The usage of lean tools in healthcare environment

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Abstract
This study aims to cover aspects that were not addressed in previous reviews and update them. A review was conducted on 48 articles published in journals indexed by Web of Science and/or Scopus. The results were compared with those presented in previous reviews on the same subject: lean healthcare. This study identified the state of the art of lean healthcare, considering aspects such as lean tools, healthcare areas, and other factors. Understanding the current knowledge about barriers and tools for implementing lean healthcare should be valuable for healthcare managers. Furthermore, we emphasize that previous studies did not address the mapping of barriers to lean healthcare adoption.
Keywords: Lean healthcare; Lean hospital; Tools; Health service.

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O uso de ferramentas *lean* no ambiente de saúde

Resumo
Este trabalho visa cobrir aspectos não abordados em revisões anteriores e atualizá-los. Realizou-se uma revisão em 48 artigos publicados em periódicos indexados pela *Web of Science* e/ou *Scopus*. Os resultados foram comparados com os apresentados nas revisões anteriores no mesmo assunto: *lean healthcare*. Este trabalho identificou o estado da arte da saúde *lean*, levando em consideração aspectos como ferramentas *lean*, áreas da saúde e entre outros aspectos. Conhecer o início da arte sobre as barreiras e ferramentas para aplicar o *lean healthcare* deve ser valioso para os gestores de saúde. Além disso, destacamos que os trabalhos anteriores não abordaram o mapeamento de barreiras para a adoção do *lean healthcare*.
Palavras-chave: *Lean healthcare*; *Lean* hospital; Ferramentas; Serviço de saúde.

El uso de herramientas *lean* en el entorno sanitario

Resumen
Este trabajo tiene como objetivo cubrir aspectos no abordados en revisiones anteriores y actualizarlos. Se realizó una revisión de 48 artículos publicados en revistas indexadas por *Web of Science* y/o *Scopus*. Los resultados se compararon con los presentados en revisiones anteriores sobre el mismo tema: *lean healthcare*. Este trabajo identificó el estado del arte de la salud *lean*, teniendo en cuenta aspectos como las herramientas *lean*, las áreas de la salud y otros aspectos. Conocer el estado del arte sobre las barreras y herramientas para aplicar *lean healthcare* debería ser valioso para los gestores de salud. Además, destacamos que los trabajos anteriores no abordaron el mapeo de las barreras para la adopción de *lean healthcare*.
Palabras clave: Salud *lean*; Hospital *lean*; Instrumentos; Servicio de salud.

Introduction

According to Sugimori, Kusunoki, Cho and Uchikawa (1977), the focus of the Toyota Production System (TPS) is to produce better quality goods having higher added value and at even lower production costs. The TPS originated the basis of the so-called Lean Manufacturing systems, as it appears in Delbridge and Oliver (1991) and in Hogg (1993). Since its appearance, it has been used in different industries, as it appears in Table 1.

Table 1 - Lean references by industry

Industry	Reference
Automotive	Yin, Stecke and Li (2018); Kehr and Proctor (2017); Sugimori, Kusunoki, Cho and Uchikawa (1977)
Pharmaceutical	Kumar and Mukherjee (2020); Newell, Steinmetz-Malato and Dyke (2011); Papavasileiou, Koulouris, Siletti and Petrides (2007)
Chemical	Caicedo Solano, García Llinás and Montoya-Torres (2020); Persoon, Zaleski and Frerichs (2006); Melton (2005)
Oil & gas	Mustapha, Ageh, Maduekwe and Ojulari (2012)
Civil construction	Chung and Mutis (2020); Koskela, Ferrantelli, Niiranen, Pikas and Dave (2019); Bryde and Schulmeister (2012)

Source: The authors (2022).

Inspired by the positive results reached in industrial segments, lean manufacturing has been adapted and extended for the services sectors, mainly in the health segment. According to Johnson, Shanmugam, Roberts, Zinkgraf, Young, Cameron and Flores (2004), lean healthcare is the adoption of lean in the healthcare environment, which could reduce the number of people in the waiting room, triage and attending room, beyond reducing waste of time and other resources.

However, the records of these actions are spread in the literature, which, as described Pereira and Costa (2015), it should imply in loss of systemic vision about the state-of-art in this subject. Aiming to fulfil this gap, Mazzocato, Savage, Brommels, Aronsson and Thor (2010), Souza (2009), Costa and Godinho Filho (2016) and Gomes, Vieira and Reis (2017) produced literature reviews that approach the use of lean in healthcare management. Despite the advances in the previous reviews, it is necessary to update and even expand the results from such works and to indicate research trends.

In this paper, we contribute to fulfilling this gap through a structured analysis of papers' metadata and content, identifying the state of the art of the lean healthcare.

Previous systematic reviews about lean healthcare

In the review described in Souza (2009) a set composed of 90 articles was analyzed, covering the period from 2002 up to 2008. The case studies analyzed refer to the use of Lean tools in some departments of a hospital, including, pharmacy, radiology, pathology, and laundry. The study of the patient flow made it possible to reduce the waiting list and the costs, yet it improved the quality of patient care and patient satisfaction, they realized the use and effectiveness of other Lean tools applications like A3, 5S, and Just in Time. They identified the United States, United Kingdom and Australia as the main countries in the implementation of Lean, according to the literature.

The study of Mazzocato, Savage, Brommels, Aronsson and Thor (2010) analyzed 33 studies on Lean healthcare covering the period from 1998 up to 2008 and highlights four tools as the most usual in Lean healthcare context. These tools are Value Stream Mapping (VSM), Process mapping, 5 whys, and 5S (so-called due to the first letter of 5 Japanese words Seiri - Classification, Seiton - Order, Seiso - cleaning, Seiketsu - standardization, Shitsuke - Discipline).

