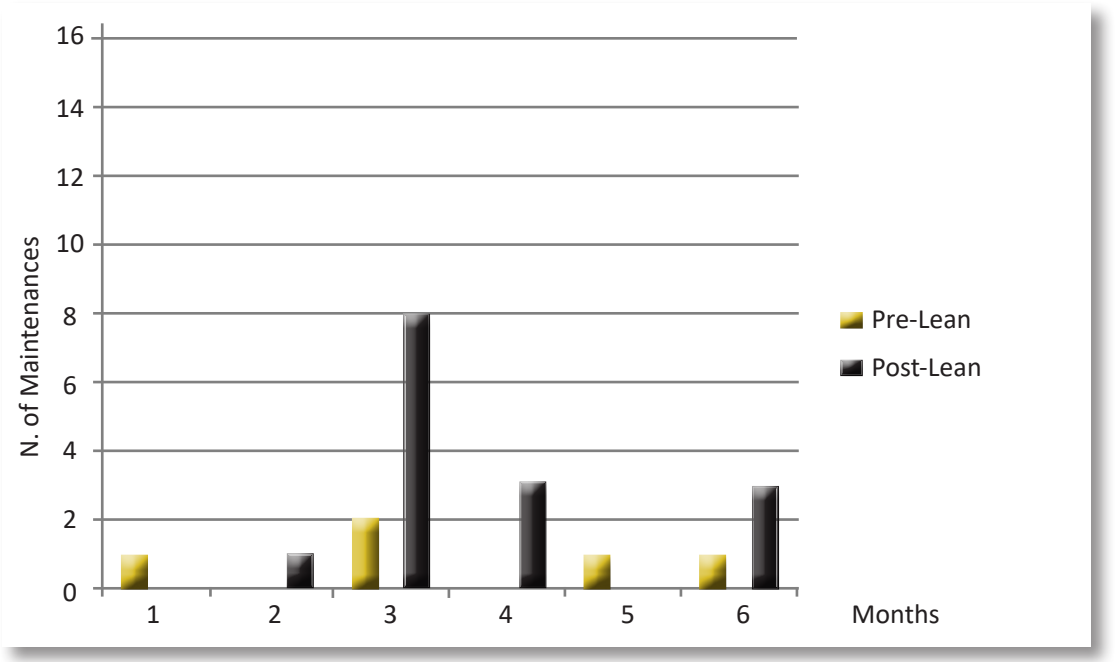
SOURCE: The authors (2017)

4.5.1 Findings

The exhibit 11 shows the comparison between pre and post lean implementation. The first semester of the analysis, presented 2 corrective maintenances and 3 operational errors. Curiously on the second semester, the result of TPM and Andon implementation resulted in an increase of maintenances: 11 corrective maintenances and 4 operational errors.

This result provided by Andon and TPM implementation is very satisfying, considering the operators started to anticipate problems, the required corrective maintenances were realized in less than 24 hours, reducing the downtime. The reduction of the response time to correct defects on machinery is very important, mainly in medical devices.

EXHIBIT 11 – Data comparison – Company 4



SOURCE: The authors (2017)

Normally (as mentioned before) an intervention to repair a machine takes around 48 hours, which represents 6 treatments not available. When a company do not have available machines to provide treatments to patients, it is necessary to change the patient's schedule or temporarily transfer him to another clinic (which generates loss of revenue).

Table 7 shows how much was possible to save considering the intervention time was less than 24 hours to be realized.

TABLE 7 – Saving – Company 4

Cost of Opportunity per Treatment			
179,03			
Number of Machines	Machine Not Available (Hours)	Number of Lost Treatments	Lost Incoming
1	12	3	R$ 537,09
9	108	27	R$ 4.833,81
		Saving	R$ 4.833,81

SOURCE: The authors (2017)

CONCLUSION

This study aimed to analyze the implementation of lean manufacturing principles in health services, more specifically in nephrology clinics. The literature reviews were carried out considering two focuses: one to define the concept of lean manufacturing, and the other, to identify the studies already carried out in the health sector, how lean principles were applied and what results were obtained, also to check for existing gaps in lean healthcare studies.

The literature review has shown that the concept of lean healthcare is still a very recent concept that emerged in the mid-2000s. The few bibliographical references of the practices of the lean healthcare philosophy and its limitations on methodology demonstrate how the subject is recent and little discussed. References of studies in Brazil are even more difficult to find, which shows great opportunities for further studies.

In this context, this study aimed to offer a contribution, justifying the exploratory character.

