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**The current state of Lean implementation in healthcare – literature
review**

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Abstract

Purpose – The purpose of this paper is to discuss the current state of implementation of Lean production in healthcare. The study focuses on Lean definition in healthcare, implementation process, barriers, challenges, enablers and outcomes of implementing lean production methods in healthcare.

Design/methodology/approach – A comprehensive search of the literature concerning the implementation of Lean production in healthcare was used to generate a synthesis of the literature around the chosen research questions.

Findings – Lean production in healthcare is mostly used as a process improvement approach and focuses on three main areas: defining value from the patient point of view, mapping value streams and eliminating waste in an attempt to create continuous flow. Value Stream Mapping is the most frequently applied Lean tool in healthcare. The usual implementation steps include conducting Lean training, initiating pilot projects and implementing improvements using interdisciplinary teams. One of the barriers is lack of educators and consultants who have their roots in the healthcare sector and can provide support by sharing experience and giving examples from real-life applications of Lean in healthcare. The enablers of Lean in healthcare seem not to be different from enablers of any other change initiative. The outcomes can be divided into two broad areas: the performance of the healthcare system and the development of employees and work environment.

Keywords: Lean, healthcare, implementation, barriers, challenges, enablers and outcomes.

Article Type: Literature review

Introduction

Healthcare organisations are under strong pressure to improve. Society is aging, the demand for healthcare services is increasing, but financial conditions for healthcare systems are not improving or even worsening. In this millennium, healthcare systems are challenged to be as affordable, accessible, safe, thorough, efficient and cost effective as possible. There is a need to look for new and more efficient ways of providing care. Many healthcare organisations adopt the Toyota Production System as the performance improvement approach, often called the Lean Healthcare management system. The Lean approach seeks improvements within the framework of an organisation's existing processes. Lean production does not focus on substantial reorganisation requiring large-scale investments, but it gives healthcare organisations an alternative methodology for achieving improvements without high investments ¹.

There are many views of what constitutes Lean thinking. It is undeniable that Lean has its roots in the Toyota Production System (TPS) ^{2,3}. The first descriptions of TPS appeared in the late 1970s ⁴, but the book *The Machine That Changed the World* by Womack and Jones ⁵ first popularised the approach under the name "Lean production". Nowadays Lean production is applied in various types of organisations all over the world. There has been considerable development of the concept over time and there is no consistent definition of the approach ^{6,7}. Different authors have different opinions on which characteristics should be associated with the approach ⁶.

Womack and Jones were among the first authors to propose how Lean techniques could be applied to services and specifically to healthcare ⁸. They argued that the first step in implementing Lean thinking in healthcare is to put the patient in the foreground and include time and comfort as key performance measures of the system. The Lean principles as multi-skilled teams taking care of the patient and an active involvement of the patient in the care process were emphasised. Since then, many applications of Lean in healthcare have been published in academic journals ^{e.g. 9, 10-17}.

Young et al. (2004) argue that an obvious application of Lean thinking in healthcare lies in eliminating waiting times, repeat visits, errors and inappropriate procedures. Spear¹⁶ emphasize empowerment of employees by providing them with the necessary tools to improve processes in their area of work. This means that all healthcare staff become focused not only on taking care of the patient, but also on finding better ways to take care of patients. Lean enhances process steps that are valuable and essential for patient care, while eliminating those that fail to add value. As a result staff members feel empowered to improve care processes and are more satisfied with their jobs¹⁶.

Based on the literature review this paper aims to present the current state of Lean implementation in healthcare. The study focuses on Lean definition in healthcare, implementation process, barriers, challenges, enablers and outcomes of implementing lean production methods in healthcare.

Methodology

The starting point for the analysis was an extensive search in several databases, e.g. Emerald, PubMed, ScienceDirect, Wiley Interscience. Effort was made to review journals from several areas such as quality management, healthcare management and operations management as well as medical journals. The search criteria included keywords like “lean healthcare”, “lean hospital”, “Toyota Production System”, “lean management” and “healthcare” and the like. A systematic review of the references cited in the articles found was also made. This broad search strategy was necessary since the papers on Lean Healthcare have been published in a wide range of journals in many subject areas. An initial search for the keywords mentioned above resulted in more than 200 hits. However, a careful analysis of the content limited the number of identified papers to around 60. The primary problem was that the mentioned keywords were used in a wider context and didn't contain enough in-depth information for the analysis. The second review of papers, based on specific areas of interest such as Lean Healthcare characteristics, Lean implementation, barriers, challenges, enablers and outcomes, limited the number of papers included in this literature review to around 30 relevant works.