Briefly, Value Stream Mapping (VSM) is used to understand processes, identify and analyze problems. Process mapping is utilized to organize more efficient and/or effective processes. The 5 whys technique is employed to improve error detection, relay information to problem solvers, and prevent errors from causing damage. Lastly, 5S is a method used to manage change and solve problems with a scientific approach. It is named after the first letter of 5 Japanese words: Seiri - Classification, Seiton - Order, Seiso - Cleaning, Seiketsu - Standardization, and Shitsuke - Discipline.

Another conclusion of Mazzocato, Savage, Brommels, Aronsson and Thor (2010) is that the main results of Lean Healthcare are: improving patient satisfaction and reduction of errors, mortality, costs, and waiting time. This work also highlighted that Lean tool were mostly applied in the following health sectors: emergencies, anesthesiology/intensive care, gynecology, and obstetrics.

The study conducted by Costa and Godinho Filho (2016) updated the results found out in Souza (2009) and Mazzocato, Savage, Brommels, Aronsson and Thor

(2010), by analyzing 107 articles covered by Engineering Village, Web of Knowledge, Scopus, and Google Scholar databases published between 2009 and 2014.

This study discovered that most (42%) of papers analyzed have applied Lean in clinical ad therapeutic operations. Another point highlighted in Costa and Godinho Filho (2016, p. 5) is that there is a tendency to focus improvement in healthcare on "distinct features of the system rather than the system as a whole", which follows a characteristic observed in Lean manufacturing.

Concerning the Lean tools and methods used in the healthcare environment, this study discovered that Lean healthcare tools usage is concentrated in assessment and improving rather than in monitoring scope, and, that the four most adopted tools are: Value stream mapping, standardized work, rapid improvement events/Kaizen event, and process mapping. These tools are also among the six most frequently identified in Mazzocato, Savage, Brommels, Aronsson and Thor (2010).

Regarding the geographical distribution of the research in the Lean healthcare subject Costa and Godinho Filho (2016) reports that the United States, the United Kingdom and the Netherlands appear as the countries leading the number of articles recorded in the datasets researched. It is interesting to note that neither authors from China nor Japan appear as authors in the papers investigated.

The focus of the Lean healthcare approached in the papers analyzed in Costa and Godinho Filho (2016), were organized into four categories:

- Support activities: such as finance and accounting, marketing, human resources, and information technology), named support activities. In This category (support activities), the studies were realized in the Information Department. Despite it is a support activity, the results shown in the papers underline that such actives produce benefits to patients such as: reduction in waiting time of the patients in the system, and reduction in queue length.
- Ancillary services: the hospital pharmacy was the most approached in the papers, followed by pathology, radiology, laboratory, ambulatory, sterile, laundry and anesthesia. It has been observed that this kind of service is similar to manufacturing operations in their repetitive nature, offering great potential for standardization. On the other hand, one of the manuscripts analyzed, underlined that Kim, Spahlinger, Kin, Coffey and Billi (2009) showed unsatisfactory results in ambulatory, resulting in project interruption "because of the team's discouragement with the slow progress, cross-departmental barriers and time constraints".

- Clinical and therapeutic operations: most of the papers were performed in Emergency Department, followed by Operating Room, Mental Health Centre (4), Ophthalmology (3), Nursing Department (3), Health Visiting Service (2), Audiology (1), Cardiology (2), Physiology (1), Pediatrics (1), Orthopedics (1), and Oncology (1). It was observed a strong resistance to changes mainly the way process moves to standardization.
- Hospital: In this category, a set composed of 23 articles were analyzed, most of them describing the implementation of Lean tools and methods. The most used were value stream mapping, Ishikawa diagram, and DMAIC, resulting in financial performance improvement, cost reduction, length time to stay "in process", waiting time reduction, and increasing service capacity. On the other hand, according to Machado and Leitner (2010), it is important to treat the hospital as one unity with several of dependent processes once a transformation in one process can influence other ones, even by shifting problems in the linked process.

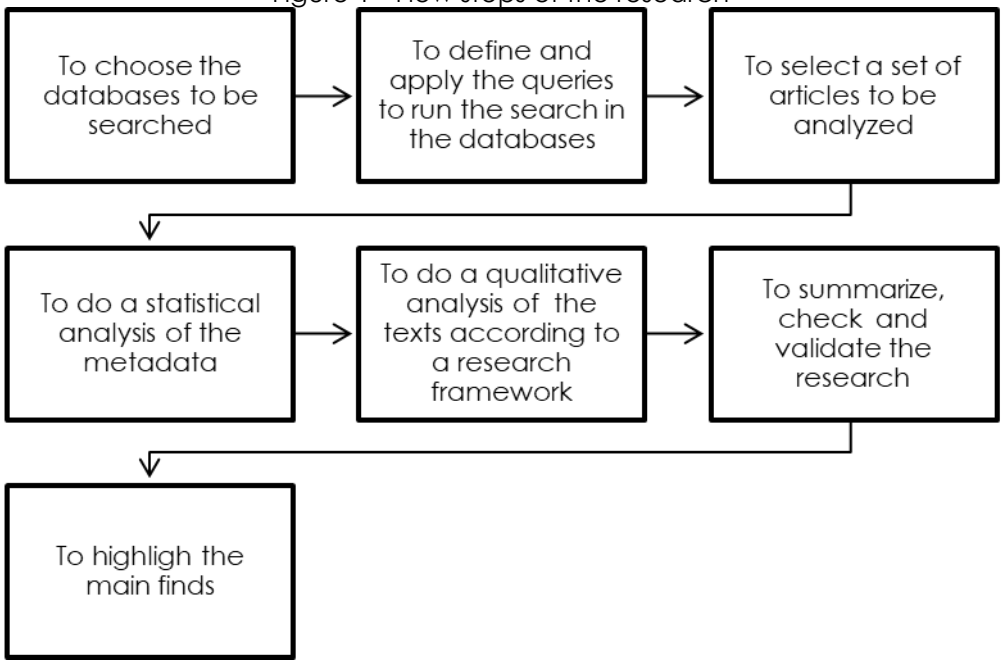
In Gomes, Vieira and Reis (2017), a systematic literature review was carried out including 175 articles from the years 2002 up to 2015. Three main Lean tools and techniques mentioned in this literature review were Value Stream Mapping, Kaizen, and 5S. It was also noted the use of quantitative tools applied along with the Lean approach such as Six Sigma and Simulation. The health sector identified as the most used area for Lean tools application are emergencies, followed by the surgery sector and the post-operative team. Decreased processing time (exams and visits) and reduced queues were the results found.

