Implementation of lean in health care environments: an update of systematic reviews

Rui M. Lima, José Dinis-Carvalho, Thiago A. Souza, Elisa Vieira and Bruno Gonçalves

Department of Production and Systems, ALGORITMI Research Centre, School of Engineering, University of Minho, Guimarães, Portugal

Received 1 July 2019
Revised 16 October 2019
12 April 2020
Accepted 28 May 2020

Abstract

Purpose – Even though the implementation of lean in health care environments is relatively recent, it has been receiving a lot of attention in recent years. Partly because of the fact that it is a recent field of practise and research and partly because the number of works developed in this field has grown rapidly, it is important to frequently update the perspectives on this field of investigation. Thus, this study aims to review the implementation of lean tools and techniques applied to hospital organizational areas in a five-year period, between 2014 and 2018, complementing some of the most relevant reviews already published. The most important criteria such as tools, methods and principles, hospital areas intervened, improvements and difficulties were assessed and quantified.

Design/methodology/approach – As starting point for this systematic literature review (SLR), a set of selected pre-existing review publications was used to support the current study and as the ground base for the expansion of the studies about lean health care. The current study contemplated 114 articles from a five-year period between 2014 and 2018. A subset of 58 of these articles was critically assessed to understand the application of lean tools and methods in different hospital areas.

Findings – The thorough analysis of selected articles show a lack of works in continuous improvement approaches when compared to the application of production organization methods, visual management and diagnosing and problem-solving tools. The reported improvement results demonstrate alignment with the principles and foundations of lean philosophy, but such results are presented in isolated initiatives and without robust evidence of long-term maintenance. Moreover, this study shows an evolution in the number of articles referring to lean implementation in hospital areas, but in its great majority, such articles report isolated implementations in different areas, not spreading those for the global organization. Thus, some of the main recommendations are the need to implement studies on complete flows of patients, drugs and materials, instead of isolated initiatives and strive to promote the cultural change of hospitals through structural changes, following new visions and strategic objectives, supported by real models of continuous structural and sustained improvement.

Originality/value – The current study develops a new perspective of the articles published under the thematic of lean health care, published in a recent period of five years, which are not completely covered by other works. Additionally, it explicitly applied, in an innovative way, an approach that used a set of previous reviews as the starting point for this SLR. In this way, it integrates approaches and categories from different SLRs, creating a framework of analysis that can be used by future researchers. Finally, it shows the most recent implementations of lean health care, exposing the current trends, improvements and also the main gaps.

Keywords Lean health care, Operations management, Systematic literature review

Paper type Literature review

This work has been supported by FCT – Fundação para a Ciência e Tecnologia within the R&D Units Project Scope UIDB/00319/2020 and project POCI-01-0145-FEDER-030299.

International Journal of Lean Six Sigma
Vol. 12 No. 2, 2021
pp. 399-431

2040-4166
DOI 10.1108/IJLSS-07-2019-0074

1. Introduction

Health promotion is essential for the well-being of humanity and for sustainable economic and social development, with most countries ranking health as one of their highest priorities (Cashin *et al.*, 2017). Hospitals, in this context, are crucial organizations for the implementation of health policies because they provide various health services to the community. Their activities may include healing, rehabilitation, prevention and promotion of health education (Chaerul *et al.*, 2008). According to the Cashin *et al.* (2017), there are different levels of government commitment to health. As an example, from the World Health Organization Regional Office for Europe, which includes countries with different levels of gross domestic product, government commitment to health varies from 4% to 20% of total government spending. More than an investment issue because of rising costs and poor management, the health system is undergoing financial, social and political pressures, needing to develop a more robust capability of aligning current and future services according to its structure and high demand. Health systems will only succeed if they have the capacity to innovate by crossing organizational, political, geographical and sectoral barriers (Roberts *et al.*, 2016).

According to Vendemiatti *et al.* (2010) hospital dynamics is composed of complex interrelationships between processes and people working at different levels of hierarchy, specialization and organizational identity. The administrative and nursing groups have a contractual link to the organization and are subject to the authority of the organizational chart of the hospital, while the medical group has high levels of autonomy over the clinical processes. In this sense, hospitals could benefit from a more professional management approach through management systems similar to the ones used in the business world (Matos, 2002). However, hospitals are usually analysed as complex structures that tend to be impervious to change (Santos, 2008). Nevertheless, hospitals require efforts related to continuous improvement culture and operations management, just like any other existing organization.

Based on this interest in considering hospital dynamics as a regular company, hospitals have promoted studies related to strategic planning, informatization, cost reduction, etc, in a context of increasing demand, increasing expenses and competitiveness (Weber and Grisci, 2010). Given this complexity (and inherent taken responsibility to patients), hospital managers need robust management techniques that allow the evaluation and improvement of their processes (de Souza *et al.*, 2009), the increase of quality and efficiency and to develop a vision of flow/stream.

To mitigate the problems and inefficiencies of the hospital world, methodologies and management techniques from manufacturing and operations management have emerged (Kim *et al.*, 2006). Some of these type of improvement methodologies and management techniques are related to lean thinking (Graban, 2011). Lean thinking may be characterized as a philosophy for reducing waste and adding value by improving organizational processes (Womack and Jones, 2003). This approach applied to production systems, has its conceptual basis in the Toyota Production System – TPS (Ohno, 1988). It is relevant to state that, as referred by Sugimori *et al.* (1977), a key aspect of the Toyota model is the central focus given to human aspects such as respect for employees and teamwork. The principles of TPS are the result of more than three decades of evolution of Toyota Motor Corporation's production methods developed mainly by Taiichi Ohno (Hines *et al.*, 2004).

According to Womack and Jones (1997), lean thinking is based on five principles, namely, identify value; map the value stream; create continuous flow; promote pull production; and a continuous search for perfection. There are evidences of a trend on lean application in areas such as construction, insurers, banks, pharmaceutical industries and hospitals (Souza, 2009).

From the hospital viewpoint, the term lean health care has been used to name the use of the lean philosophy in the context of health care. Lean health care can be characterized as a philosophy of improvement, supported by tools, methods and principles that improve the way hospitals are organized, redesigning physical spaces and processes and engaging administrative professionals, nurses and medical staff in the search for continuous improvement (Graban, 2011). In lean health care the patient should always be the focus of the study, being the lean health care goal to provide the right care at the right time, with quality and with the flexibility to keep up with the changing health system environment. Therefore, understanding the value for the patients is the guiding principle that allows defining the necessary changes for hospitals (Weinstock, 2008). Ajmera and Jain (2019) showed in their study that health care organizations may capitalize high-efficiency earnings by understanding and improving the main factors (and their relative importance, interdependencies and relationships) that influence the implementation of lean principles in the health care industry. Factors such as lean leadership, professional organizational culture and teamwork and interdepartmental cooperation are pointed out as the top-level factors influencing adoption of lean philosophy in health care organizations.

Bertolini *et al.* (2011) identified some critical processes in the hospital environment using techniques of Operations Management such as simulation of processes, which demonstrated to be useful in the definition of scenarios and critical analysis of the organization. Such hypothetical scenarios simulated the use of resources, allowing the analysis and identification of bottlenecks and utilization rates. In the health sector such problems, related to the operations management, are considered complex because of the inherent complex nature of the sector, added with the high management autonomy of doctors, the lack of performance measurements, the customization of treatments and the difficulty to standardize processes. These are just some of the aspects that hinder the adoption of management tools from other areas, like industrial engineering.

Although there is research on operations management and planning in hospital context, there are still gaps in the integration of these two areas of knowledge. Hospital administrators aim to improve service quality and reduce costs, which are core issues in the field of operations management. Thus, although being possible to draw positive comparisons between hospitals and industrial sector regarding operational problems, there are fundamental differences. Two of the most relevant differences are the interaction between caregivers and clients (patients) and the large professional and philosophical gap between "business operations managers" (managers/administrators) and "clinical operations managers" (medical staff/doctors). These are critical issues, already presented by Butler *et al.* (1996), that should be assigned to an operations manager and that should be addressed by the hospital's strategic plan and by its operations management strategy. The application of these tools, brought from other business areas/industries to hospitals, requires in-depth studies and adaptations according to the nature of the care process and the focus on the patient (Evans *et al.*, 2001).

From the lean health care's historical perspective, Souza (2009) assumes that a precise date for the first application of lean in health is uncertain and indicates Heinbuch (1995), Jacobs and Pelfrey (1995) and Whitson (1997) as possible first applications of lean concepts in hospitals, even though the authors had not yet coined the term lean in their research projects. However, Souza (2009) speculates that the first potential publication related to the use of lean health care appeared in an article by the NHS Modernization Agency (2001). Daultani *et al.* (2015), Souza (2009), Mazzocato *et al.* (2010), Holden (2011), D'Andreamatteo *et al.* (2015), Costa and Godinho Filho (2016) and Mousavi Isfahani *et al.* (2019) expose and explain the state of publications in this theme, using literature review approaches and

discussing an evolution over the years. Despite the fact that these works bring a summary of the publications and synthesize in a useful way the knowledge about lean health care, they bring a natural and understandable difficulty when studying the implementation of lean in hospitals. These were works developed by different researchers in different periods of time and present both, tools, methods and principles and hospital organizational areas, with different classifications. This lack of uniformity makes it difficult to understand, which tools, methods and principles are applied to different areas and the approaches to different issues (Régis *et al.*, 2018) in hospitals.

Partly because of the fact that the implementation of lean in health care environments is a recent field of practise and research and partly because the number of works developed in this field has been rapidly growing, creates the need to answer to the following question: What are the lean tools, methods and principles applied to hospital organizational areas in recent years and what could be seen as missing? As the previous review works are relevant and useful, the authors of the current work decided to use them as the basis for answering to this question, enlarging the knowledge about the theme being studied and additionally creating a uniform framework of analysis depicted from their works.

Thus, this study aims to systematically analyse articles for understanding the implementation of lean principles, tools and techniques applied to hospital organizational areas in a five-year period, between 2014 and 2018. This objective is materialized through the identification of the main tools, methods and principles applied in lean health care studies, the identification of the main hospital organizational areas and related to these two subthemes, what are the main improvement results and difficulties identified in the reviewed articles. Linked to the above-stated objective, there is another equally relevant objective, which is related to the identification of lean tools, methods and principles applied to hospital organizational areas in recent years that could be seen as missing.

2. Systematic literature review methodology

Linde and Willich (2003) argue that a systematic literature review (SLR) can be useful to identify emerging themes for future research and can also be useful for synthesizing information from a set of studies carried out separately on a given subject. The studies may present results that may or may not, coincide with each other. Considering these arguments, the selection of SLR as a research approach is adequate to analyse and synthesize a perspective on the implementation of lean tools, techniques and principles applied to hospital organizational areas in a five-year period, between 2014 and 2018. A critical analysis of those works will also allow to identify potential gaps and propose them as a possible target for future research.

A systematic review is a type of scientific research presented in the form of retrospective observational studies and critical literature review. These reviews aim to identify, group, critically analyse and synthesize the results of several primary studies (Briner and Denyer, 2012; Galvão and Pereira, 2014).

Systematic reviews should include a research question, a systematic and comprehensive study analysis, an explicit and reproducible data extraction process, an adequate and critical data presentation and interpretation and may suggest future research related to the synthesis of the analysis (Ravindran and Shankar, 2015).

2.1 Method

The current work adapted the design proposed by Tranfield *et al.* (2003), which describe a structure for systematic reviews based on three main phases, namely,

(1) *Phase 1 – Planning of the review*: Identification of the need for the review; proposal preparation for review; development of the review protocol.

(2) *Phase 2 – Conduct the review*: Identification of the research; selection of studies; assessment of study quality, data extraction, data synthesis.

(3) *Phase 3 – Report and disseminate*: Results and recommendations, expose practical evidences.