Literature review

Overview of Lean Healthcare characteristics

Table 1 presents the most frequently mentioned principles, methods and tools in the reviewed papers on Lean Healthcare. The analysis and the chosen characteristics were inspired by Pettersen ⁶. The table is organised based on frequency of appearance. Characteristics discussed by less than three authors were excluded from the table. The other reviewed principles, tools and methods may be found at the bottom of the table. In the left column under the reviewed characteristic a number of papers are listed, which discussed the specific Lean principle, method or tool in the context of healthcare.

The reviewed papers can be categorised into two sets: theoretical and case studies as suggested by de Souza ¹⁸. The first set refers to papers that discuss the application of Lean in healthcare based on general examples and the knowledge and experience of the authors in healthcare settings. The second set of papers is based on case studies or other empirical evidence collected in research projects. Both types of papers were included in the analysis. The criteria for including the reference in the table were that the Lean characteristic was either used by case organisation or it was discussed in the context of healthcare. To be included it was not enough that the Lean principle, method or tool was mentioned in the paper text, for example in the literature review.

The results of the analysis were the foundation for the discussion of different aspects of applying Lean in healthcare presented in the next sections.

What is Lean Healthcare?

There is little evidence of the complete Lean philosophy being applied in the healthcare system ¹⁹, ²⁰. When reviewing literature on Lean Healthcare, one underlying theme becomes apparent: Lean is often perceived as a set of tools and techniques for improving processes (see Table 1, row 1). The words “process”, “value stream” and “continuous flow” appear in almost all papers that discuss the

application of Lean in healthcare. Lean Healthcare is about simplifying processes by understanding what adds value and eliminating waste^{9, 11, 21-25}. It is often emphasised that current healthcare systems consist of fragmented process which require a shift in how the flow of patient care delivery is perceived and organised²⁶.

<Insert TABLE 1 about here>

The care processes in large healthcare organisations simply evolve over time and are seldom a result of conscious planning and action^{9,26}. The healthcare processes are organised with a focus on the doctors, nurses and other clinical staff and are often not optimised for patients^{1,25}. The care is organised in departmental silos and often the only person who sees the whole of the patient journey is the patient himself or herself^{1,9}. In such systems, a patient can typically spend hours in hospitals for only some ten minutes of value-added time. Applying Lean thinking, specifically value stream and continuous flow, has the potential to help break down the silo mentality, enabling changes to occur across functional boundaries¹. Much of the work which is performed within the healthcare setting does not directly add value from the patient's point of view⁹. It is rarely clearly specified how processes should ideally work in healthcare operations. The consequence is inconsistency in care, unreliable access to resources and processes, and constant interruptions, which in turn implies inefficiencies, long waiting times, increased potential for errors, and worker frustration¹¹.

As stated before, Lean Healthcare is mostly about how to manage and improve processes, but what does it actually mean in practice?

First, the healthcare units recognised the patient as the primary customer and as a critical factor to be taken into consideration when designing processes and delivering care^{9, 21, 22, 25-29}. Many papers discussed the value from the patient's point of view (for references see Table 1, row 9). In order to improve processes it is necessary to have a clear view of the customer and what is value added as opposed to non-value added from the customer point of view.

The second step is learning to see the processes as they are performed with all problems and shortcomings ⁹. It is necessary to categorize the huge variety of patients with different conditions into groups with similar needs and value streams and see the different patient flows through the healthcare system ³⁰. One of the frequently discussed and used principles in Lean Healthcare is patient pathway/journey/flow. The patient flows through a series of different processes in the patient pathway/journey. The point is to follow the route through which a patient needs to travel from the demand for care to the completion of treatment as the patient experiences it. All the steps in a patient's pathway can be visualised with help of Value Stream Mapping (VSM). According to the analysis in Table 1 VSM is the most popular Lean tool applied in healthcare. With Value Stream Mapping staff can quickly come to understanding that all work is a process and all processes can be improved ⁹. The focus also lies on improving the whole process, and not just optimising individual parts ²⁶.