As one can observe, most of the literature review in the Lean healthcare subject has focused on the tools, results, and health scope, resulting in a lack about barriers to Lean healthcare adoption.

The research and the results

In this study, we provide an extension and update the previous studies. The research process was carried out through the steps that are summarized in Figure 1, which were inspired in previous reviews works, such as: Moher, Liberati, Tetzlaff and Altman (2009), Silva and Costa (2015) and Pereira, Costa and Pereira (2019).

Figure 1 - Flow steps of the research



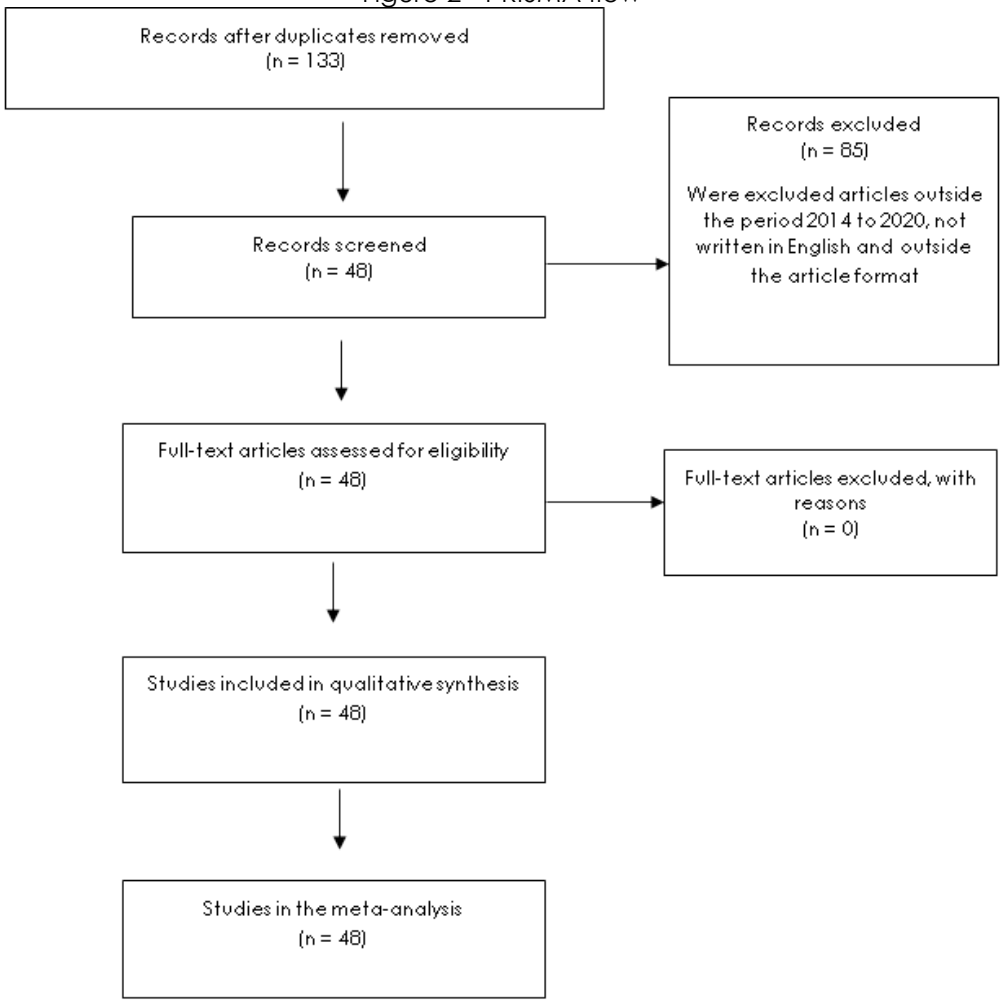
Source: The authors (2022).

To select the databases and articles

The Web of Science and Scopus were used as source of articles. As reported in Sanchez Rodriguez, Carmo and Costa (2013), this choice is justified because it reduces the probability of using predatory sources or even no blinded reviewed ones. It follows a copy of the queries, just as they were inserted in the Web of Science and Scopus. As one can see in Figure 2, by applying the filtering process of PRISMA (MOHER; LIBERATI; TETZLAFF; ALTMAN, 2009) it resulted in 48 documents for the analysis.

- Web of Science: TOPIC: ("Lean Healthcare") OR TOPIC: ("Lean Hospital") AND TOPIC: ("Tools"). Refined by: YEARS OF PUBLICATION: (2020 OR 2016 OR 2019 OR 2015 OR 2018 OR 2014 OR 2017) AND LANGUAGE: (ENGLISH) AND TYPES OF DOCUMENTS: (ARTICLE).
- Scopus: (TITLE-ABS-KEY ("Lean healthcare") OR TITLE-ABS-KEY ("Lean hospital") AND TITLE-ABS-KEY ("tools")) AND (LIMIT TO (PUBYEAR (2020) OR LIMIT-TO (PUBYEAR (2019) OR LIMIT-TO (PUBYEAR (2018) OR LIMIT-TO (PUBYEAR (2017) OR LIMIT-TO (PUBYEAR (2016) OR LIMIT-TO (PUBYEAR (2015) OR LIMIT-TO (PUBYEAR (2014)) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")).