Phase 1 of the study, as described by Tranfield *et al.* (2003), may not be a closed sequence of steps and, instead, it may be developed iteratively. In the case of the current work, during the initial iteration on Phase 1, for establishing the need of the study and the purpose, an initial analysis of pre-existing review publications was developed. These review publications include, extensively, the analysis of publications mainly prior to 2014. Thus, they are used as a ground basis of this study, which expands the review timespan to the five-year period from 2014 to 2018, overlapping temporally a few articles from 2014 and 2015 of previous works. As those previous review works are considered highly relevant for the area, it was considered appropriate to define a method based on the analysis of a subset of existing systematic reviews and update them with more recent data and an analysis supported by a new integrated framework of criteria and categories. This approach intends to contribute to the integration of different categories that could be used by other researchers and practitioners, making this and future perspectives on lean health care more uniform. Nevertheless, such framework of analysis cannot be considered static and future researchers may and should, update it as needed, either because of the evolution of the theme or to bridge gaps not covered by this work. This framework of analysis is presented in Section 2.2. During this iteration was possible to close the research question, presented in the introduction section.

In the second iteration of Phase 1, a deeper analysis of the pre-existing review works was developed as a contribution for the definition of the review criteria to be used in the analysis of the articles. This part of the process was based in seven systematic review studies (Table 1) considered highly relevant for the purpose of this article.

During this phase two highly recent review works were analysed, but they are not able to fully answer to our research question. The work from Mousavi Isfahani *et al.* (2019) includes articles until august 2015 and for that reason it does not allow to answer to our research question. Moreover, because of a more focussed research objective the analysis includes a small number of works from 2014 (10 articles) and 2015 (three articles) than the current work. Additionally, a recent review from Ramori *et al.* (2019) also cover a small number of papers from the five-year period considered here, but because of a much more focussed thematic ("lean business models in health care") objective compared to the one used in the present work, it does not allow to answer to the research question of the current study and was not included in the subset of review papers used to support the current work. The criteria of analysis of the selected review studies partially overlap and may be considered as complementary. Thus, it was decided to analyse, integrate and extend the criteria of these articles to increase its scope and usefulness. The definition of the criteria of analysis and the way it would be applied is also part of Phase 1, as defined by Tranfield *et al.* (2003) and the details are described in the following Section 2.2.

Still in Phase 1, a set of keywords were defined by intersecting the keywords used by the authors of the review articles mentioned in Table 1 and adding up relevant keywords considered by the researchers involved in the current study. Souza (2009) evaluated 90 articles using keywords such as "lean health care", "lean hospital", "lean health" and "lean medical" in the period between 2002 and 2008. D'Andreamatteo *et al.* (2015) conducted a

literature review based on 243 articles selected between 2003 and September 2013 exploring the Scopus and Pubmed databases using keywords such as "lean health care", "lean six sigma", "Toyota management system", "Kaizen", "Rapid improvement event", "health system", "hospital". Mazzocato *et al.* (2010) performed a systematic review between January 1998 and February 2008, initially finding 1,000 publications of which 112 were identified as potentially relevant to the study and from these (after the bibliometrics analysis) the authors defined 33 publications to analyse. Costa and Godinho Filho (2016) analysed 107 articles using the keywords "lean health", "lean health care" and "lean hospital" between March 2008 and November 2014, exploring the engineering village, Web of Knowledge, Scopus and Google Scholar databases. Daultani *et al.* (2015) applied a systematic review between 2002 and 2014 using the keywords "lean", "health care", "hospital" in international databases, finding 335 potential articles and, after discarding 211 articles with no relevance to the topic, 124 articles were kept. Mousavi Isfahani *et al.* (2019) used a search strategy that included the terms "lean principles", "lean Six Sigma", "lean process", "lean thinking", "lean methodology", "Toyota production system lean processing", "lean techniques" and "hospital". This search strategy resulted in 967 articles, from which 48 were finally selected and analysed.

After analysing the keywords used in the selected review articles, the researchers of the current study have decided for broad search terms during the definition of the search procedure, resulting in the following search query: TITLE-ABS-KEY ["lean healthcare" OR "lean hospitals") OR TITLE-ABS-KEY ("lean thinking" AND (hospitals OR healthcare)].

At this point, it is possible to *conduct the review*, Phase 2 according to Tranfield *et al.* (2003). Thus, the search query was applied to two index databases, Scopus and the Web of Knowledge. Considering that the number of results of the first one (Scopus) included the great majority of the results of the second one (Web of Knowledge), it was decided to use the list of results obtained in the Scopus database search, resulting in a total of 366 articles found prior to 2019. Then, as a quality criterion of inclusion, these articles were filtered by selecting journal publications only, resulting in a total of 245 articles. Considering the period of time delimitation of this study, the search included articles in the years 2014 to 2018, resulting in 136 articles.

In this phase, the articles' files were downloaded and, after a first screening process based on the title and abstract, 22 articles were excluded: three because of the different scope of the study and 19 due to lack of access to full text, resulting in a total of 114 final articles, as illustrated by Figure 1.

Table 1. Systematic review articles used as the basis for this study

Authors	Title	Review period
Souza (2009)	Trends and approaches in lean healthcare	2002 to 2008
Mazzocato *et al.* (2010)	Lean thinking in healthcare: a realist review of the literature	1998 to 2008
Holden (2011)	Lean thinking in emergency departments: a critical review	2005 to 2010
D'Andreamatteo *et al.* (2015)	Lean in healthcare: a comprehensive review	2003 to 2013
Daultani *et al.* (2015)	A decade of lean in healthcare: current state and future directions	2002 to 2014
Costa and Godinho Filho (2016)	Lean healthcare: review, classification and analysis of literature	2008 to 2014
Mousavi Isfahani *et al.* (2019)	Lean management approach in hospitals: a systematic review	2010 to 2015

As stated by Easterby-Smith *et al.* (2018, p. 46), the critical phase of the assessment "follows the criteria and (emerging) themes of the review". These criteria and themes, described in the next section, were a result of integrating and expanding the criteria from the works referred in Table 1. Moreover, their meaning and interpretations were debated and clarified amongst all researchers and subsequently applied by one of the researchers to all articles. Whenever doubts arose, they were clarified amongst all the researchers and a decision was made by consensus amongst them. These criteria are described in detail in the next section.

Finally, after conducting the review, the work enters in Phase 3, *report and disseminate*, where results and recommendations are presented, in addition to the practical evidence exposed. The analysis and synthesis of the articles are reported using a structure based on the review criteria defined in Section 2.2, followed by discussion, recommendations and conclusion. Finally, the complete list of articles and the relation with the criteria identified is presented in the Appendix.

2.2 Review criteria

As explained in the previous section, the first filter applied in this study was the selection of the most relevant reviews in the studýs field of knowledge (Table 1). After selecting the reviews, the criteria were chosen according to Costa and Godinho Filho (2016) and were crosschecked for each article. Costa and Godinho Filho (2016) classified the articles according to six criteria and this study adapted and updated five of those criteria by crossing with the other selected systematic reviews. The criteria applied were:

(1) Year, the number of publications per year by Souza (2009), D'Andreamatteo *et al.* (2015) and Daultani *et al.* (2015).

(2) Country, also analysed by Souza (2009).

(3) Research approaches, also analysed by Souza (2009), Mazzocato *et al.* (2010), D'Andreamatteo *et al.* (2015) and Daultani *et al.* (2015).

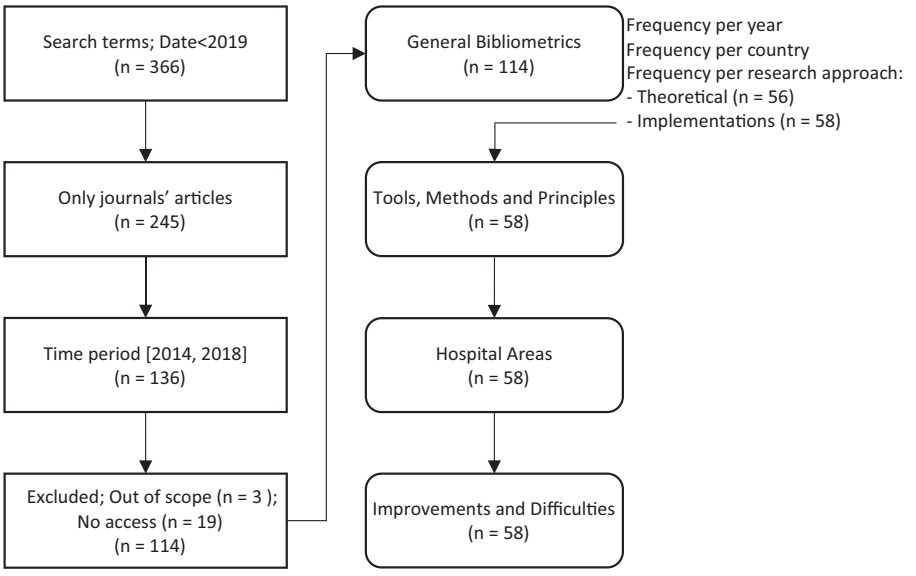

Figure 1.
Structure and organization to conduct the review

(4) Tools, Methods and Principles, also studied by Souza (2009), Mazzocato *et al.* (2010), D'Andreamatteo *et al.* (2015), Daultani *et al.* (2015) and Mousavi Isfahani *et al.* (2019); including principles and techniques related to Lean health care.

(5) Hospital areas, also studied by Mazzocato *et al.* (2010), Daultani *et al.* (2015), Holden (2011) and Mousavi Isfahani *et al.* (2019).

(6) Improvements and difficulties, also studied by Mazzocato *et al.* (2010), Daultani *et al.* (2015), Holden (2011) and Mousavi Isfahani *et al.* (2019).

2.2.1 General bibliometrics. The first three criteria identified above are mainly related to the analysis of the frequency of the number of published references, grouped by year, country and type of research approaches used in each study. These analyses, entitled as *general bibliometrics*, present an overview about the recent history around this theme.

Regarding the research approaches used in lean health care articles, Souza (2009) addressed his analysis in two categories, namely, theoretical and case studies, in which theoretical studies would not demonstrate a real implementation, while case studies would do. D'Andreamatteo *et al.* (2015) used the criteria of Souza (2009) to divide the articles into two types of clusters, namely, Empirical and Theoretical. Costa and Godinho Filho (2016) analysed the articles as theoretical-conceptual (TC), action research (AR), case study (CS), Survey (S) and Ethnography (E).

After reading the abstract and, if needed, other parts of the article, they were assessed according to the methodological approach, using the classification of Costa and Godinho Filho (2016), as TC, S, AR, CS and E. None of the articles was classified as using E. Fifty-eight (58) articles were assessed as case studies and action-research, with the application of lean tools and methods in health care contexts. These 58 papers were qualitatively analysed, with the objective of developing a critical assessment of the implementation of lean tools and methods in empirical works, encompassing a timeframe of five years.

Furthermore, considering the objective of understanding tools and techniques applied to lean health care, the 58 articles categorized as case studies and action-research were analysed in detail according to the criteria 4 to 6, as described below.

2.2.2 Tools, methods and principles. Daultani *et al.* (2015) analysed a wide range of tools and techniques and their combinations applied in lean health care and show that VSM (value stream mapping) is one of the most frequent tools cited, but without a complete demonstration of its potential. Costa and Godinho Filho (2016) also identify tools and techniques applied to lean health care with a classification previously proposed by Radnor *et al.* (2012) where these tools are divided into three main classifications, namely, assessment; Improvement; and, monitoring. Within these main general classifications, Mazzocato *et al.* (2010) included tools, methods and principles based on their review. Mousavi Isfahani *et al.* (2019) classified studies in 10 generic terms with different levels of aggregation. Examples of terms used are lean tools, lean six sigma, lean methodology or lean principles.