Third, process improvement in healthcare implies specifying how work is expected to be conducted and removing waste in the form of waiting time, rework due to poor procedures, workarounds, interruptions, etc. ²⁴. In this respect the most commonly mentioned Lean principles and methods are standardised work, waste reduction and continuous flow. As can be seen in Table 1, continuous flow is the second most frequently discussed principle in articles on Lean Healthcare. Creating continuous flow is the goal of process improvement. The idea is that the patient should flow between healthcare units and staff groups without interruptions. Ideally patients should move from one step in their care to the next without delay. In order to achieve continuous flow, staff need to gain an understanding about processes, identify waste and bottlenecks and find out root causes of problems. This added perspective is valuable since studies show that when healthcare staff experiences an interruption, problem, or other distraction in routine, they work around the problem without bringing attention to it. They are focused on getting the job done but whatever caused their problem remains uninvestigated e.g. ³¹. Continuous flow also implies increasing cooperation and breaking down barriers between multiple operating units ²⁵. Optimizing the performance of an

individual area is insufficient and it is necessary to integrate the single processes owned by different healthcare units in one value flow to enhance the comprehensiveness and continuity of patient care^{1, 26, 32}.

All three steps require an interdisciplinary team approach, which is an explanation for the frequent occurrence of the Lean principle “teamwork” in the reviewed articles.

Lean Healthcare and five Lean principles

Womack and Jones⁸ defined a five-step process for guiding the implementation of Lean techniques:

1. Specify value from the standpoint of the end customer
2. Map the value stream
3. Create flow
4. Establish pull
5. Seek perfection

There are relatively few articles referring explicitly to the five principles, but one may notice that the three steps emerging in the Lean Healthcare articles have a good coverage with the three steps as defined by Womack and Jones⁸. This coverage is however difficult to see with step four “Establish pull” and step five “Seek perfection”. Only seven papers discussed the application of the pull system in healthcare. The discussions were short and undeveloped and the examples rather poor. In fact only two case-based examples of the application of the pull principle in healthcare setting were found^{33, 34}.

The fifth principle (“Seek perfection”) is about striving for perfection through continuous improvement. An organisation should constantly evaluate itself, learn from its mistakes and continuously improve the value stream⁸. Although at first sight it looks like “continuous improvement” (see Table 1, row 7) is not poorly represented in Lean Healthcare articles, the

situation is far from what can be characterised as “seeking perfection”. Continuous improvement is a broad concept that refers to a wide range of activities. An example of an activity identified as “continuous improvement” but not what Womack and Jones (2003) exactly mean by “Seek perfection” is Kaizen blitz (sometimes referred to as Rapid Improvement Events or RIE). Kaizen blitz is focused, intense, short-term project to improve a process^{1, 25, 35, 36}. “Seeking perfection” is more about developing a continuous improvement culture, where employees are continuously focused on the goal of eliminating waste and encouraged to develop ideas to improve their work, and where improvement activities become a part of the everyday work^{8, 25}. Spear¹⁶ argues that Lean Healthcare is about turning employees into problem-solvers by teaching them to stop going around problems, and instead fix them right away.

The fact that the steps “Establish pull” and “Seek perfection” are not well represented in the Lean Healthcare articles may indicate that healthcare organisations implementing Lean have not achieved this level of maturity. Several authors are concerned about one-sided focus on “process improvement” in Lean Healthcare applications e.g.^{23, 25}. They state that “*Lean implementers sometimes lose their perspective on the fact that for any process to perform better the people who compose the process need to be better at what they do*”. An important element of Lean is developing people and creating continuous improvement culture rather than applying Lean tools to every process²³. The application of tools provides good results, but these improvements are rarely sustained. The real challenge is to go beyond the simple application of Lean tools and to develop a lean culture of continuous questioning and improvement²⁶. Several authors argue that the success of Lean implementation lies in the understanding that Lean is a system, not simply a toolbox^{e.g. 13, 23, 37}. The application of Lean tools is also important however since the tools embody the Lean principles and support the development of the Lean culture¹¹.