Figure 2 - PRISMA flow



Source: The authors (2022).

To analyze the metadata of the articles

The metadata of the selected papers was analyzed throughout the following framework: geographical origin, most frequent journals, keywords occurrence, Co-citation map. Regard the size limit this article, the authors decide to describe only the analysis of the geographical and keywords metadata.

Geographical metadata

It was discovered that Brazil and the United States are two countries that stand having, respectively, 13 and six publications in the field of Lean Healthcare in the last five years. We also highlight Sweden with five, Italy and England with four publications each, Ireland and India with two publications each. Scotland, Canada, Spain, Thailand, Kuwait, Netherlands, New Zealand, Oman, Czech Republic, Senegal, Turkey, Hungary, Lebanon and United Arab Emirates published one article

each. We also found out that Brazil appears as the origin of most papers analyzed, covering the period from 2015 up to 2020.

This result differs from the one shown in Costa and Godinho Filho (2016) that pointed out the United States, United Kingdom and the Netherlands as the countries leading the number of articles recorded in the subject.

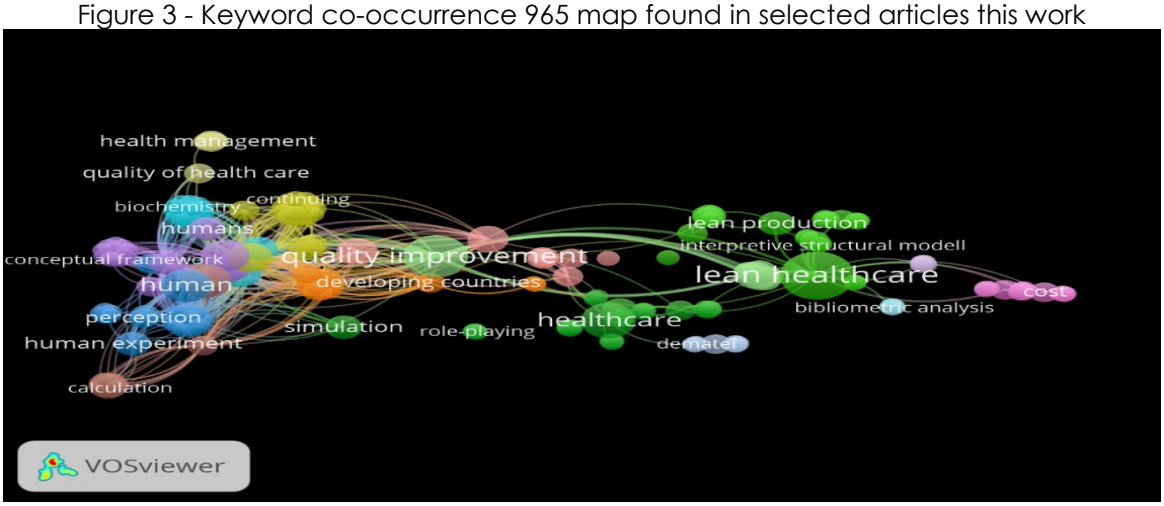
The other reviews mentioned in the second section of the present work, did not show an analysis of the geographical metadata.

Keywords co-occurrence

In Figure 3 it is shown a map of keywords co-occurrence. It was generated by inputting the keywords and metadata into VOSViewer software. Eck and Waltman (2010), to address the keywords used in the articles. Note that the hot topics are: "Lean healthcare", "quality improvement", "human" and "total quality management".

The keyword co-occurrence network shown in Figure 3, the colors in this figure are a chronological indicative to the appearance of them in the references' set. As an example, the keyword "human" in light-blue color has been mentioned in the literature in the last years, while the keyword was more present in the earlier years analyzed in the set. It is interesting to note that the previous reviews did not approach a similar analysis.

Figure 3 - Keyword co-occurrence 965 map found in selected articles this work



Source: The authors (2022).

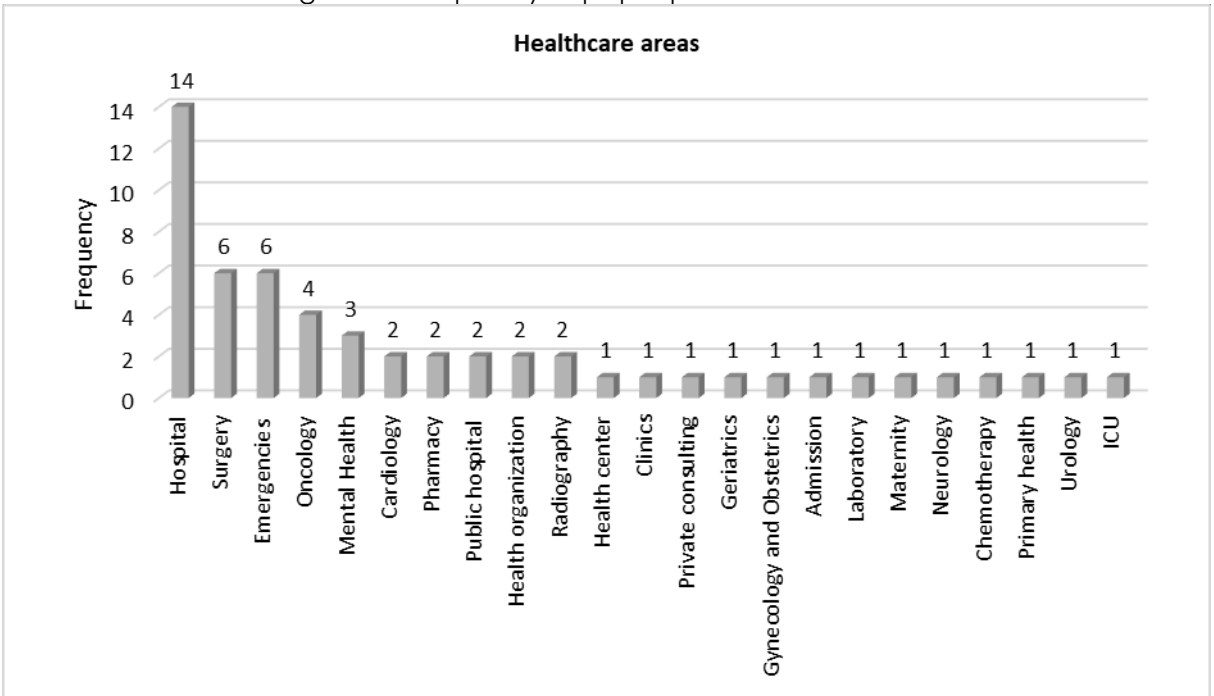
Qualitative analysis of the articles' content