According to the list of tools and techniques presented in the studies by Daultani *et al.* (2015), Costa and Godinho Filho (2016) and Mazzocato *et al.* (2010), the current study compiled and synthesized a list of tools, methods and principles from the selected articles and divided it into five classes, as shown in the list below of tools, methods and principles. These classes are a result of a debate between three lean experts regarding the six review articles used to support the current work and considering their experience, both in research and in practical developments with industries and hospitals. The main objective of this classification is to present a more useful result for practitioners and for other research works.

The classes refer to two lean principles, "production flow" and "continuous improvement" and other dimensions transversally related to lean, "work organization and visual management", "diagnosing and problem-solving" and "complementary management approaches".

List of tools, methods and principles

(1) Production flow:
- T1 – Continuous flow
- T2 – Heijunka (levelling)
- T3 – Just in time
- T4 – Kanban
- T5 – One-piece-flow
- T6 – Pull system
- T7 – Quick changeovers (SMED – single minute exchange of die)
- T8 – Takt time
- T9 – Work cells
- T10 – Workload balancing

(2) Continuous improvement:
- T11 – Continuous improvement teams
- T12 – DMAIC (define-measure-analyse-improve-control)
- T13 – Go to Gemba
- T14 – Hoshin kanri
- T15 – Kaizen/rapid improvement event
- T16 – Kata
- T17 – KPIs (key performance indicators) monitoring
- T18 – PDCA/PDSA (plan, do, check, act/plan, do, study, act)
- T19 – VOC, VOB, CTQ (voice of business, the voice of the customer, critical to quality)

(3) Work organization and visual management:
- T20 – 5S (seiri, seiton, seiso, seiketsu, shitsuke)
- T21 – Andon (patient safety alert system and "stop the line")
- T22 – Daily meetings/rounds
- T23 – Jidoka
- T24 – Mistake-proofing (Poka-yoke)
- T25 – Multidisciplinary task training
- T26 – Physical work setting redesign
- T27 – Standardized work
- T28 – Teamwork
- T29 – Visual management

(4) Diagnosing and problem-solving:
- T30 – Five whys
- T31 – A3 reports

- T32 – ABC analysis
- T33 – Ishikawa diagram (cause and effect/fishbone diagram)
- T34 – Kobetsu
- T35 – OEE (overall equipment effectiveness)
- T36 – Process mapping, process redesign
- T37 – Risk analysis (failure modes, effects analysis)
- T38 – SIPOC (suppliers, inputs, process, outputs, customer)
- T39 – Spaghetti diagram
- T40 – Statistical process control
- T41 – VSM
- T42 – Wastes analysis

(5) Complementary management approaches:

- T43 – Benchmarking
- T44 – Lean Six Sigma
- T45 – Project management
- T46 – SCRUM
- T47 – Simulation/systems approach
- T48 – Theory of constraints
- T49 – Total productive maintenance
- T50 – Total quality management

2.2.3 Hospital areas. Amongst the articles containing implementation studies, the main hospital areas were found according to the authors Mazzocato *et al.* (2010), D'Andreamatteo *et al.* (2015), Costa and Godinho Filho (2016), Daultani *et al.* (2015), Mousavi Isfahani *et al.* (2019). Mazzocato *et al.* (2010) listed the 16 main areas and clinical specialties in which lean was applied. These areas were divided into: "clinical specialties"; "diagnostic services"; and "other". Costa and Godinho Filho (2016) present 23 hospital areas by adapting the proposals by Mazzocato *et al.* (2010). In addition to these authors, D'Andreamatteo *et al.* (2015) indicate that the main studies appear in areas such as surgery and emergency. Thus, it was not possible to find a consensus for classifying Hospital Areas.

Considering the areas referred above from the several review works, the current study compiles and synthesizes the main areas and fields of study in lean health care, which are presented in List. The refinement was based on the differentiation between hospital areas and hospital medical specialties. However, as some specialties may use certain areas, it was decided to define more generic areas instead of detailing it by specialty. The reasoning is that there could be duplication of references (in terms of areas and medical specialties), for example: when an article refers to the "surgery" specialty, the "operating room" area was the classification assigned. Operating room is also the terminology adopted by Mousavi Isfahani *et al.* (2019).

List of hospital areas

- A1 – Emergency department
- A2 – General (for studies that do not specify the studied area)
- A3 – General hospital

- A4 – General outpatient clinic
- A5 – Hospital laundry
- A6 – Information department
- A7 – Intensive care
- A8 – Laboratory
- A9 – Mental health centre
- A10 – Nursing department
- A11 – Oncology
- A12 – Operating room
- A13 – Pathology
- A14 – Pharmacy
- A15 – Primary health care
- A16 – Radiology
- A17 – Specialties
- A18 – Sterile services department
- A19 – Support activities

All areas identified in the list were extracted and refined from the selected review works, except the "primary health care" area, which emerged from the analysis of the following two papers, namely, Drotz and Poksinska (2014) and Poksinska *et al.* (2017). These articles refer to case studies related to care centres that provide primary health care services in Sweden. Thus, this area was added to the list presented above.

2.2.4 Improvements and difficulties. The improvements and difficulties were qualitatively assessed in the selected articles and a list of the main improvements and difficulties (regarding to the scope of the study) was developed. The development of this analysis was made by two researchers, which identified the main improvements and difficulties and reported it as a synthesis of the analysis. This analysis allows lean health care practitioners and researchers to identify the main risks and plan actions to overcome eventual difficulties. Additionally, practitioners and researchers may become aware of the potentially positive results from the application of lean health care.

3. General bibliometrics

This section presents the main results of the analysis regarding the number of published references, grouped by year, by country and by type of research approach used in each study.

Figure 2 presents an updated scenario of the number of journal articles published per year. There is an evolution on the number of publications between the years 2000 and 2015, with a trend to stabilize in the following years. Instead of showing just a five-year period of publications, this analysis includes all the 245 journal articles found, covering the period from 1994 to 2018, for a broader perspective on the evolution publications per year.

Souza (2009) identified the first publication related to lean health care as being from 1995. In the current work one publication from 1994 was identified (Pfaff, 1994). This work already referred the term lean production and discussed if it could be considered a model for hospitals. Aligned to the lean principles, it argued that lean at the hospitals should promote the participation of the patients.

As a result of his work, Souza (2009) shows that 57% of the analysed articles are originated in the private sector in the USA, 29% in the public sector in the UK, 4% in Australia and 9% in other countries. Costa and Godinho Filho (2016) confirmed that most of the studies are still from authors of the USA and UK, and observed the emergence of a third country, The Netherlands, which stood out in the number of publications in relation to other countries.

Figure 3 reveals the top 15 countries with the higher number of lean health care articles published in journals, previous from 2019. This result confirms a tendency similar to preview review studies, revealing USA as the top country in lean health care journal publications per year. UK, Sweden, Australia, Canada and the Netherlands also appear, as in previous studies. Notably, in the five-year period from 2014 to 2018, the countries with a higher number of publications are respectively USA, Italy and Brazil. It should be noted that, in the update provided by this study, other countries (such as Italy and Brazil) emerge with a great number of publications occupying the third and sixth places in the ranking, respectively (Figure 3).

Previous reviews on lean health care classified the majority of articles as being theoretical, stating that more empirical studies with evidences to the management results are missing (Souza, 2009; D'Andreamatteo *et al.*, 2015). From the 114 articles analysed in detail in the current study, Figure 4 shows that 44 articles were identified as TC, 12 as surveys, 29 as action-research and 29 as CS. As case studies and AR works represent in the current study the works reporting implementations, this may indicate an increasing attention to implementation works of lean in health care environments.

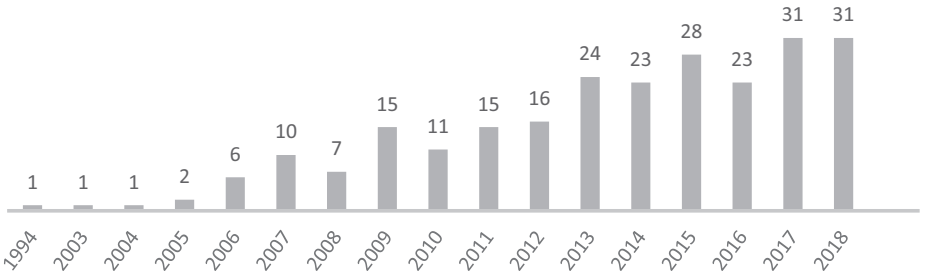

Figure 2.
Evolution of the number of publications per year

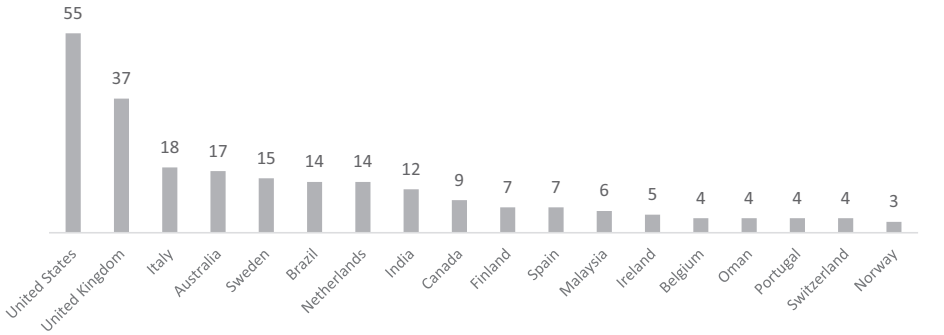

Figure 3.
Number of articles per country

This is a trend that could not be identified neither from the works of Souza (2009) nor D'Andreamatteo *et al.* (2015).

4. Tools, methods and principles

Régis *et al.* (2018) evaluated the implementation of lean health care in three Brazilian hospitals and found similarities between the use of tools and methods and identified the motivation for the implementations as being derived from strategic planning. The use of methods such as PDCA and DMAIC, VSM and kaizen were found similar in all cases. Mazzocato *et al.* (2010) present the most frequent methods in their study: process vision; team approach to problem-solving and rapid improvement events; visual management; VSM; and, standard procedures. Costa and Godinho Filho (2016) stated in their study that the most used tools were VSM, Ishikawa Diagrams and the DMAIC method. Daultani *et al.* (2015) presented the main tools and methods used in studies as being VSM; process mapping and standardization; Kaizen events; root-cause analysis (five Whys, A3 reports, Cause and effect/Fishbone diagram); and 5S applications. In the current study, the VSM, 5S, Standardized Work and Visual Management are the tools identified as the most frequent (Figure 5), corroborating the most used tools cited by previous authors.

According to Henrique *et al.* (2016) a key tool for lean implementations is VSM. However, VSM models used in health care are simple adaptations of the original manufacturing models and do not always represent important activities regarding the flow of patients. In this context, Henrique *et al.* (2016) present a new approach to VSM for hospital environments, focussing on activities that directly affect treatment time and, consequently, value-added. As stated by Souza (2009), frequently, studies entitled as "lean" do not show an appropriate level of systemic view, approaching lean by the simple application of one or two tools or lean principles.

In the current study, the tools, methods and principles in lean health care were categorized (see categories in the list) and Figure 6 depicts their compilation and distribution by the defined categories. It is possible to observe that there are much more publications assigned to the categories "diagnosing and Problem Solving" and "work organization and visual management" because of the use of the principles, tools, methods and techniques identified in the articles and represented in Figure 5.