How is Lean implemented in healthcare?

The literature was reviewed in search of implementation patterns for Lean Healthcare. The following key steps were identified^{22, 38 1, 9, 11, 24, 25, 29, 35, 39-43}:

- Conducting Lean training
- Initiating pilot projects
- Implementing the changes

The first step usually included training days in which the basic Lean principles, methods and tools were introduced. The basic idea was to facilitate widespread use of Lean tools and create a base for initial practical work. The target groups for training differed between cases. The training was either intended for all staff members or only for leaders or Lean facilitators that would be responsible for the Lean initiative in an organisation. In the second case leaders or Lean facilitators then received the responsibility to train a group of their peers. This approach assumes that those trained in Lean will train others and that learning will gradually disseminate across the organisation^{11, 22}. Several authors stressed the importance of training their own Lean facilitators recruited from the healthcare organisations instead of employing external consultants^{23, 39, 44}. People's knowledge, creativity and commitment seem to be important for building a sustainable Lean organisation. Lean implementation shouldn't rely on consultants who tell how it should be done; instead employees should be trained in all Lean aspects to initiate and drive the improvement work.

The second step included testing ideas and initiating some pilot projects using Lean tools and methods. The pilot projects were sometimes part of the education program or were initiated in direct connection to training days. The idea was to let people try the ideas in organisations and create some quick results. The pilot projects usually included Value Stream Mapping. The healthcare staff was organised in cross-functional teams and performed analysis of patient flow, assessed the time required to perform process steps and identified value-added vs. non-value-added activities^{22, 25, 26, 36, 41}. The overall objectives included reducing lead time and waste elimination in processes. The

primary focus of pilot projects was to engage frontline staff in identifying problems and to involve them in the improvement work. The outcome of this step was an action plan for change.

The third step is about driving the change processes with the full involvement of the employees. There are only a very limited number of cases, however, describing the practises^{24, 25, 35}. This step is a problem-solving process and may include the use of different Lean tools and techniques. A team of five to ten members, often including all professions and different organisational levels, analyses causes of a problem, generates and selects some solutions, plans for actions and evaluates results. This problem-solving process is referred to in some cases as Rapid Improvement Event (RIE)³⁶, Kaizen event²⁵ or Rapid Process Improvement Workshop³⁵.

There is no single correct way of implementing Lean in healthcare. The articles showed that different healthcare units require different approaches. Several authors stressed that Lean is not a one-time change of work processes, but a new way of thinking and working. There is little chance to succeed if Lean is implemented top down as a fully defined and complete concept for reducing costs and improving performance. It is difficult to take ideas from one culture and apply them in another, especially if these ideas involve people, behaviours, practices and ways of thinking. An appropriate implementation strategy is an adaptation-oriented approach with focus on finding ways that are consistent with the specific conditions and suit a healthcare culture³⁰. Healthcare units implementing Lean need to make a critical review of how the principles, methods and tools can be used in their own organisation and adapt the concept to fit their context. The active choices concerning values, methods and tools can improve the chances of achieving long-term sustainable improvements^{9, 25, 30}.

Barriers and challenges of Lean implementation

The first barrier that needs to be overcome in Lean implementation is to convince staff that Lean can work in a healthcare setting^{26, 27, 9, 39, 43}. When talking about Lean in healthcare the usual reaction is that patients are not cars and healthcare organisations have completely different

organisational settings than the automotive industry. However, when the training is provided, the staff gradually understands that there is a great amount of waste in the processes and applying Lean principles could provide great benefits³⁰.

The training itself is a challenge, however. There are few people in healthcare who have a well-founded knowledge of and experience in Lean production principles, methods and tools. There is a lack of qualified people inside healthcare to teach about Lean^{25,29}. Educators need to be hired from the manufacturing sector, but they often talk manufacturing language and lack relevant examples from the healthcare sector⁴⁵. This makes more difficult for healthcare staff to accept the ideas and requires longer assimilation periods^{24,36}.