We also analyzed the content of each paper under the following construct: health areas of implementation, lean tools identified in the survey, how Lean tools were applied.

Health areas of implementation. Figure 4 shows the results from the analysis of the article's data set, according to the departments of health that applied the methods and tools of Lean Healthcare. Most of the papers described the application in hospitals as a whole, 14 documents, followed by Lean adoption in emergencies and surgery department, found in six documents. Even so, it was also verified the application of Lean tools in other health sectors such as oncology, mental health center, cardiology, radiography, pharmacy, public hospitals, health organizations, chemotherapy, urology, Intensive Care Unit - ICU, and among other sectors.

Comparing the results found out in our research against those that appear in previous reviews, we observe that Urology, Primary health, Rehabilitation, Chemotherapy, Neurology, Maternity, Admission, Geriatrics, Health organization and Health center are the novelty in the subject of areas of Lean healthcare adoption.

Figure 4 - Frequency of paper per healthcare area



Source: The authors (2022).

In order to allow the auditing of the data collected in the research, Table 2 shows the list of analyzed articles, the health services addressed and frequency in which each area of health was addressed in the studied literature.

Table 2 - Assigning the healthcare areas covered by Lean healthcare with the references

Area	Citations	Frequency
Hospital (public hospitals and private hospitals)	Barnabè, Giorgino, Guercini, Bianciardi and Mezzatesta (2018); Barnabè, Guercini and Di Perna (2019); Barnabè, Giorgino, Guercini, Bianciardi and Mezzatesta (2017); Drotz and Poksinska (2014); Henrique, Rentes, Godinho Filho and Esposto (2015); Holden, Eriksson, Andreasson, Williamsson and Dellve (2015); Ponanake, Limnararat, Pithuncharurnlap and Sangmanee (2014); Rees and Gauld (2017); Schonberger (2018); Singh (2019); Siqueira, Siqueira, Lopes, Gonçalves and Sarantopoulos (2019); Tortorella, Fogliatto, Anzanello, Marodin, Garcia and Esteves (2017); Vashi, Lerner, Urech, Asch and Charns (2019); Vavrušová (2015); White, Butterworth and Wells (2017)	16
Surgery	Fogliatto, Anzanello, Tonetto, Schneider and Magalhães (2020); Costa, Godinho Filho, Rentes, Bertani and Mardegan (2017); Régis, Santos and Gohr (2019); van Rossum, Aij, Simons, Eng and Have (2016); White, Wells and Butterworth (2014b); Paim, Costa, Carvalho and Lima (2016)	6
Emergencies	Efe and Efe (2016); Gomes, Vieira and Reis (2017); Leite, Bateman and Radnor (2020); Régis, Gohr and Santos (2018); Régis, Santos and Gohr (2019); Romano, Guizzi and Chiocca (2015)	6
Oncology	Eiro and Torres-Junior (2015); Régis, Gohr and Santos (2018); Régis, Santos and Gohr (2019); Mehdi and Al Bahrani (2017);	4
Mental health	Cheng, Bamford, Papalexi and Dehe (2015); Colldén, Gremyr, Hellström and Sporraeus (2017); DiGioia III, Greenhouse, Chermak and Hayden (2015)	3
Cardiology	Régis, Gohr and Santos (2018); Régis, Santos and Gohr (2019)	2
Pharmacy	Costa, Godinho Filho, Rentes, Bertani and Mardegan (2017); Régis, Santos and Gohr (2019)	2
Laboratory	Gupta, Kapil and Sharma (2018); Régis, Santos and Gohr (2019)	2
Health organization	Fournier and Jobin (2018); Kahm and Ingelsson (2017)	2
Radiography	McCann, Hassard, Granter and Hyde (2015); Costa, Godinho Filho, Rentes, Bertani and Mardegan (2017)	2
Health center	Kanamori, Sow, Castro, Matsuno, Tsuru and Jimba (2015)	1
Clinic	Fisher, Ding, Hochheiser and Douglas (2016)	1
Geriatrics	White, Wells and Butterworth (2014b)	1
Ginecology and Obstetrics	Demosthenes, Lane and Blackhurst (2015)	1
Admission	Haddad, Zouein, Salem and Otayek (2016)	1
Maternity	Paim, Costa, Carvalho and Lima (2016)	1
Neurology	Régis, Santos and Gohr (2019)	1
Chemotherapy	Costa, Godinho Filho, Rentes, Bertani and Mardegan (2017)	1
Rehabilitation	White, Wells and Butterworth (2014b)	1
Primary health	Poksinska, Fialkowska-Filipek and Engström (2016)	1
Intensive Care Unit	Trzeciak, Mercincavage, Angelini, Cogliano, Damuth, Roberts, Zanotti and Mazzarelli (2018)	1
Urology	Boronat, Budia, Broseta, Ruiz-Cerdá and Vivas-Consuelo (2018)	1

Source: The authors (2022).