The vision of flow encompassed by the "production flow" class and the long-term improvement culture represented by the "continuous improvement" class appear with fewer

Figure 4.
Number of papers per research approach

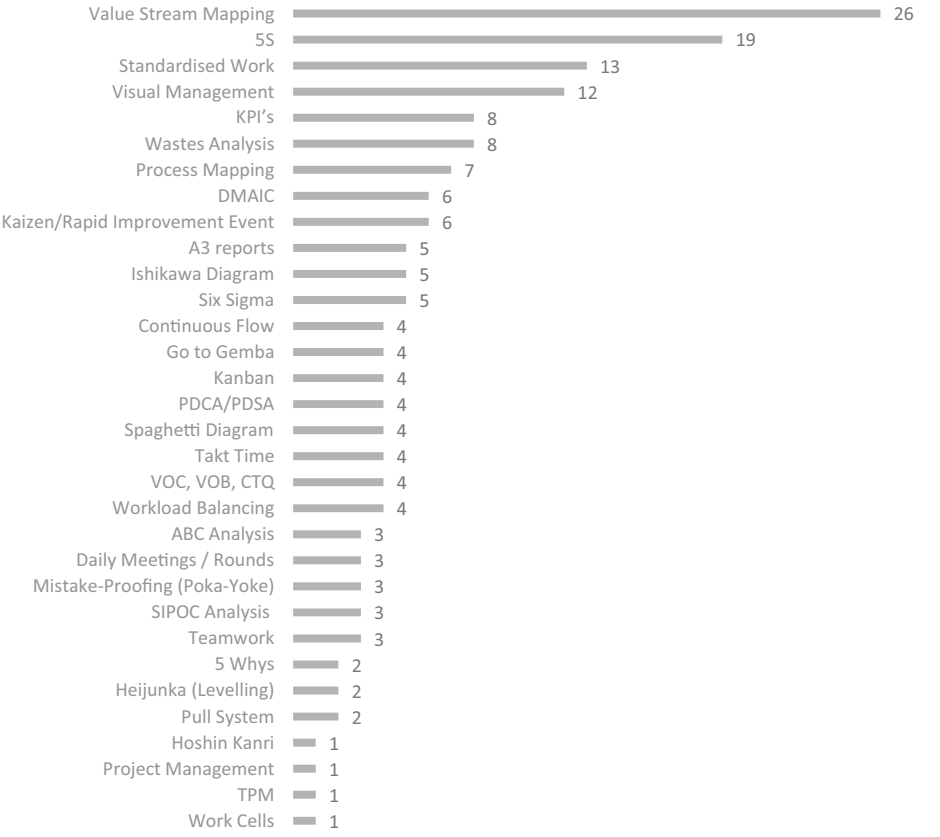

Figure 5.
Tools, methods and principles in lean implementations

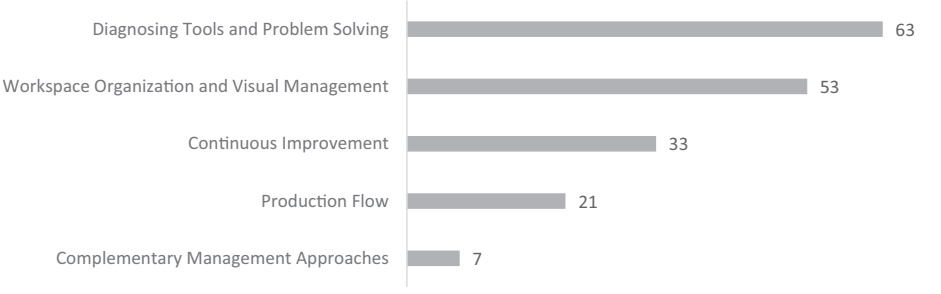

Figure 6.
Categories of tools, methods and principles in lean implementations

publications. It is possible to analyse and speculate, that these results may be justified by the use of tools in an isolated manner rather than in a global approach, in which the focus would be on priority flows and driven by a long-term improvement vision.

One additional discussion that could arise is that most referred lean tools are solutions developed in the context of Toyota plants. The referred lean tools try to materialize the lean

or TPS principles and concepts. It could be argued that these lean tools may not be the most appropriate solutions in hospital environments. One type of flow in the hospital context that is somehow similar to the industry is the flow of materials such as medicines, medical material, cleaning products, gauze, hygiene products, sheets and towels. The principles of flow and pull flow may be pursuit by using similar tools as the ones originated in Toyota plants, however other medical activities and the flow of people may require the development of specific tools for hospital environments. VSM appears as the most referred tool (Figure 5) and its use is mainly effective in streams of materials, which is a small subset of hospital activities.

The following three items in the list are 5S, visual management and standard work. The 5S technique is very effective and needed in hospitals, as it brings efficiency, safety and quality to the activities in hospitals. Visual management allows transparency and simplifies the management work, contributing for a higher performance. The standard work is also an important concept to create consistency and predictability to hospital tasks. Tasks in hospitals are performed by nurses, doctors and other personnel, many times according to their own way of working, allowing different ways of performing the same task, and therefore, bringing inconsistency in results, time spent and quality.

One recommendation that could be given at this point is that more effort should be applied in continuous improvement integrated systems designed for hospitals, with *Hoshin Kanri* strategic deployment, as proposed by Barnabè and Giorgino (2017). This would seriously change the hospital structure by encouraging everyone to contribute to small improvements every day. These improvements should be focussed on how the work could be performed in an easier way with better results for patients and hospital staff.

In summary, this way of categorizing the Tools, Methods and Principles presented in Figure 6, allowed to clearly illustrate that much less effort is made in more systemic implementations of lean. Considering that lean implementations that are focussed in the application of tools for improving a subsystem, may, in some cases, "have a negative impact on the wider system" (Papadopoulos *et al.*, 2011, p. 171) and as advocated by lean thinking, more effort should be made on studying lean implementations focussed in complete process flows and sustainable systems for continuous improvement.

5. Hospital areas

Costa and Godinho Filho (2016) and D'Andreamatteo *et al.* (2015) identified the Emergency Department and Surgical Centre as the main areas of implementation of lean health care. Daultani *et al.* (2015) indicate the same areas and added the general hospital area, as the more frequent areas in the studies. In the current study, as can be seen in Figure 7, general (for areas not specified), general hospital, emergency department, information department, specialties, oncology, operating room and pharmacy were the main areas in terms of lean implementation. This update confirms some of the previously identified main areas cited by other authors and demonstrates two emerging areas related to drug flow (pharmacy) and the information flow (information department). Despite the fact that more areas of the hospital are being referred, this analysis show that studies of the application of lean in all hospital areas are missing and are required to have broader and systemic implementations of lean in hospitals.

The pharmacy area has a considerable number of published articles, maybe because it is the area that most closely resembles the Toyota plant activities with the flow of physical materials between stock areas. The tools and knowledge that comes from industry is quite easily applicable in this area because it deals with stock management, material handling and material flow. It should be also noted that the detailed analysis of the 58 articles did not find

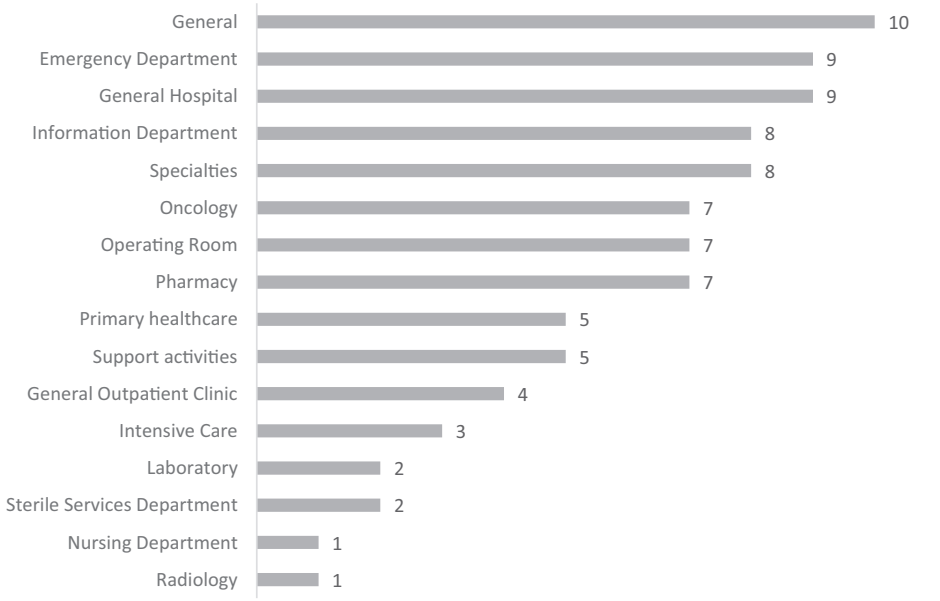

Figure 7.
Lean implementation by hospital areas

works related to the following three areas, namely, Hospital Laundry, Mental Health Centre and Pathology. These three areas and the ones above with less references (radiology and nursing department) should be the object of future implementations to extend the knowledge of the application of lean thinking to health organizations.

6. Improvements and difficulties

D'Andreamatteo *et al.* (2015) indicate that the main results of lean health care implementations have positive impact on productivity and cost efficiency. The most common results found in the study performed by Mazzocato *et al.* (2010) include gains in time and service punctuality, cost reductions or improvements in productivity and quality and processes for reducing errors and defects, improving staff and patient satisfaction. Mousavi Isfahani *et al.* (2019) analysed 48 articles and their improvements, determining that 69 out of 150 assessed indicators were meaningfully improved.

In the current study, the option was to develop an aggregated analysis, which inform researchers and practitioners about types of improvements and the corresponding published studies. In this way, it would make it possible for them to investigate the works specifically related to their objectives. Moreover, this approach allows to identify an important part of the overall picture of research in lean health care.

In the current study, the improvements results are listed below:

- I1 – Time gains, reduction of lead time, reduction of patient waiting time, improvement of cycle time, improvement of hospitalization time, reduction of waiting lists – 22 articles.
- I2 – Reduction of errors, identification and reduction of waste, reduction of stocks, reorganization of physical space and reduction of costs – 19 articles.

- I3 – Improved organizational culture, increased team spirit and communication, employee and supplier satisfaction, improved workload for nurses and reduced overtime – 18 articles.
- I4 – Efficiency and productivity gains, bottleneck identification, improved patient and information flow, capacity levelling – 17 articles.
- I5 – Positive impact on quality and safety indicators, reduced number of complaints, increased customer satisfaction (patient) – seven articles.

Albliwi *et al.* (2014) expose some common factors as a threat to lean application such as lack of commitment and involvement of management, lack of communication, lack of training of stakeholders and limited resources. In relation to the difficulties observed in the implementation studies analysed in the current work, it is possible to highlight the following:

- D1 – Lack of training of teams linked with scepticism and distrust in lean practices, which may create obstacles to reach sustainable lean implementations in the long term – six articles.
- D2 – The focus on the flow and the overall vision of the process is limited, predominating isolated initiatives ("local vision") – six articles.
- D3 – Low involvement between stakeholders and operational team resulting in demotivation and undesired team performance – six articles.
- D4 – Difficulty in collecting data and building reliable information – two articles.
- D5 – Failure of communication between lean professionals and other professionals, especially care professionals (nursing and clinical staff) and traditional managers – two articles.
- D6 – Excess of bureaucracy in the hospital field because of regulations, protocols and legislation often used ineffectively and as a mean of "blocking" (compromising) lean applications – one article.

Previous review works (Mazzocato *et al.*, 2010; D'Andreamatteo *et al.*, 2015) stressed the fact that most of the research developed under this theme report mainly positive results and failure results could also contribute for the advancement of knowledge. The current review work did not look for failure projects but instead, focussed on the identification of difficulties and obstacles reported by published articles. This identification adds a set of categories of difficulties found by researchers when implementing lean in health care environments, which may be of special help for practitioners and researchers when addressing new implementations of lean or even researching this subtheme.

7. Discussion, recommendations and conclusion

The adoption of lean thinking to the hospital context has transformative potential in the reengineering of health services, focussing on improvements in quality, safety, efficiency and standardization (Kim *et al.*, 2006). Despite the growing academic assessment of lean health care, there is still a lack of research to explore in detail the implementation of lean and its interaction with existing care practices (Waring and Bishop, 2010). These authors indicate that the application of lean in health systems is likely to be a highly contested process, as it is reinterpreted by different actors from a social environment full of conflicts and disagreements, evidencing a traditional management vision.