Another problem is lack of clear focus on the customer. One of the basic Lean principles is to understand value as defined by the customer. The term of “customer” in healthcare is not straightforward, however. The primary “customer” in healthcare is the patient, but the patient is not a customer from the market economy perspective. The patient usually doesn’t pay directly for the service. Other customers, such as family members, caregivers, decision-makers, local communities and taxpayers, also need to be considered. To understand what is value added there needs to be a clear view of the customer without confusion of conflicting requirements and priorities from different stakeholders. The ambiguous notion of the patient as customer and the dynamics between the different stakeholders are seen as a barrier in the Lean implementation process^{21,46,47}

Another factor perceived as inhibiting Lean implementation was the organisational structure of healthcare. Professional knowledge is organisational power. The healthcare structure is still very hierarchical, with physicians as the dominant decision makers. Physicians are highly trained individuals and they have been trained to act with autonomy. Lean culture requires teamwork, collaboration and good communication, skills that traditionally have not been emphasised in physicians’ professional training^{23,27}.

Several authors reported difficulties related to cooperation with other departments ^{36, 41, 48}. Healthcare is a complex system with many interdependent units. One of the challenges is to improve the entire system, not just optimize the performance of individual departments. Improving value streams may require involvement of several healthcare units, which are not always ready to recognise, understand and acknowledge changes or simply lack the necessary prerequisites to perform the change. The risk is also that an improvement activity may fix some problems at one unit, but cause other problems at another unit. It is therefore important to take the holistic approach and consider the impact of the actions on other units, and not just shift the problems to other areas ²³.

Change enablers

The enablers for Lean Healthcare discussed in the literature seem not to be different from enablers of any other change initiative. Three key factors that contribute to the success of Lean implementation in healthcare are recurring in several papers.

First: commitment and participation of healthcare staff in the improvement processes. Employees are considered experts at performing their work and their full involvement enables their professional knowledge, skill and experience to be used for the organisation's improvement ^{11, 39}. Empowered staffs are more eager to realise their ideas as opposed to a reluctant staff feeling forced to carry out top-down process improvements ^{25, 44}. It is therefore crucial that healthcare staff own and drive the improvement work ^{1, 21, 28, 47}.

Second: to focus on developing people before developing organisation. It is essential to provide training and give responsibility to employees, so they will be able to take initiative to make improvements on their own ^{23, 24, 39, 49}. Developing is not only about teaching Lean tools and methods, but about learning a new approach to thinking where employees feel they can make use of their skills and creativity, can take initiatives, and cause things to happen ^{28, 44, 45, 49}.

Third: support from managers at all levels. For top-level managers it is vital to show a genuine interest in the Lean implementation work, pay attention to the results that are being delivered and provide necessary resources^{1, 9, 39, 41}. Nelson-Peterson and Leppa³⁵ mention daily presence of top management on the unit as necessary condition for success of Lean implementation. Managers at lower levels who lead healthcare units implementing Lean need to take ownership of the change and actively support their employees in the improvement process^{1, 11, 41, 42}. Dickson et al.²⁵ tell of management taking a subordinate role in the improvement process, where empowered staff identified problems and implemented their own solutions.

What are the outcomes from Lean Healthcare?

There is a lack of rigorous research on the outcomes from Lean Healthcare. Several studies report results from the Lean initiatives, but methodologically these studies are not comparative and include mostly self-reporting results⁵⁰.

The outcomes from the Lean initiatives can be divided into two broad areas: one set relates to the performance of the healthcare system, while the second relates to the development of employees and work environment. These areas are consistent with the categories discussed by Porras and Robertson⁵¹ in their organisational development model.

The outcomes reported on the performance of healthcare system are measurable and often stated in numbers or given as improvement rates. A summary of improvements on performance measures discussed in the healthcare literature is presented in Table 2.

<Insert TABLE 2 about here>

The results in the Table 2 mostly relate to the improvement of patient outcomes. Better outcomes for patients usually imply more accessible care with shortened treatment time and reduced waiting. As can be also seen in the Table 1 lead time reduction was a frequently discussed goal with Lean implementation and was found in 20 reviewed papers.