Lean tools

The research resulted in identifying the Value Stream Mapping (VSM) is the most used Lean tool in the set of articles analyzed. Another tool addressed as preferential is the 5S, being used in 10% percent of the studied applications and presented in 14 documents. The Kaizen method is cited in 13 articles and used in nine percent of studied applications. The 5S acts, above all, in the improvement of quality, using five "senses", sense of use and discard, sense of order and organization, sense of cleanliness, sense of standardization, and sense of self-discipline. Its importance in health can be attributed to the need for a clean and sterile environment. According to Kanamori, Sow, Castro, Matsuno, Tsuru and Jimba (2015), there is a reduction in the time to find items; greater capacity to move around the office; the centrality of the patient; reduction of waiting time for patients; better guidance for patients; improved sterilization processes and others. These were the results found by applying the 5S tools and Kaizen methods.

Again, comparing these results against those that appear in the previous reviews, we noticed Value Stream Mapping as the most used Lean in healthcare systems. The newness is the grown-up of 5S, Kaizen and visual management. It was also observed a preference for using simple tools providing faster actions in problem solutions.

Ways in which lean tools were applied

Analyzing the selected documents, it was observed the primordial ways of implementing tools and the main results obtained. In general, as a form of implementation, there are team training workshops, project simulation, meetings with the team, information gathering, separation of activities that generate value and those that do not generate value, the engagement between employees, and questionnaire with patients to find what is valuable to the patient and what the patient identifies as waste.

The key findings revealed several significant outcomes: a reduction in hospital waste, including expired medications and inventory; enhanced patient satisfaction; decreased lead time; process stabilization; increased number of visits. In addition these points, reduced errors by doctors and in blood collection procedures; the shorter average time for exam delivery; decreased patient stay duration; cost reduction in appointments; and a decrease in both appointment and exam

cancellations. Therefore, the analysis of texts below relates 13 cases that show the application of the Lean tools in health services, highlighting its methods and achievements.

The tools of Lean 5S and Kaizen were implemented in the sterilization of surgical materials in Brazil in the study by Fogliatto, Anzanello, Tonetto, Schneider and Magalhães (2020). For implementation, Lean principles were studied and organized into which surgical materials could be prioritized and which could be rationalized to reduce costs and the burden of sterilization processes, divided the teams into Kaizens groups to achieve the objective of continuous improvement. They reported the results proposing a strategy to address the trays rationalization, prioritizing complex and frequent surgical specialties, and using group technology to group surgical trays, streamlining specialized analyses. Thus, they reduced the number of instruments by an average of 9.75% and the time to assemble trays by 9.68%, achieving an annual savings of US $ 285,756.00 in sterilization processing costs.

In the study by Barnabè, Giorgino, Guercini, Bianciardi and Mezzatesta (2018), the authors applied the principles of Lean thinking and shared competencies in collaborative processes in a hospital, devoted to educational tools for training health decision-making agents. They used the role-playing game (RPG) as a simulation measure and team training. It guaranteed the satisfaction of patient demand, patients reported improvement in the process, in lead time, and in the process quality according to health professionals and patients.

Barnabè, Giorgino, Guercini, Bianciardi and Mezzatesta (2017) suggested the development of a simulation game that not only offers a suitable physical environment within the hospital (such as open space), but also actively promotes and motivates the utilization of a wide range of medical instruments (such as a portable chest X-ray machine), administrative documents (including medical records and laboratory tests) and Lean tools. The aim is to create a simulation that closely emulates real-life scenarios and encourages active participation and engagement. The game challenges participants with work-related tasks, a variety of possible scenarios (for example, a growing patient demand), and a complete set of metrics to measure their performance. In particular, a dedicated business intelligence software program is used to monitor and evaluate performance. The graphs, key performance assessments, tables and panels inform the discussion and decision-making during all phases of the game. As a result, participants obtained recognition

of the simulated environment as realistic (58.8%) or realistic (17.6%). In total, 86.7% of the participants perceived an increase in knowledge and understanding about the specific simulated process. 93.4% of the participants emphasized that the basis of a simulation game was more useful and effective than traditional classroom training. Specifically, players stated that this simulation game encouraged them to reflect and use/implement various Lean tools and techniques (for example 5S technique, visual management tools, various Lean metrics, value stream mapping) during the simulation. Overall, 94% of the participants were willing to participate more often in the simulation game.

Barnabè, Guercini and Di Perna (2019) identified two streams: knowledge and practice. In his study, Lean training was reported to identify value creation for decision-makers have defined a measurement framework to identify what is of value to the patient and training of staff for Lean implementation. Results obtained were improvement in lead time, reduction in the people displacement, reduction in the cost of processes, reduction of walking time to 154 km, quality of care and safety in health processes.

Boronat, Budia, Broseta, Ruiz-Cerdá and Vivas-Consuelo (2018) used three steps for the implementation: 1) team training and improved feedback among professionals; 2) process management and super-specialization; and 3) improvement of assessments (continuous improvement). The assessments were obtained from the hospital's information systems. The main source of information was the Balanced Scorecard for health systems management. The comparison with other autonomous and national urology departments was carried out through a platform, with the help of the Hospital's records department. A baseline was established with the assessment obtained in 2011 for the comparative analysis of the results after the Lean Healthcare implementation approach. The results were: high professional satisfaction, improving quality assessment, reaching a risk-adjusted complication rate of 0.59, and a risk-adjusted mortality rate of 0.24 in four years. A value of 0.61 was reached with the efficiency assessment, with savings of 2.869 stays compared to the national benchmarking. The risk-adjusted readmission index was the only assessment above the standard, with a value of 1.36, but with a progressive annual improvement.

In the article by Cheng, Bamford, Papalexi and Dehe (2015), lean training workshops were carried out, resulting in the establishment of current state diagnosis for lean application in each environment of the mental health center. The results

mentioned in this study were the stabilization of the operational processes in a current state within each team of the mental health center and identification of operational issues.