The current study concludes that there has been an evolution of lean health care in the past years, but with a trend of stabilization in the publications. The USA, Italy and Brazil are the countries with the highest number of journal publications in the 2014–2018 period. In terms of tools, methods and principles, VSM, 5S, visual management and standardized work appear as the most used, which may reveal non-systemic approaches for lean development and application. Thus, one of the most important conclusions that can be drawn from this study is that in most cases the introduction of lean thinking in hospitals is performed through the application of lean tools, in specific areas with little structural changes in hospitals' management and organization structure.

Considering the hospital areas with high number of works reported in previous review studies, there is still a tendency to develop works in the Emergency Department and Surgical Centre. Nevertheless, in contrast with other studies, the current work found a new trend of ascending number of works related to the Information Departments and Pharmacy. Another trend identified by this study is the lack of studies related with Hospital Laundry, Mental Health Centre, Pathology, Radiology and Nursing department.

One important conclusion that can be drawn is that unfortunately, very few or non-existing works were published reporting some of the most critical factors contributing to the success of lean implementations. These factors are related to the invisible part of lean as called by Rother (2010) and as the key behavioural indicators or the social science side of lean as mentioned in the Shingo model (Miller, 2018). Those are the same critical factors that are missing in most lean implementation failures. The missing factors are some of the key principles of the Shingo model (Shingo Institute, 2019) and the Toyota Way (Krijnen, 2007). Regarding the enterprise alignment (from Shingo model) and "long-term philosophy" (from Toyota Way) only one publication was found referring *Hoshin Kanri* strategic deployment. Moreover the focus on patients is not properly addressed in terms of value-added, which is related to the "create value for the customer" Shingo principle and the first principle of lean thinking. Also missing from the large majority of the work published is the reference to the cultural enablers "respect every individual" and "lead with humility" (from Shingo model) and "add value to the organization by developing your people" group of principles (from Toyota Way). Those aspects are so important that they were already referred by Sugimori *et al.* (1977) as "treat the workers with respect as human beings and with consideration" as being one of the two TPS basic concepts. In the publications considered in this literature review there is a lack of works focussing on motivation and work satisfaction, which is not properly addressed when referring to hospital staff (e.g. nurses, doctors, support personal, managers, administrative personal and technicians). In summary, the continuous improvement set of principles still seems to be poorly understood in most lean implementations in hospitals. Although the Toyota Way principle "go and see for yourself to thoroughly understand the situation" is referred frequently, another principle of the same group of principles "become a learning organization through relentless reflection (hansei) and continuous improvement" is missing. Most published work reports improvements and problem-solving but the sustainability of the continuous improvement system is seldom addressed.

With regard to main improvement results reported, lead time improvement, increased productivity and efficiency, waste reduction, improved team spirit and quality assurance demonstrate alignment with the principles and foundations of lean philosophy, but such results are presented in isolated initiatives and without robust evidence of long-term maintenance. Amongst the difficulties encountered, the lack of communication between the multidisciplinary teams, the low involvement of the management staff and the high bureaucracy in the hospital field emerged as frequent difficulties, which may explain the

lack of works related to cultural change factors referred above. Moreover, another important difficulty identified in the current work, is the difficulty in collecting data and the lack of communication between teams, which opens an excellent opportunity to apply current trends of data analytics and business intelligence in selection, processing and driving that data into the teams and other stakeholders, in ways that are meaningful for them. This seems to be a potential opportunity to improve the impact of lean implementations in the future, simultaneously bridging gaps between different stakeholders.

Souza (2009) stated that lean health care was still at an early stage of development when compared to the implementation of lean principles in the automotive industry and the review presented in this study shows an evolution of the implementations, but still with a small number of publications, which report isolated applications in different hospital areas and are developed locally instead of globally. Other authors suggested that lean should be developed holistically in health care (Matthias and Brown, 2016; Mazzocato *et al.*, 2010) exploring creativity and innovation-related approaches (Hoerl and Gardner, 2010). Thus, as future recommendations for studies, it would be important to develop works related to different dimensions and type of hospitals in different world regions, as these characteristics may affect the nature of the process and the demand for health care, thus guiding different approaches for continuous and sustained improvement interventions. In addition, it is recommended to develop applied studies on end-to-end (global) flows rather than isolated initiatives, bringing more robustness and proof of lean results.

Based on what is published about lean implementation in hospitals, one additional recommendation to be made is that hospitals should be culturally reshaped through structural changes, following new visions and strategic goals, supported by real models of structural and sustained continuous improvement. The structure could be based on teamwork, with daily improvement, targeting specific objectives aligned with the appropriate strategic vision of top management. Senior management's vision should emphasize value addition from the patient's point of view and clearly emphasize worker motivation and well-being. The proper focus on the value-added to patients and the well-being improvements amongst hospital workers, created by a well-designed sustainable continuous improvement system, would certainly represent an enormous contribution to society.

References

Aij, K.H. and Teunissen, M. (2017), "Lean leadership attributes: a systematic review of the literature", *Journal of Health Organization and Management*, Vol. 31 Nos 7/8, pp. 713-729, available at: https://doi.org/10.1108/JHOM-12-2016-0245

Aij, K.H., Aernoudts, R.L. and Joosten, G. (2015), "Manager traits and quality-of-care performance in hospitals", *Leadership in Health Services*, Vol. 28 No. 3, pp. 200-215, available at: https://doi.org/10.1108/LHS-07-2014-0053

Ajmera, P. and Jain, V. (2019), "A fuzzy interpretive structural modeling approach for evaluating the factors affecting lean implementation in Indian healthcare industry", *International Journal of Lean Six Sigma*, Vol. 11 No. 2, available at: https://doi.org/10.1108/IJLSS-02-2018-0016

Al-Balushi, S., Sohal, A.S., Singh, P.J., Hajri, A.A., Farsi, Y.M.A. and Abri, R.A. (2014), "Readiness factors for lean implementation in healthcare settings – a literature review", *Journal of Health Organization and Management*, Vol. 28 No. 2, pp. 135-153, available at: https://doi.org/10.1108/JHOM-04-2013-0083

Al Farsi, Y., Al Abri, R., Al Hajri, A. and Al Balushi, S. (2014), "The need for lean thinking in the omani health care sector", *Oman Medical Journal*, Vol. 29 No. 4, pp. 248-249, available at: https://doi.org/10.5001/omj.2014.66

Albliwi, S., Antony, J., Abdul Halim Lim, S. and van der Wiele, T. (2014), "Critical failure factors of lean six sigma: a systematic literature review", *International Journal of Quality and Reliability Management*, Vol. 31 No. 9, pp. 1012-1030.

Aleem, S., Torrey, W.C., Duncan, M.S., Hort, S.J. and Mecchella, J.N. (2015), "Depression screening optimization in an academic rural setting", *International Journal of Health Care Quality Assurance*, Vol. 28 No. 7, pp. 709-725, available at: https://doi.org/10.1108/IJHCQA-01-2015-0012

Alshahrani, S., Rahman, S. and Chan, C. (2018), "Hospital-supplier integration and hospital performance: evidence from Saudi Arabia", *The International Journal of Logistics Management*, Vol. 29 No. 1, pp. 22-45, available at: https://doi.org/10.1108/IJLM-12-2016-0287

Andersen, H. and Røvik, K.A. (2015), "Lost in translation: a case-study of the travel of lean thinking in a hospital", *BMC Health Services Research*, Vol. 15 No. 1, available at: https://doi.org/10.1186/s12913-015-1081-z

Andersen, H., Røvik, K.A. and Ingebrigtsen, T. (2014), "Lean thinking in hospitals: is there a cure for the absence of evidence? A systematic review of reviews", *BMJ Open*, Vol. 4 No. 1, available at: https://doi.org/10.1136/bmjopen-2013-003873

Anuar, A. and Sadek, D.M. (2018), "Validity test of lean healthcare using Lawshe's method", *International Journal of Supply Chain Management*, Vol. 7 No. 6, pp. 197-203.

Anuar, A., Saad, R. and Yusoff, R.Z. (2018), "Sustainability through lean healthcare and operational performance in the private hospitals: a proposed framework", *International Journal of Supply Chain Management*, Vol. 7 No. 5, pp. 221-227.

Bal, A., Ceylan, C. and Taçoğlu, C. (2017), "Using value stream mapping and discrete event simulation to improve efficiency of emergency departments", *International Journal of Healthcare Management*, Vol. 10 No. 3, pp. 196-206, available at: https://doi.org/10.1080/20479700.2017.1304323

Barnabè, F. and Giorgino, M.C. (2017), "Practicing lean strategy: Hoshin Kanri and X-matrix in a healthcare-centered simulation", *The Tqm Journal*, Vol. 29 No. 4, pp. 590-609, available at: https://doi.org/10.1108/TQM-07-2016-0057

Barnabè, F., Giorgino, M.C., Guercini, J., Bianciardi, C. and Mezzatesta, V. (2017), "Engaging professionals with serious games: the lean healthcare lab at Siena University Hospital", *Development and Learning in Organizations: An International Journal*, Vol. 31 No. 3, pp. 7-10, available at: https://doi.org/10.1108/DLO-06-2016-0051

Barnabè, F., Giorgino, M.C., Guercini, J., Bianciardi, C. and Mezzatesta, V. (2018), "Management simulations for lean healthcare: exploiting the potentials of role-playing", *Journal of Health Organization and Management*, Vol. 32 No. 2, pp. 298-320, available at: https://doi.org/10.1108/JHOM-07-2017-0191

Bertolini, M., Bevilacqua, M., Ciarapica, F.E. and Giacchetta, G. (2011), "Business process re-engineering in healthcare management: a case study", *Business Process Management Journal*, Vol. 17 No. 1, pp. 42-66.

Bittencourt, O., Verter, V. and Yalovsky, M. (2017), "Daily capacity management for hospitals: a brazilian case study", *International Journal of Services and Operations Management*, Vol. 27 No. 1, pp. 102-121, available at: https://doi.org/10.1504/IJSOM.2017.083342

Blouin-Delisle, C.H., Drolet, R., Gagnon, S., Turcotte, S., Boutet, S., Coulombe, M. and Daneau, E. (2018), "Improving flow in the or: how lean process studies can lead to shorter stays in the recovery ward", *International Journal of Health Care Quality Assurance*, Vol. 31 No. 2, pp. 150-161, available at: https://doi.org/10.1108/IJHCQA-01-2017-0014

Booker, C., Turbutt, A. and Fox, R. (2016), "Model of care for a changing healthcare system: are there foundational pillars for design?", *Australian Health Review*, Vol. 40 No. 2, pp. 136-140, available at: https://doi.org/10.1071/AH14173

Boronat, F., Budia, A., Broseta, E., Ruiz-Cerdá, J.L. and Vivas-Consuelo, D. (2018), "Application of lean healthcare methodology in a urology department of a tertiary hospital as a tool for improving

efficiency | aplicación de la metodología lean healthcare en un servicio de urología de un hospital terciario como herramienta de mejora de l", *Actas Urológicas Españolas*, Vol. 42 No. 1, pp. 42-48, available at: https://doi.org/10.1016/j.acuro.2017.03.009

Briner, R.B. and Denyer, D. (2012), "Systematic review and evidence synthesis as a practice and scholarship tool", *Handbook of Evidence-Based Management: Companies, Classrooms and Research*, pp. 112-129.

Bruno, F. (2017), "Lean thinking in emergency departments: concepts and tools for quality improvement", *Emergency Nurse*, Vol. 25 No. 6, pp. 38-41, available at: https://doi.org/10.7748/en.2017.e1679

Butler, T.W., Leong, G.K. and Everett, L.N. (1996), "The operations management role in hospital strategic planning", *Journal of Operations Management*, Vol. 14 No. 2, pp. 137-156.