Four Brazilian Nephrology companies were chosen develop the study. Those responsible for the companies did not know the term lean manufacturing or lean healthcare. The companies were chosen because people with management and health knowledge recognized the applicability of these tools in their organizations, they also showed interest and openness to know new ideas and practices more efficient of management that could improve its performance and reduce wastes (which is fundamental for the Nephrology sector). There was a real interest in improving the processes in the organizations studied, which makes the possibility of applying new methodologies promising.

The analysis of the cases allowed to verify how the tools adapt to the health services besides reinforcing the idea that any process can incorporate the lean principles and also that the lean tools should be applied as a whole, not in parts, which could be less effective (WOMACK; JONES, 1996). It was also possible to demonstrate how the processes were implemented, and what results were obtained through data collection.

The organizations studied presented a strong concern for excellence in the processes selected as the object of the case study. Since the lean concept brings in itself the quest for process perfection, it was possible to establish a common ground for the analysis of principles. A good criterion for selecting a process to begin to apply lean principles is the process that is intended to lead to excellence, in this case, because it is a continuous treatment, the main point was the hemodialysis systems.

The principles of lean philosophy presented in organizations were: to eliminate activities that do not add value and to establish continuous flow. The principle of not

wasting the patient's time is also present in the 4 of the organizations studied; however, the adoption of each principle differs in levels of application and results.

The clinic 1 project, the most robust of all (though simple), demonstrates how a simple introduction and training to a concept can yield good results. The company that initially became interested in Kaizen philosophy training, and then, on behalf of its own employees, started to promote ideas of internal improvements, which contributed directly to the elimination of waste (time, money, patient time).

In general, TPM and PDCA training were extremely important for a direct reduction in patients' time wastage (for all clinics), since it dramatically reduced the rate of machine breakdown and consequently increased the availability of machines to perform of hemodialysis treatments (thus avoiding transfer of the patient to another location, or change in the day of treatment). We can say that even an isolated tool, with an operational character, has direct positive impacts in reducing wasted time and inputs (in the health area).

Some results of the implementations could have been better exploited, in a more specific and in depth way, but there were limitations refering to the business confidentiality, which ended up limiting the evolution in the matter of elimination of wastes (in question of values and items).

The main limitations factors to develop Lean manufacturing tools within Brazilian hospitals are the required conditions by ANVISA – Agência Nacional de Vigilância Sanitária (National Health Surveillance Agency) which required some working conditions, which are not addressed in this paper.

As a suggestion to other studies, the basic working conditions imposed by ANVISA (in Brazil) should be more explored, in order to develop lean manufacturing tools within Health sector, regarding these conditions need to be managed.

REFERENCES

ADLER, N. E. et al. Socioeconomic inequalities in health: no easy solution. **Jama**, v. 269, n. 24, p. 3140-3145, June 1993.

ALLWAY, M.; CORBETT, S. Shifting to lean service: stealing a page from manufacturers' playbooks. **Journal of Organizational Excellence**, New York, v. 21, n. 2, p. 45-54, Feb. 2002.

BALLÉ, M.; RÉGNIER, A. **Lean as a learning system in a hospital ward**. Leadership in health services, Califórnia, v. 20, n. 1, p. 33-41, May 2007.

BASTOS, M. G. et al. Doença renal crônica: problemas e soluções. **Jornal Brasileiro de Nefrologia**, Califórnia, v. 26, n. 4, p. 202-15, jun. 2004.

BENFIELD, C. B. et al. Applying lean principles to continuous renal replacement therapy processes. **American Journal of Health-System Pharmacy**, New York, v. 72, n. 3, Apr. 2015.

BERTANI, T. M. **Lean healthcare**: recomendações para implantações dos conceitos de produção enxuta em ambientes hospitalares. 2012. 234 f. Tese (Doutorado em Logística) – Universidade de São Paulo, São Paulo, 2012.

BURGESS, N.; RADNOR, Z. Evaluating Lean in healthcare. **International Journal of Health Care Quality Assurance**, New York, v. 26, n. 3, p. 220-235, Aug. 2013.

BUZZI, D.; PLYTIUK, C. F. Pensamento enxuto e sistemas de saúde: um estudo da aplicabilidade de conceitos e ferramentas lean em contexto hospitalar. **Qualidade Emergente**, São Paulo, v. 2, n. 2, p. 98-132, abr. 2011.

CHALICE, R. Improving healthcare using Toyota lean production methods: 46 steps for improvement. Milwaukee: ASQ Quality, 2007.

CONBOY, K. Agility from first principles: reconstructing the concept of agility in information systems development. **Information Systems Research**, New York, v. 20, n. 3, p. 329-354, fev. 2009.