The study by Demosthenes, Lane and Blackhurst (2015) for implementing lean identified items with the high cost for which there were less expensive alternatives, but with effective characteristics. As an educational intervention, were carried out the main rounds revising the research results, as well as recommendations that would allow changes in health care. In total, 50 of the 70 suppliers (71%) answered the survey. Vaginal insertions of hydrochloride acetate/pramoxine hydrochloride and dinoprostone were the target of the intervention. The use of vaginal dinoprostone insertion decreased by 50.5%, with savings of US $ 66,500 when comparing the pre-intervention period with the post-intervention period. The use of hydrocortisone acetate/pramoxine hydrochloride decreased by 90%, with savings of $ 92,655. Combined, the decrease in the use of these products led to savings of US $ 159,155 within a year after the intervention. Through the use of research and educational intervention, they demonstrated that simple interventions could lead to changes in lean healthcare quality.

In the studies by DiGioia III, Greenhouse, Chermak and Hayden (2015), Efe and Efe (2016), they used similar means for the implementation of lean and obtained similar results. As implementation means, they used employee engagement and training, space renovation, analysis of patient flow and process redesign. As a result, the elimination of waste, patient satisfaction, decreased expenditure *per* patient and length of stay was reported.

Gupta, Kapil and Sharma (2018), with their article, showed the use of VSM, Pareto Table and Ishikawa diagram (or fishbone). The application of these tools helped to identify the use of other lean tools such as 5S and Visual Management. For that, they had weekly meetings to discuss progress, training employees and identification waste. The results were a reduction in the response time for clinical examinations, patient satisfaction and teamwork.

In the work of Haddad, Zouein, Salem and Otayek (2016) to comply to improve flow, reducing time and changing culture, the types of waste in each process were identified, making it possible to build a table describing the phase, the process, the description of the waste and the type of waste. The construction of a simulation model with the support of the Arena software, which identified the move

time in the admission sector. As a result, the patient's total time in the admission system was improved by 43%, an increase of 95% in the patients' confidence level, and the processes became standardized.

In research by Costa, Godinho Filho, Rentes, Bertani and Mardegan (2017), they discovered problems and opportunities through the VSM and DMAIC application in five health departments where they analyzed patient flows, exams need and patients' schedules. They obtained a reduction in lead time and financial costs, 78% reduction in costs with pharmacy, 42% reduction in waiting time reported by patients and 93% reduction in blood analysis time.

Romano, Guizzi and Chiocca (2015) examined the use of the Fast-Track tool in an emergency department. Patients were categorized based on their severity using the Emergency Severity Index. Fast-Track focused on less serious cases to reduce waiting times. Different areas were designated for patients, based on their classification. The shock room for critical cases; the urgency area for potentially critical and in-need-of-service patients; the minor codes area for minor problems; an assisted waiting area for patients unable to access the hospital; a brief observation area for patients requiring further assessment; and a short intensive observation area for trauma and toxicology cases. The implementation of this system improved patient flow, allowing for better resource allocation and increased capacity to treat a greater number of patients.

In this way, the lean approach, such as VSM, 5S, Kaizen, and other tools mentioned in this work, can be applied to different sectors in health. Such as clinics, hospitals, surgical centers, oncology, geriatrics, gynecology and obstetrics, neurology, emergencies, cardiology, Intensive Care Unit, hospital pharmacy, SUS, mental health service, chemotherapy, radiotherapy, sterilization, maternity and primary care. The use of such methodologies is recommended for health departments that wish to achieve better results and efficiency during health procedures.

It is worth mentioning two related cases, one by Demosthenes, Lane and Blackhurst (2015) and other by Fogliatto, Anzanello, Tonetto, Schneider and Magalhães (2019), which presented results of annual savings of US $ 285,756 in sterilization processing costs and US $ 159,155 using educational research, which together generated an annual savings of US $ 444,911, resulting from the implementation of Lean Healthcare.

Despite the previous works of the review did not approach this aspect, we mind that is it worthy to highlight the main ways or mode lean healthcare was previously applied, linking that to the application environment and the main results reached in the implementation of lean healthcare.

Barriers and opportunities

The accomplishment mentioned by Leite, Bateman and Radnor (2020) describe the adoption of lean tools in an emergency sector agreed by the SUS in Brazil, aimed at identifying and understanding the barriers to implementation of lean tools in the public health system. The identified barriers could be answered with lean management consultancy, six types of barriers were elicited: influence of doctors in the process, patient behavior, restrictions related to resource management affecting the clinical team, impact of the governance model on medical work, the model that SUS operates creates restrictions, and influence of team behavior.

The results showed two types of barriers to lean implementation in the health area: ostensible and underlying. Ostensible barriers, in general, are common during the lean journey, but with deeper causes that influence its creation. These barriers come from the literature and knowledge of professionals. In contrast to, underlying barriers are based on rich qualitative data that emerge as the root cause of the ostensible.

Drotz and Poksinska (2014) reported the introduction of lean culture and leadership through daily meetings, teamwork, through Value Stream Mapping, it is possible to see opportunities for implementing other tools such as Kaizen, visual control, 5S, takt time, work standardization and *Poka-Yoke*. They mapped risks and safety and analyzed what creates value for the patient. Reported results were the reduction of waste, greater interaction and cooperation between employees and patients.

Eiro and Torres-Junior (2015) also identified that through the Value Stream Mapping there is an opportunity to implement other lean tools such as PDCA (plan, do, check and act), A3, FMEA (Failure Mode and Effect Analysis), Kaizen, 5S, work standardization, Total Quality Management and Visual Management. Therefore, it mapped risks and safety and analyzed what generates value for the patient. Results: reduction in lead time, reduction of errors with blood collection, movement of such materials and in the performance of the exam, the interaction between nursing and

pharmacy which allowed less waste with medicines and quick search for specific medications, decreased movement of health professionals.