Cashin, C., Bloom, D., Sparkes, S., Barroy, H., Kutzin, J. and O'Dougherty, S. (2017), "Aligning public financial management and health financing: sustaining progress toward universal health coverage", Health Financing Working Paper No. 17.4, World Health Organization, Geneva, License: CC BY-NC-SA 3.0 IGO, available at: http://apps.who.int/iris/bitstream/10665/254680/1/9789241512039-eng.pdf

Chaerul, M., Tanaka, M. and Shekdar, A.V. (2008), "A system dynamics approach for hospital waste management", *Waste Management*, Vol. 28 No. 2, pp. 442-449.

Chakraborty, S. and Gonzalez, J.A. (2018), *An Integrated Lean Supply Chain Framework for US hospitals. Operations and Supply Chain Management*, Vol. 11 No. 2, pp. 98-109.

Chaurasia, B., Garg, D. and Agarwal, A. (2017), "Lean six sigma application in healthcare of patients", *International Journal of Intelligent Enterprise*, Vol. 4 No. 3, pp. 275-282, available at: https://doi.org/10.1504/IJIE.2017.087670

Cheng, S.Y., Bamford, D., Papalexi, M. and Dehe, B. (2015), "Improving access to health services – challenges in lean application", *International Journal of Public Sector Management*, Vol. 28 No. 2, pp. 121-135, available at: https://doi.org/10.1108/IJPSM-05-2014-0066

Clark, K.W., Moller, S. and O'Brien, L. (2014), "Electronic patient journey boards a vital piece of the puzzle in patient flow", *Australian Health Review*, Vol. 38 No. 3, pp. 259-264, available at: https://doi.org/10.1071/AH13192

Colldén, C., Gremyr, I., Hellström, A. and Sporraeus, D. (2017), "A value-based taxonomy of improvement approaches in healthcare", *Journal of Health Organization and Management*, Vol. 31 No. 4, pp. 445-458, available at: https://doi.org/10.1108/JHOM-08-2016-0162

Costa, L.B.M. and Godinho Filho, M. (2016), "Lean healthcare: review, classification and analysis of literature", *Production Planning and Control*, Vol. 27 No. 10, pp. 823-836, available at: https://doi.org/10.1080/09537287.2016.1143131

Costa, L.B.M., Filho, M.G., Rentes, A.F., Bertani, T.M. and Mardegan, R. (2017), "Lean healthcare in developing countries: evidence from brazilian hospitals", *The International Journal of Health Planning and Management*, Vol. 32 No. 1, pp. e99-e120, available at: https://doi.org/10.1002/hpm.2331

Crema, M. and Verbano, C. (2015), "Investigating the connections between health lean management and clinical risk management: insights from a systematic literature review", *International Journal of Health Care Quality Assurance*, Vol. 28 No. 8, pp. 791-811, available at: https://doi.org/10.1108/IJHCQA-03-2015-0029

Crema, M. and Verbano, C. (2017), "Lean management to support choosing wisely in healthcare: the first evidence from a systematic literature review", *International Journal for Quality in Health Care*, Vol. 29 No. 7, pp. 889-895, available at: https://doi.org/10.1093/intqhc/mzx135

D'Andreamatteo, A., Ianni, L., Lega, F. and Sargiacomo, M. (2015), "Lean in healthcare: a comprehensive review", *Health Policy*, Vol. 119 No. 9, pp. 1197-1209, available at: https://doi.org/10.1016/j.healthpol.2015.02.002

Dannapfel, P., Poksinska, B. and Thomas, K. (2014), "Dissemination strategy for lean thinking in health care", *International Journal of Health Care Quality Assurance*, Vol. 27 No. 5, pp. 391-404, available at: https://doi.org/10.1108/IJHCQA-01-2013-0001

Daultani, Y., Chaudhuri, A. and Kumar, S. (2015), "A decade of lean in healthcare: current state and future directions", *Global Business Review*, Vol. 16 No. 6, pp. 1082-1099, available at: https://doi.org/10.1177/0972150915604520

de Souza, A., Guerra, M., Guerra, C.O., Gomide, P.L.R., Pereira, C.M. and Freitas, D.A. (2009), "Controle de gestão em organizações hospitalares", *Revista de Gestão*, Vol. 16 No. 3, pp. 15-29.

Delisle, D.R. and Freiberg, V. (2014), "Everything is 5S: a simple yet powerful lean improvement approach applied in a preadmission testing center", *Quality Management Journal*, Vol. 21 No. 4, pp. 10-22, available at: https://doi.org/10.1080/10686967.2014.11918406

DiGioia, A.M., Greenhouse, P.K., Chermak, T. and Hayden, M.A. (2015), "A case for integrating the patient and family centered care methodology and practice in lean healthcare organizations", *Healthcare*, Vol. 3 No. 4, pp. 225-230, available at: https://doi.org/10.1016/j.hjdsi.2015.03.001

Drotz, E. and Poksinska, B. (2014), "Lean in healthcare from employees' perspectives", *Journal of Health Organization and Management*, Vol. 28 No. 2, pp. 177-195, available at: https://doi.org/10.1108/JHOM-03-2013-0066

Easterby-Smith, M., Thorpe, R., Jackson, P.R. and Jaspersen, L.J. (2018), *Management and Business Research*, SAGE Publications New York, NY.

Efe, B. and Efe, Ö.F. (2016), "An application of value analysis for lean healthcare management in an emergency department", *International Journal of Computational Intelligence Systems*, Vol. 9 No. 4, pp. 689-697, available at: https://doi.org/10.1080/18756891.2016.1204117

Eiro, N.Y. and Torres-Junior, A.S. (2015), "Comparative study: TQ and lean production ownership models in health services | estudo comparativo das formas de apropriação dos modelos da qualidade total e lean production nos serviços de saúde | estudio comparativo de las formas de los modelos de propi", *Revista Latino-Americana de Enfermagem*, Vol. 23 No. 5, pp. 846-854, available at: https://doi.org/10.1590/0104-1169.0151.2605

Evans, J.H., Hwang, Y. and Nagarajan, N.J. (2001), "Management control and hospital cost reduction: additional evidence", *Journal of Accounting and Public Policy*, Vol. 20 No. 1, pp. 73-88, available at: https://doi.org/10.1016/S0278-4254(00)00024-7

Ferreira, G.S.A., Silva, U.R., Costa, A.L. and Pádua, S.I.D.D. (2018), "The promotion of BPM and lean in the health sector: main results", *Business Process Management Journal*, Vol. 24 No. 2, pp. 400-424, available at: https://doi.org/10.1108/BPMJ-06-2016-0115

Filser, L.D., da Silva, F.F. and de Oliveira, O.J. (2017), "State of research and future research tendencies in lean healthcare: a bibliometric analysis", *Scientometrics*, Vol. 112 No. 2, pp. 799-816, available at: https://doi.org/10.1007/s11192-017-2409-8

Fisher, A.M., Ding, M.Q., Hochheiser, H. and Douglas, G.P. (2016), "Measuring time utilization of pharmacists in the Birmingham free clinic dispensary", *BMC Health Services Research*, Vol. 16 No. 1, pp. 1-7, available at: https://doi.org/10.1186/s12913-016-1787-6

Fournier, P.-L. and Jobin, M.-H. (2018), "Medical commitment to lean: an inductive model development", *Leadership in Health Services*, Vol. 31 No. 3, pp. 326-342, available at: https://doi.org/10.1108/LHS-02-2018-0015

Galvão, T.F. and Pereira, M.G. (2014), "Revisões sistemáticas da literatura: passos Para sua elaboração", *Epidemiologia e Serviços de Saúde*, Vol. 23 No. 1, pp. 183-184.

Gershengorn, H.B., Kocher, R. and Factor, P. (2014), "Management strategies to effect change in intensive care units: lessons from the world of business: part II. Quality-improvement strategies", *Annals of the American Thoracic Society*, Vol. 11 No. 3, pp. 444-453, available at: https://doi.org/10.1513/AnnalsATS.201311-392AS

Godinho Filho, M., Boschi, A., Rentes, A.F., Thurer, M. and Bertani, T.M. (2015), "Improving hospital performance by use of lean techniques: an action research project in Brazil", *Quality Engineering*, Vol. 27 No. 2, pp. 196-211, available at: https://doi.org/10.1080/08982112.2014.942039

Graban, M. (2011), *Lean Hospitals: Improving Quality, Patient Safety, and Employee Satisfaction*, CRC Press Boca Raton.

Gupta, S., Kapil, S. and Sharma, M. (2018), "Improvement of laboratory turnaround time using lean methodology", *International Journal of Health Care Quality Assurance*, Vol. 31 No. 4, pp. 295-308, available at: https://doi.org/10.1108/IJHCQA-08-2016-0116

Habidin, N.F. (2017), "The development of lean healthcare management system (LHMS) for healthcare industry", *Asian Journal of Pharmaceutical and Clinical Research*, Vol. 10 No. 2, pp. 97-102, available at: https://doi.org/10.22159/ajpcr.2017.v10i2.14193

Habidin, N.F., Shazali, N.A., Ali, N., Khaidir, N.A. and Jamaludin, N.H. (2014), "Exploring lean healthcare practice and supply chain innovation for Malaysian healthcare industry", *International Journal of Business Excellence*, Vol. 7 No. 3, pp. 394-410, available at: https://doi.org/10.1504/IJBEX.2014.060782

Habidin, N.F., Shazali, N.A., Salleh, M.I., Zainol, Z., Hudin, N.S. and Mustaffa, W.S.W. (2015), "A review of supply chain innovation and healthcare performance in healthcare industry", *International Journal of Pharmaceutical Sciences Review and Research*, Vol. 35 No. 1, pp. 195-200.

Haddad, M.G., Zouein, P.P., Salem, J. and Otayek, R. (2016), "Case study of lean in hospital admissions to inspire culture change", *Engineering Management Journal*, Vol. 28 No. 4, pp. 209-223, available at: https://doi.org/10.1080/10429247.2016.1234896

Hallam, C.R.A. and Contreras, C. (2018), "Lean healthcare: scale, scope and sustainability", *International Journal of Health Care Quality Assurance*, Vol. 31 No. 7, pp. 684-696, available at: https://doi.org/10.1108/IJHCQA-02-2017-0023

Halm, M.A., Alway, A., Bunn, S., Dunn, N., Hirschkorn, M., Ramos, B. and Pierre, J.S. (2018), "Intersecting evidence-based practice with a lean improvement model", *Journal of Nursing Care Quality*, Vol. 33 No. 4, pp. 309-315, available at: https://doi.org/10.1097/NCQ.0000000000000313

Heinbuch, S.E. (1995), "A case of successful technology transfer to health care: total quality materials management and just-in-time", *Journal of Management in Medicine*, Vol. 9 No. 2, pp. 48-56.

Henrique, D.B., Rentes, A.F., Filho, M.G. and Esposto, K.F. (2016), "A new value stream mapping approach for healthcare environments", *Production Planning and Control*, Vol. 27 No. 1, pp. 24-48, available at: https://doi.org/10.1080/09537287.2015.1051159

Hines, P., Holweg, M. and Rich, N. (2004), "Learning to evolve: a review of contemporary lean thinking", *International Journal of Operations and Production Management*, Vol. 24 No. 10, pp. 994-1011.

Hoerl, R.W. and Gardner, M.M. (2010), "Lean six sigma, creativity, and innovation", *International Journal of Lean Six Sigma*, Vol. 1 No. 1, pp. 30-38.

Holden, R.J. (2011), "Lean thinking in emergency departments: a critical review", *Annals of Emergency Medicine*, Vol. 57 No. 3, pp. 265-278.