The second set of outcomes has a mostly qualitative character and concerns the influence of Lean implementation on employees and work environment. One of the most frequently mentioned outcomes in this set is increased attention of employees to waste and more proactive attitude to problem solving. Staff stops assuming that waste is part of their work and doesn't accept workarounds and fire fighting anymore, but instead takes initiative to resolve problems ^{11, 38, 44}. Lean Healthcare offers employees more responsibility, greater involvement, and a sense of ownership in their work ^{35, 39}.

Another outcome is a much calmer and more organised work environment ^{23, 25, 27, 40}. Lean focuses on eliminating non-value adding activities and removing wasted time from processes. The work becomes more orderly and predictable and thereby less stressful. As a result healthcare staff is more focused on their assignments, and consequently far more receptive to patient demands ²³.

Conclusions

This study showed that Lean is mostly used in healthcare as a process improvement approach. Value Stream Mapping is the most frequently applied Lean tool in healthcare. The process orientation is crucial, but still weak in healthcare organisations ⁵². However, many current problems of healthcare can be solved by applying process improvement approaches. Using Value Stream Mapping, all steps in the patient journeys are analysed as a whole from start to end: from diagnosis, through treatment, to discharge. This allows for reducing waiting times and duplicate work and ensuring that the interrelated steps connect. Many healthcare units work in silos and are not aware of the effects of their efforts outside their own departments. Problems and difficulties frequently appear in the crossings between different units.

Lean Healthcare applied as a process improvement approach focuses on three main areas: defining value from the patient point of view, mapping value streams and eliminating waste with the effort to create continuous flow. Although the five Lean principles as defined by Womack and Jones ⁸ are

not widely discussed in Lean Healthcare literature, an analogy can be seen between how Lean is currently applied in healthcare and the five Lean principles. Healthcare organisations seem to pursue only the first three steps. The steps “Establish pull” and “Seek perfection” are poorly discussed in the Lean Healthcare literature and there is little evidence of their application. This fact may indicate that healthcare organisations implementing Lean have not achieved this level of maturity or have problems moving beyond a simple application of Lean tools. Several authors state that Lean is more than just tools and that to achieve long-term sustainable results it is necessary to change the organisational culture^{23, 37}. The question of “How to ensure that Lean becomes more than another set of tools but becomes a sustainable way of working” is crucial, but couldn’t be answered by reviewing the current literature on Lean healthcare.

There is no single correct way of implementing Lean in healthcare. The evidence indicates that the approach has been adapted rather than simply adopted. However, in respect to the differences between healthcare and the manufacturing sector Lean cannot simply be copied into healthcare settings. Lean implementation in healthcare requires adaptation and development of the approach to fit the specific context and allow healthcare staff to own the approach. The usual implementation steps include conducting Lean training, initiating pilot projects and implementing improvements using interdisciplinary teams.

There are some challenges which face the implementation of Lean in the healthcare including:

- Healthcare staff do not like care services being compared to car assembly lines. They believe that their organisational settings and problems are unique and cannot be simply solved by methods coming from manufacturing industry. It takes time before staff understand how Lean works, and begin to realize potential benefits
- There is a lack of educators and consultants who have their roots in the healthcare sector and can provide support by sharing experience and giving examples from real-life applications

of Lean in healthcare. Educators and consultants are usually hired from the manufacturing sector, which makes it more difficult for healthcare staff to accept Lean

- The key principle in Lean production is to understand value as seen by the customer. The term “customer” in healthcare is not straightforward, however. Healthcare organisations may have multiple customers including patients, family members, caregivers, decision-makers, local communities and taxpayers
- The healthcare structure is hierarchical with physicians being the one profession that possess the highest rank and the most power within the organisation. Lean, however, requires teamwork that builds on collaboration and open communication
- Healthcare is a complex system with many interdependent units. The challenge is to improve the entire value stream, not just optimize the performance of individual departments

The change enablers for Lean Healthcare seem not to be different from enablers of any other change initiative. A successful Lean transformation in healthcare relies on the involvement of all professional groups. Staff needs to be trained to understand Lean principles and techniques and take an active role in the implementation work. Managers need to motivate and engage employees and provide necessary support and resources.