Comparing the results against previous works

In this stage, we summarize the comparisons of our work against the previous ones that provided a literature review on the subject of lean adoption in the health systems. The structure of this comparison is grounded in three criteria: lean tools most applied in health care, health area in which lean has been adopted, tools that were applied; and geographical areas that conducted the research.

Lean tools most applied in health services

The study of Mazzocato, Savage, Brommels, Aronsson and Thor (2010) found out that the main lean tools acting in the healthcare environment are: Value Stream Mapping, Process Mapping, 5 why and 5S. In the study by Souza (2009), the lean tools highlighted were A3, 5S and Just in Time. Costa and Godinho Filho (2016) reported the most frequent lean tools in the healthcare environment as Value Stream Mapping, Ishikawa Diagram, DMAIC and the Work Standardization. In the study by Gomes, Vieira and Reis (2017), the Value Stream Mapping, Kaizen and the 5S were ranked as the most cited lean tools.

Based on the combination of the previous reviews, the most used lean tools in the healthcare environment are Value Stream Mapping, 5S, Process Mapping, 5 why, A3, Just in Time, Ishikawa Diagram, DMAIC, Work Standardization and Kaizen.

On the other hand, in our study, we discovered that the most used lean tools that appeared in the articles analyzed, covering 2014 up to 2020, were: Value Stream Mapping, Kaizen, 5S and Visual Management. As one can see, the new here is the appearance of Visual Management, which should be explained by the rising of visual communication in our society. This study also corroborates that Value Stream Mapping, Kaizen, 5S have been useful tools in the lean healthcare atmosphere. The news discovered by our research was the grown-up of visual management tools, following the tendency nowadays in our society of shifting the communication through visual tools.

Health area in which lean has been adopted

In Mazzocato, Savage, Brommels, Aronsson and Thor (2010), the health sectors that were approached in the review were: emergencies, anesthesiology/intensive

care, gynecology and obstetrics. Souza (2009) refers to the use of lean tools in some departments of a hospital, including pharmacy, radiology, pathology and laundry. Costa and Godinho Filho (2016) cited hospital pharmacy, radiology, pathology, anesthesia, laboratory, hospital laundry, outpatient clinics, emergency rooms and the operating room as the main actors of lean. In the study by Gomes, Vieira and Reis (2017), the health sector identified as the most used for lean tools application are emergencies, followed by the surgery sector and the postoperative team.

Comparing the results against those that appear in previous reviews, we observe that urology, primary health, rehabilitation, chemotherapy, neurology, maternity, admission, geriatrics, health organization, and health center and are the novelty of areas of lean healthcare adoption.

Geographical area of the papers

Mazzocato, Savage, Brommels, Aronsson and Thor (2010) and Souza (2009) showed reviews that covered from 1998 to 2008 and from 2002 up to 2008, respectively. They discovered that most of the paper they analyzed came from United States, United Kingdom and Australia. In another research, the study by Costa and Godinho Filho (2016) included papers published between 2009 and 2014. The results pointed out United States, United Kingdom and the Netherlands as the geographical area that was most frequent as the origin of the papers. Covering a similar period (2002 up to 2015), the work of Gomes, Vieira and Reis (2017) reveals the research progress in the subject being carried out in Brazil, followed by the United States and Sweden. Concerning the countries found with the largest number of publications, Souza (2009) mentioned the United States, United Kingdom and Australia. In the study by Costa and Godinho Filho (2016), the highlighted countries were the United States, the United Kingdom and the Netherlands.

In the other hand, our research found out that Brazil appears as the origin of most papers analyzed, covering the period from 2015 up to 2020, which shows a tendency not identified in the previous reviews.

Aspects not covered in the previous reviews

This work includes other variables to the lean healthcare reviews game: a meta-analysis of journals, co-citations, and co-occurrence maps, and identified some barriers and opportunities. It follows a summary of these additional results:

- The journals that must published in this subject are Journal of Health Organization and Management; Production Planning and Control; BMC Health Services Research; Benchmarking: An International Journal.
- The following terms are the most frequent or are "Hot Topics" in the sample of articles analyzed: "lean healthcare"; "quality improvement"; "human"; and "total quality management".
- We mapped the following barriers as mentioned in the last five years:
  - Doctors' interference in the process
  - Patients' behavior
  - Resources' management affecting the clinical team
  - Impact of the governance model on medical work
  - The governance constraints of public health management
  - Team's behavior
  - Culture change
  - Leadership threat
  - Through daily meetings

Conclusion

The results show a growth in the usage of lean healthcare practices in several countries, such as: Brazil, the United States, Sweden, England and Italy. It is necessary to emphasize that Brazil has stood out in this scenario with greater production of articles.

After analyzing the set of articles, we conclude that it is possible to apply the tools, even though some adaptations and considerations were made by the authors who published their results. It was also found out that, in 2017, it occurred a greater number of publications on the theme.

Authors with the largest number of publications brought in their studies mean for the implementation of lean tools in the health sectors. These means include workshops, team training, team engagement, simulation project, meetings, information gathering among other less mentioned ways. Most articles showed acceptance and good results with the implementation of Lean Healthcare.

We highlight that present work approaches aspects not faced in the previous reviews: to identify ways in which lean healthcare has been implemented and the main barriers for its adoption. Though comparing our results against the previous

literature revies, we also discovered significant changes in countries of papers' origin, the usage of lean tools and hospital areas where lean healthcare has been applied.

Limitation

This study was limited for years of publication between January 2014 to April 20, 2020, documents of type: articles and only English language written articles were synthesized. This limitation implies not catching the effects of lean healthcare over healthcare in the pandemic environment caused by COVID-19 and vice-versa.

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