Holden, R.J., Eriksson, A., Andreasson, J., Williamsson, A. and Dellve, L. (2015), "Healthcare workers' perceptions of lean: a context-sensitive, mixed methods study in three Swedish hospitals", *Applied Ergonomics*, Vol. 47, pp. 181-192, available at: https://doi.org/10.1016/j.apergo.2014.09.008

Hutton, S.A., Vance, K., Burgard, J., Grace, S. and Van Male, L. (2018), "Workplace violence prevention standardization using lean principles across a healthcare network", *International Journal of Health Care Quality Assurance*, Vol. 31 No. 6, pp. 464-473, available at: https://doi.org/10.1108/IJHCQA-05-2017-0085

Hwang, P., Hwang, D. and Hong, P. (2014), "Lean practices for quality results: a case illustration", *International Journal of Health Care Quality Assurance*, Vol. 27 No. 8, pp. 729-741, available at: https://doi.org/10.1108/IJHCQA-03-2014-0024

Improta, G., Romano, M., Di Cicco, M.V., Ferraro, A., Borrelli, A., Verdoliva, C., . . . Cesarelli, M. (2018), "Lean thinking to improve emergency department throughput at AORN Cardarelli Hospital", *BMC Health Services Research*, Vol. 18 No. 1, available at: https://doi.org/10.1186/s12913-018-3654-0

Jacobs, S.M. and Pelfrey, S. (1995), "Applying just-in-time philosophy to healthcare", *The Journal of Nursing Administration*, Vol. 25 No. 1, pp. 47-51.

Jiang, N. and Malkin, B.D. (2016), "Use of lean and CAHPS surgical care survey to improve patients' experiences with surgical care", *Otolaryngology – Head and Neck Surgery* , Vol. 155 No. 5, pp. 743-747. (United States), available at: https://doi.org/10.1177/0194599816657051

Jorma, T., Tiirinki, H., Bloigu, R. and Turkki, L. (2016), "Lean thinking in finnish healthcare", *Leadership in Health Services*, Vol. 29 No. 1, pp. 9-36, available at: https://doi.org/10.1108/LHS-08-2015-0021

Kahm, T. and Ingelsson, P. (2017), "Lean from the first-line managers' perspective – assuredness about the effects of lean as a driving force for sustainable change", *Management and Production Engineering Review*, Vol. 8 No. 2, pp. 49-56, available at: https://doi.org/10.1515/mper-2017-0017

Kanamori, S., Sow, S., Castro, M.C., Matsuno, R., Tsuru, A. and Jimba, M. (2015), "Implementation of 5S management method for lean healthcare at a health center in Senegal: a qualitative study of staff perception", *Global Health Action*, Vol. 8 No. 1, available at: https://doi.org/10.3402/gha.v8.27256

Kasivisvanathan, R. and Chekairi, A. (2014), "The productive operating theatre and lean thinking systems", *Journal of Perioperative Practice*, Vol. 24 No. 11, pp. 245-248.

Kim, C.S., Spahlinger, D.A., Kin, J.M. and Billi, J.E. (2006), "Lean health care: what can hospitals learn from a world-class automaker?", *Journal of Hospital Medicine*, Vol. 1 No. 3, pp. 191-199.

Knapp, S. (2015), "Lean six sigma implementation and organizational culture", *International Journal of Health Care Quality Assurance*, Vol. 28 No. 8, pp. 855-863, available at: https://doi.org/10.1108/IJHCQA-06-2015-0079

Kovacevic, M., Jovicic, M., Djapan, M. and Zivanovic-Macuzic, I. (2016), "Lean thinking in healthcare: review of implementation results", *International Journal for Quality Research*, Vol. 10 No. 1, pp. 219-230, available at: https://doi.org/10.18421/IJQR10.01-12

Krijnen, A. (2007), "The toyota way: 14 management principles from the world's greatest manufacturer", *Action Learning: Research and Practice*, Vol. 4 No. 1, available at: https://doi.org/10.1080/14767330701234002

Li, L.M. and Johnson, S. (2015), "Lean thinking to mind the gap in healthcare management | pensamento enxuto na gestão da saúde", *Arquivos de Neuro-Psiquiatria*, Vol. 73 No. 11, p. 979, available at: https://doi.org/10.1590/0004-282X20150147

Linde, K. and Willich, S.N. (2003), "How objective are systematic reviews? Differences between reviews on complementary medicine", *JRSM*, Vol. 96 No. 1, pp. 17-22.

Lot, L.T., Sarantopoulos, A., Min, L.L., Perales, S.R., Boin, I.F.S.F. and Ataide, E.C. (2018), "Using lean tools to reduce patient waiting time", *Leadership in Health Services*, Vol. 31 No. 3, pp. 343-351, available at: https://doi.org/10.1108/LHS-03-2018-0016

McCann, L., Hassard, J.S., Granter, E. and Hyde, P.J. (2015), "Casting the lean spell: the promotion, dilution and erosion of lean management in the NHS", *Human Relations*, Vol. 68 No. 10, pp. 1557-1577, available at: https://doi.org/10.1177/0018726714561697

Maijala, R., Eloranta, S., Reunanen, T. and Ikonen, T.S. (2018), "Successful implementation of lean as a managerial principle in health care: a conceptual analysis from systematic literature review", *International Journal of Technology Assessment in Health Care*, Vol. 34 No. 2, pp. 134-146, available at: https://doi.org/10.1017/S0266462318000193

Mannon, M. (2014), "Lean healthcare and quality management: the experience of ThedaCare", *Quality Management Journal*, Vol. 21 No. 1, pp. 7-10, available at: https://doi.org/10.1080/10686967.2014.11918371

Matos, A.J.D. (2002), *Gestão de Custos Hospitalares: Técnicas, Análise e Tomada de Decisão*, In Gestão de custos hospitalares: técnicas, análise e tomada de decisão.

Matt, D.T., Rauch, E. and Franzellin, V.M. (2015), "An axiomatic design-based approach for the patient-value-oriented design of a sustainable lean healthcare system", *International Journal of Procurement Management*, Vol. 8 Nos 1/2, pp. 66-81, available at: https://doi.org/10.1504/IJPM.2015.066288

Matthias, O. and Brown, S. (2016), "Implementing operations strategy through lean processes within health care: the example of NHS in the UK", *International Journal of Operations and Production Management*, Vol. 36 No. 11, pp. 1435-1457.

Mazzocato, P., Savage, C., Brommels, M., Aronsson, H. and Thor, J. (2010), "Lean thinking in healthcare: a realist review of the literature", *BMJ Quality and Safety-*, Vol. 19 No. 5, pp. 2009.

Mehdi, I. and Al Bahrani, B.J. (2017), "Are we prepared to implement a lean philosophy within cancer-care service in Oman?", *Saudi Medical Journal*, Vol. 38 No. 7, pp. 691-698, available at: https://doi.org/10.15537/smj.2017.7.17712

Miller, R.D. (2018), *Hearing the Voice of the Shingo Principles: Creating Sustainable Cultures of Enterprise Excellence*, Routledge New York, NY.

Miller, R. and Chalapati, N. (2015), "Utilizing lean tools to improve value and reduce outpatient wait times in an indian hospital", *Leadership in Health Services*, Vol. 28 No. 1, pp. 57-69, available at: https://doi.org/10.1108/LHS-01-2014-0001

Moraros, J., Lemstra, M. and Nwankwo, C. (2016), "Lean interventions in healthcare: do they actually work? A systematic literature review", *International Journal for Quality in Health Care*, Vol. 28 No. 2, pp. 150-165, available at: https://doi.org/10.1093/intqhc/mzv123

Mousavi Isfahani, H., Tourani, S. and Seyedin, H. (2019), "Lean management approach in hospitals: a systematic review", *International Journal of Lean Six Sigma*, Vol. 10 No. 1, pp. 161-188, doi: 10.1108/IJLSS-05-2017-0051.

Nanda, U., Rybkowski, Z.K., Pati, S. and Nejati, A. (2017), "A value analysis of lean processes in target value design and integrated project delivery: stakeholder perception", *Herd: Health Environments Research and Design Journal*, Vol. 10 No. 3, pp. 99-115, available at: https://doi.org/10.1177/1937586716670148

Narayanamurthy, G. and Gurumurthy, A. (2018), "Is the hospital lean? A mathematical model for assessing the implementation of lean thinking in healthcare institutions", *Operations Research for Health Care*, Vol. 18, pp. 84-98, available at: https://doi.org/10.1016/j.orhc.2017.05.002

Narayanamurthy, G., Gurumurthy, A. and Lankayil, A.A. (2018), "Experience of implementing lean thinking in an Indian healthcare institution", *International Journal of Lean Six Sigma*, available at: https://doi.org/10.1108/IJLSS-10-2016-0062

Nayar, P., Ojha, D., Fetrick, A. and Nguyen, A.T. (2016), "Applying lean six sigma to improve medication management", *International Journal of Health Care Quality Assurance*, Vol. 29 No. 1, pp. 16-23, available at: https://doi.org/10.1108/IJHCQA-02-2015-0020

NHS Modernisation Agency (2001), "Ideal design of emergency access (IDEA) programme", available at: http://wales.nhs.uk/sites3/w-docopen.cfm?orgid¼530&id¼58478&1936FC9F-1143-E756-5CD3645843009ACA (accessed 11 December 2018).

Ohno, T. (1988), *Toyota Production System: Beyond Large-Scale Production*, Productivity Press.

Organização Mundial da Saúde (OMS) (2010), "Financiamento dos sistemas de saúde", O caminho para a cobertura universal.

Papadopoulos, T., Radnor, Z. and Merali, Y. (2011), "The role of actor associations in understanding the implementation of lean thinking in healthcare", *International Journal of Operations and Production Management*, Vol. 31 No. 2, pp. 167-191, doi: 10.1108/01443571111104755.

Patri, R. and Suresh, M. (2018), "Factors influencing lean implementation in healthcare organizations: an ISM approach", *International Journal of Healthcare Management*, Vol. 11 No. 1, pp. 25-37, available at: https://doi.org/10.1080/20479700.2017.1300380

Pfaff, H. (1994), "Lean production – a model for the hospital? Risks, chances and visions", *Journal of Public Health*, Vol. 2 No. 1, pp. 61-80, doi: 10.1007/BF02959716.

Pineda Dávila, S. and Tinoco González, J. (2015), "Improvement in the efficiency of a rehabilitation service using lean healthcare methodology | mejora de la eficiencia de un servicio de rehabilitación mediante metodología lean healthcare", *Revista de Calidad Asistencial*, Vol. 30 No. 4, pp. 162-165, available at: https://doi.org/10.1016/j.cali.2015.03.002

Poksinska, B.B., Fialkowska-Filipek, M. and Engström, J. (2017), "Does lean healthcare improve patient satisfaction? A mixed-method investigation into primary care", *BMJ Quality and Safety*, Vol. 26 No. 2, pp. 95-103, available at: https://doi.org/10.1136/bmjqs-2015-004290

Ponanake, P., Limnararat, S., Pithuncharurnlap, M. and Sangmanee, W. (2014), "Path analysis of the core competency of thai private hospitals in the ASEAN economic community", *Research Journal of Business Management*, Vol. 8 No. 3, pp. 157-172, available at: https://doi.org/10.3923/rjbm.2014.157.172

Radnor, Z.J., Holweg, M. and Waring, J. (2012), "Lean in healthcare: the unfilled promise?", *Social Science and Medicine*, Vol. 74 No. 3, pp. 364-371.

Ramori, K.A., Cudney, E.A., Elrod, C.C. and Antony, J. (2019), "Lean business models in healthcare: a systematic review", *Total Quality Management and Business Excellence*, Vol. 1, pp. 1-16, doi: 10.1080/14783363.2019.1601995.

Ravindran, V. and Shankar, S. (2015), "Systematic reviews and meta-analysis demystified", *Indian Journal of Rheumatology*, Vol. 10 No. 2, pp. 89-94.