COOK, D. J.; MULROW, C. D.; HAYNES, R. B. Systematic reviews: synthesis of best evidence for clinical decisions. **Annals of Internal Medicine**, Califórnia v. 126, n. 05, p. 376-380, mar. 1997.

COSGROVE, T. Value-based health care is inevitable and that's good. **Harvard Business Review**, New York, v. 03, n. 05, p. 134-225, Oct. 2013.

COSSON, I. O. et al. Perfil dos pacientes em terapia renal substitutiva em unidade de nefrologia. **Revista de Enfermagem UFPE**, Recife, v. 8, n. 10, p. 3693-3699, abr. 2014.

D'ANDREAMATTEO, A. et al. Lean in healthcare: a comprehensive review. **Health Policy**, Califórnia, v. 119, n. 9, p. 1197-1209, Aug. 2015.

FLEURY, A.; FLEURY, M. T. L. **Aprendizagem e inovação organizacional**: as experiências de Japão, Coréia e Brasil. 2. ed. São Paulo: Atlas, 1997.

GHINATO, P. **Elementos fundamentais do Sistema Toyota de Produção**: produção e competitividade – aplicações e inovações. Recife: Almeida & Souza; Editora Universitária da UFPE, 2000.

GLASER, B.; STRAUSS, A. **The discovery of grounded theory**. New York, NY: A. de Gruyter, 1967.

HART, C. **Doing a literature review**: releasing the social science research imagination. London: Sage Publications, 1998.

HEINBUCH, S. E. A case of successful technology transfer to health care: total quality materials management and just-in-time. **Journal of management in Medicine**, New York, v. 9, n. 2, p. 48-56, May 1995.

HEUVEL, J. van den; DOES, R. J. M. M.; KONING, H. de. Lean Six Sigma in a hospital. **International Journal of Six Sigma and Competitive Advantage**, New York, v. 2, n. 4, p. 377-388, Apr. 2006.

JIMMERSON, C.; WEBER, D.; SOBEK, D. K. Reducing waste and errors: piloting lean principles at Intermountain Healthcare. **The Joint Commission Journal on Quality and Patient Safety**, Califórnia, v. 31, n. 5, p. 249-257, May 2005.

JONES, D. T.; FILOCHOWSKI, J. Lean healthcare: think yourself thin. **The Health Service Journal**, New York, v. 116, n. 6000, p. suppl 6, 2006.

KAPLAN, G. S.; PATTERSON, S. H. Seeking perfection in healthcare: a case study in adopting Toyota Production System methods. **Healthcare Executive**, Califórnia, v. 23, n. 3, p. 16-8, 20-1, Aug. 2007.

KAPLAN, R. S.; PORTER, M. E. The Big Idea: how to solve the cost crisis in health care. **Harvard Business Review**, Ohio, v. 03, n. 05, p. 46, May 2012.

KIM, C. S. et al. The application of lean thinking to the care of patients with bone and brain metastasis with radiation therapy. **Journal of Oncology Practice**, New York v. 3, n. 4, p. 189-193, June 2007.

KONING, H. et al. Lean six sigma in healthcare. **Journal for Healthcare Quality**, Ohio, v. 28, n. 2, p. 4-11, Sept. 2006.

KOVÁCS, I. Novas formas de organização do trabalho e autonomia no trabalho. **Sociologia**: Problemas e Práticas, São Paulo, n. 52, p. 41-65, Abr. 2006.

MANOS, A.; SATTLER, M.; ALUKAL, G. Make healthcare lean. **Quality Progress**, Texas, v. 39, n. 7, p. 24, May 2006.

MARCHWINSKI, C.; SHOOK, J. (Ed.). **L**éxico lean: glossário ilustrado para praticantes do pensamento lean. São Paulo: Lean Institute Brasil, 2003.

MARX, R. **Trabalho em grupo e autonomia como instrumentos de competição**. 2. ed. São Paulo: Atlas, 2010.

MAZZOCATO, P. et al. Lean thinking in healthcare: a realist review of the literature. **Quality and Safety in Health Care**. New York, v. 19, n. 5, p. 376-382, June 2010.

MCCRAY, E.; MORELAND, M.; GRUNDEN, N. 5S Catches on at the VA Pittsburgh Health System. In: CHALICE, R. (Ed.). **Improving Healthcare Quality using Toyota lean Production Methods**: 46 Steps for Improvement. Milwaukee: Quality, 2007. p. 151-156.