The literature review shows that there have been some significant tangible and intangible outcomes in organisations that have adopted Lean principles. The outcomes can be divided into two broad areas: one set relates to the performance of the healthcare system, while the second relates to the development of employees and work environment. The first set includes results such as increased patient throughput and reduced waiting times. The second set is related to the change of employees' role from a passive to an active role in improving and developing healthcare processes and organisation. The second set also includes improvements in work environment such as more predictable and calmer working days.

It is crucial that the knowledge about how Lean can be applied in healthcare settings is shared and that organisations learn from others' mistakes and successes. Lean Healthcare is a widely debated subject; however, the available articles in the area present only a limited view of the potential advantages and disadvantages of Lean in healthcare. In fact, no articles were found criticising the application of Lean in healthcare. Many articles found in the area have a speculative character and are not based on empirical evidence. More rigorous and holistic research is required to evaluate the real impact and to understand more about underlying factors influencing the success and sustainability of Lean in healthcare.

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Table 1: Overview of Lean Healthcare characteristics

Lean characteristic	References
1. Process improvement (28 papers)	1, 9, 11, 13, 16, 21-23, 25, 26, 28, 29, 32-36, 38-40, 44, 46, 53-57
2. Continuous flow (23 papers)	1, 9, 11, 13, 21, 23, 25-27, 29, 32-36, 38, 39, 46, 47, 53, 54, 56, 57
3. Value stream mapping including more traditional process mapping (22 papers)	9, 11, 13, 21, 25-27, 32-36, 38, 40, 44, 46-48, 53-56
4. Waste elimination (22 papers)	1, 9, 11, 13, 16, 21, 22, 25-27, 34, 35, 36, 38, 39, 44, 46, 47, 54, 55, 56, 57
5. Teamwork (22 papers)	1, 9, 11, 13, 16, 21-23, 25, 26, 28, 29, 32, 34-36, 38, 39, 41, 47, 48, 53
6. Lead time reduction (20 papers)	1, 11, 13, 16, 22, 23, 25, 27, 32-35, 39, 40, 53-57
7. Kaizen/continuous improvement (15 papers)	1, 13, 21, 23, 25, 26, 28, 29, 38, 39, 41, 44, 48, 56, 57
8. Education/cross training (15 papers)	1, 9, 11, 23, 25, 28, 33, 38-41, 44, 48, 55, 56
9. Value from patient's point of view (14 papers)	9, 13, 21, 22, 25-27, 33, 34, 36, 39, 44, 46, 47
10. Standardised work (14 papers)	9, 13, 22, 23, 25, 26, 28, 33, 38, 40, 44, 47, 54, 57
11. Patient pathway/journey/flow (10 papers)	9, 11, 22, 23, 32, 33, 36, 39, 40, 46
12. 5S (10 papers)	9, 23, 33, 34, 38, 41, 44, 48, 54, 57
13. Pull system (7 papers)	9, 13, 33, 34, 38, 39, 46, 54
14. Root cause analysis (6 papers)	1, 11, 22, 27, 28, 33
15. Just in time (5 papers)	23, 32, 35, 38, 54
16. Visual management (5 papers)	9, 36, 38, 47, 54
17. Poka yoke, error proofing (3 papers)	13, 38, 54
18. One Piece flow (3 papers)	35, 56, 57
Other reviewed Lean principles and tools: Policy deployment/hoshin kanri; layout adjustments; production leveling/heijunka; andon; takt production; TPM/preventive maintenance; autonomation/jidoka; kanban	

Table 2: Outcomes from Lean Healthcare related to performance of healthcare systems

Performance measure	References
Decreased overall time patients spent on care	22, 26 1, 27, 29, 39-41
Increased number of patients which can be handled (patient throughput)	1, 22, 25, 29, 39
Reduced number of errors and incidents	11, 23, 24, 29, 39, 41, 44
Reduced waiting times	27, 39, 40, 44
Increased patient satisfaction	11, 25, 35, 41, 44
Increased employee satisfaction	11, 29, 35, 41, 44
Reduction of overtime hours	11, 29
Decreased inventory costs	29, 39
Reduction in travel time/walking distance for patient and staff	1, 29, 41