MENEZES, F. G. de et al. Panorama do tratamento hemodialítico financiado pelo Sistema Único de Saúde: uma perspectiva econômica. **Jornal Brasileiro de Nefrologia**, Califórnia, v. 37, n. 3, p. 367-378, ago. 2015.

MERRIAM, S. B. **Qualitative research and case study applications in education**: revised and expanded from case study research in education. San Francisco: Willey, 1998.

MILLER, D. **Going Lean in Health Care**: IHI Innovation Series white paper. Cambridge, MA: Institute for Healthcare Improvement, 2005.

NELSON-PETERSON, D. L.; LEPPA, C. J. Creating an environment for caring using lean principles of the Virginia Mason Production System. **Journal of nursing administration**, New York, v. 37, n. 6, p. 287-294, Aug. 2007.

OHNO, T. **O Sistema Toyota de Produção além da produção**. São Paulo: Bookman, 1997.

_____. **Toyota production system**: beyond large-scale production. Ohio: CRC, 1988.

ORGANIZAÇÃO MUNDIAL DA SAÚDE (OMS). **Financiamento dos sistemas de saúde**: o caminho para a cobertura universal – Relatório mundial de saúde. Genebra: OMS, 2010. Disponível em: <http://www.who.int/whr/2010/whr10_pt.pdf>. Acesso em: 23 set. 2017.

PERALTA, C. B. da L.; FORCELLINI, F. A. Lean Healthcare: uma análise da literatura. **Produto & Produção**, New York, v. 16, n. 2, p. 124-178, Apr. 2015.

PORTER, M. E.; LEE, T. H. The strategy that will fix health care. **Harvard Business Review**, New York, v. 91, n. 12, p. 24, June 2013.

RIANI, A. M. **Estudo de caso**: o lean manufacturing aplicado na Becton Dickinson. 2006. 234 f. Tese (Doutorado em Logística) – Universidade Federal de Juiz de Fora, Juiz de Fora, 2006.

SILBERSTEIN, A. C. L. **Um estudo de casos sobre a aplicação de princípios enxutos em serviços de saúde no Brasil**. 2006. 298 f. Dissertação (Mestrado em Logística) – Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2006.

SOBEK II, D. K.; JIMMERSON, C. A3 reports: tool for process improvement. In: ANNUAL CONFERENCE, 12., 2004, Califórnia. **Proceedings...** Califórnia: Institute of Industrial Engineers-Publisher, 2004. p. 123-234.

SOBEK II, D. K.; SMALLEY, A. **Understanding A3 thinking**: a critical component of Toyota's PDCA management system. New York: CRC, 2011.

SOCIEDADE BRASILEIRA DE NEFROLOGIA. Disponível em: <https://sbn.org.br/publico>. Acesso em: 16 maio 2017.

SOUZA, A. C.; BATOCCHIO, A. Sistemas de manufatura: uma abordagem cronológica. CONGRESSO BRASILEIRO DE ENGENHARIA DE FABRICAÇÃO, 2., 2003, Uberlândia. **Anais...** Uberlândia: ABCM, 2003. v. 2.

SOUZA, L. B. de. Trends and approaches in lean healthcare. **Leadership in health services**, New York, v. 22, n. 2, p. 121-139, Apr. 2009.

SOUZA, L. B.; PIDD, M. Exploring the barriers to lean health care implementation. Public **Money & Management**, Califórnia, v. 31, n. 1, p. 59-66, Aug. 2011.

STOLLE, R.; PARROTT, D. It's not easy being lean, but scripting can help. **Health Management Technology**. New York, v. 28, n. 2, p. 26-34, May 2007.

WEBSTER, J.; WATSON, R. T. Analyzing the past to prepare for the future: writing a literature review. **Management Information Systems Quarterly**, New York, v. 04, n. 05, p. 78-86, June 2002.

WOMACK, J. P.; JONES, D. T. **Lean thinking**. New York: Simon & Schuster, 1996.

WOMACK, J. P.; JONES, D. T. **Lean thinking**: banish waste and create wealth in your corporation. 2 ed. New York: Simon and Schuster, 2010.

WOMACK, J. P.; JONES, D. T.; ROOS, D. **A máquina que mudou o mundo**. 2. ed. Rio de Janeiro: Campus, 1992.

YOUNG, T. An agenda for healthcare and information simulation. **Health Care Management Science**, Califórnia, v. 8, n. 3, p. 189-196, May 2005.

YOUNG, T. et al. Using industrial processes to improve patient care. **Brihish Medical Journal**, Califórnia, v. 328, n. 7432, p. 162-164, Jan. 2004.