Rees, G.H. (2014), "Organisational readiness and lean thinking implementation: findings from three emergency department case studies in New Zealand", *Health Services Management Research*, Vol. 27 Nos 1/2, pp. 1-9, available at: https://doi.org/10.1177/0951484814532624

Rees, G.H. and Gauld, R. (2017), "Can lean contribute to work intensification in healthcare?", *Journal of Health Organization and Management*, Vol. 31 No. 3, pp. 369-384, available at: https://doi.org/10.1108/JHOM-11-2016-0219

Regattieri, A., Bartolini, A., Cima, M., Fanti, M.G. and Lauritano, D. (2018), "An innovative procedure for introducing the lean concept into the internal drug supply chain of a hospital", *The Tqm Journal*, Vol. 30 No. 6, pp. 717-731, available at: https://doi.org/10.1108/TQM-03-2018-0039

Régis, T.K.O., Gohr, C.F. and Santos, L.C. (2018), "Lean healthcare implementation: experiences and lessons learned from brazilian hospitals", *Revista de Administração de Empresas*, Vol. 58 No. 1, pp. 30-43, available at: https://doi.org/10.1590/S0034-759020180103

Reijula, J., Reijula, E. and Reijula, K. (2016), "Insight into healthcare design: lessons learned in two university hospitals", *Journal of Facilities Management*, Vol. 14 No. 3, pp. 266-282, available at: https://doi.org/10.1108/JFM-01-2016-0001

Reijula, J., Karvonen, S., Petäjä, H., Reijula, K. and Lehtonen, L. (2016), "Participative facility planning for obstetrical and neonatal care processes: beginning of life process", *Journal of Healthcare Engineering*, Vol. 2016, available at: https://doi.org/10.1155/2016/7836493

Rewa, O., Mottes, T. and Bagshaw, S.M. (2015), "Quality measures for acute kidney injury and continuous renal replacement therapy", *Current Opinion in Critical Care*, Vol. 21 No. 6, pp. 490-499, available at: https://doi.org/10.1097/MCC.0000000000000262

Richards, K. and Mellott, J. (2014), "Great expectations: linking vision to everyday work", *Nurse Leader* , Vol. 12 No. 3, pp. 67-70, available at: https://doi.org/10.1016/j.mnl.2013.09.015

Roberts, J.P., Fisher, T.R., Trowbridge, M.J. and Bent, C. (2016), "A design thinking framework for healthcare management and innovation", *Healthcare*, Elsevier, Vol. 4 No. 1, pp. 11-14.

Romano, E., Guizzi, G. and Chiocca, D. (2015), "A decision support tool, implemented in a system dynamics model, to improve the effectiveness in the hospital emergency department", *International Journal of Procurement Management*, Vol. 8 No. 1/2, pp. 141-168, available at: https://doi.org/10.1504/IJPM.2015.066291

Rother, M. (2010), "Toyota KATA", McGraw-Hill, available at: https://doi.org/10.1017/CBO9781107415324.004

Ruohoaho, U.-M., Kokki, M., Hirvonen, J., Joukainen, S., Aaltomaa, S., Fraunberg, M., ... Reijula, J. (2018), "Value stream map assessment of the extended day: 23h surgery model", *Intelligent Buildings International*, Vol. 12 No. 1, pp. 1-15, available at: https://doi.org/10.1080/17508975.2018.1448253

Salam, M.A. and Khan, S.A. (2016), "Value creation through lean management: a case study of healthcare service operations", *International Journal of Services and Operations Management*, Vol. 25 No. 3, pp. 275-293, available at: https://doi.org/10.1504/IJSOM.2016.079513

Sánchez, M., Suárez, M., Asenjo, M. and Bragulat, E. (2018), "Improvement of emergency department patient flow using lean thinking", *International Journal for Quality in Health Care*, Vol. 30 No. 4, pp. 250-256, available at: https://doi.org/10.1093/intqhc/mzy017

Santos, B.D.S. (2008), "A queda do angelus novus: o fim da equação moderna entre raízes e opções", En: Santos, B. de S. Gramática do tempo: para uma nova cultura política, 2.

Sarantopoulos, A., Spagnol, G.S., Newbold, D. and Li, L.M. (2017), "Establishing face validity of the EPLIT questionnaire", *British Journal of Healthcare Management*, Vol. 23 No. 5, pp. 221-227, available at: https://doi.org/10.12968/bjhc.2017.23.5.221

Schonberger, R.J. (2018), "Reconstituting lean in healthcare: from waste elimination toward 'queue-less' patient-focused care", *Business Horizons*, Vol. 61 No. 1, pp. 13-22, available at: https://doi.org/10.1016/j.bushor.2017.09.001

Shakoor, M., Abu Jadayil, W., Jabera, N. and Jaber, S. (2017), "Efficiency assessment in emergency department using lean thinking approach", *Jordan Journal of Mechanical and Industrial Engineering*, Vol. 11 No. 2, pp. 97-103.

Shingo Institute (2019), "Shingo institute – home of the shingo prize", available at: https://shingo.org/ (accessed 20 January 2020)

Simons, P.A., Benders, J., Marneffe, W., Pijls-Johannesma, M. and Vandijck, D. (2015), *International Journal of Health Care Quality Assurance*, Vol. 28 No. 1, pp. 64-74, available at: https://doi.org/10.1108/IJHCQA-01-2014-0007

Simons, P., Backes, H., Bergs, J., Emans, D., Johannesma, M., Jacobs, M., ... Vandijck, D. (2017), "The effects of a lean transition on process times, patients and employees", *International Journal of Health Care Quality Assurance*, Vol. 30 No. 2, pp. 103-118, available at: https://doi.org/10.1108/IJHCQA-08-2015-0106

Souza, L.B. (2009), "Trends and approaches in lean healthcare", *Leadership in Health Services*, Vol. 22 No. 2, pp. 121-139.

Steere, L., Rousseau, M. and Durland, L. (2018), "Lean six sigma for intravenous therapy optimization: a hospital use of lean thinking to improve occlusion management", *Journal of the Association for Vascular Access*, Vol. 23 No. 1, pp. 42-50, available at: https://doi.org/10.1016/j.java.2018.01.002

Stelson, P., Hille, J., Eseonu, C. and Doolen, T. (2017), "What drives continuous improvement project success in healthcare?", *International Journal of Health Care Quality Assurance*, Vol. 30 No. 1, pp. 43-57, available at: https://doi.org/10.1108/IJHCQA-03-2016-0035

Sugimori, Y., Kusunoki, K., Cho, F. and Uchikawa, S. (1977), "Toyota production system and kanban system materialization of just-in-time and respect-for-human system", *International Journal of Production Research*, Vol. 15 No. 6, pp. 553-564.

Swartz, J., Davis, D. and Graban, M. (2015), "Lean hospital(ist)s", *Hospital Medicine Clinics*, Vol. 4 No. 4, pp. 581-593, available at: https://doi.org/10.1016/j.ehmc.2015.06.008

Tay, H.L., Singh, P.J., Bhakoo, V. and Al-Balushi, S. (2017), "Contextual factors: assessing their influence on flow or resource efficiency orientations in healthcare lean projects", *Operations Management Research*, Vol. 10 Nos 3/4, pp. 118-136, available at: https://doi.org/10.1007/s12063-017-0126-3

Tejedor-Panchón, F., Montero-Pérez, F.J., Tejedor-Fernández, M., Jiménez-Murillo, L., C., De La Barca-Gázquez, J.M. and Quero-Espinosa, F.B. (2014), "Improvement in hospital emergency department processes with application of lean methods | mejora del proceso de un servicio de urgencias de hospital mediante la metodología lean", *Emergencias*, Vol. 26 No. 2, pp. 84-93.

Terra, J.D.R. and Berssaneti, F.T. (2018), "Application of lean healthcare in hospital services: a review of the literature (2007 to 2017)", *Producao*, Vol. 28, available at: https://doi.org/10.1590/0103-6513.20180009

Tortorella, G.L., Fogliatto, F.S., Anzanello, M., Marodin, G.A., Garcia, M. and Reis Esteves, R. (2017), "Making the value flow: application of value stream mapping in a Brazilian public healthcare organisation", *Total Quality Management and Business Excellence*, Vol. 28 No. 13-14, pp. 1544-1558, available at: https://doi.org/10.1080/14783363.2016.1150778

Tranfield, D., Denyer, D. and Smart, P. (2003), "Towards a methodology for developing evidence-informed management knowledge by means of systematic review", *British Journal of Management*, Vol. 14 No. 3, pp. 207-222.

Trzeciak, S., Mercincavage, M., Angelini, C., Cogliano, W., Damuth, E., Roberts, B.W., ... Mazzarelli, A.J. (2018), "Lean six sigma to reduce intensive care unit length of stay and costs in prolonged mechanical ventilation", *Journal for Healthcare Quality*, Vol. 40 No. 1, pp. 36-43, available at: https://doi.org/10.1097/JHQ.0000000000000075

Ulhassan, W., Von Thiele Schwarz, U., Westerlund, H., Sandahl, C. and Thor, J. (2015), "How visual management for continuous improvement might guide and affect hospital staff: a case study", *Quality Management in Health Care*, Vol. 24 No. 4, pp. 222-228, available at: https://doi.org/10.1097/QMH.0000000000000073

Van Leijen-Zeelenberg, J.E., Brunings, J.W., Houkes, I., Van Raak, A.J.A., Ruwaard, D., Vrijhoef, H.J.M. and Kremer, B. (2016), "Using lean thinking at an otorhinolaryngology outpatient clinic to improve quality of care", *The Laryngoscope*, Vol. 126 No. 4, pp. 839-846, available at: https://doi.org/10.1002/lary.25741

van Rossum, L., Aij, K.H., Simons, F.E., van der Eng, N. and ten Have, W.D. (2016), "Lean healthcare from a change management perspective: the role of leadership and workforce flexibility in an operating theatre", *Journal of Health Organization and Management*, Vol. 30 No. 3, pp. 475-493, available at: https://doi.org/10.1108/JHOM-06-2014-0090

Vavrušová, V. (2015), "LEAN: 4W & 1H of lean in medical facilities", *Scientific Papers of the University of Pardubice, Series D: Faculty of Economics and Administration*, Vol. 22 No. 34, pp. 125-136.

Vendemiatti, M., Siqueira, E.S., Filardi, F., Binotto, E. and Simioni, F.J. (2010), "Conflito na gestão hospitalar: o papel da liderança", *Ciência and Saúde Coletiva*, Vol. 15 No. suppl 1, pp. 1301-1314.

Vitásková, E. (2015), "Is czech health care going to be lean? Scientific papers of the university of pardubice", *Series D: Faculty of Economics and Administration*, Vol. 22 No. 34, pp. 137-148.

Waring, J.J. and Bishop, S. (2010), "Lean healthcare: rhetoric, ritual and resistance", *Social Science and Medicine (1982)*, Vol. 71 No. 7, pp. 1332-1340.

Weber, L. and Grisci, C.L.I. (2010), "Trabalho, gestão e subjetividade: dilemas de chefias intermediárias em contexto hospitalar", *Cadernos Ebape.Br*, Vol. 8 No. 1, pp. 53-70.

Weinstock, D. (2008), "Lean healthcare", *The Journal of Medical Practice Management : Mpm*, Vol. 23 No. 6, pp. 339.

White, M. and Waldron, M. (2014), "Effects and impacts of productive ward from a nursing perspective", *British Journal of Nursing*, Vol. 23 No. 8, pp. 419-426, available at: https://doi.org/10.12968/bjon.2014.23.8.419

White, M., Butterworth, T. and Wells, J.S. (2017), "Healthcare quality improvement and 'work engagement'; concluding results from a national, longitudinal, cross-sectional study of the 'productive ward-releasing time to care' programme", *BMC Health Services Research*, Vol. 17 No. 1, available at: https://doi.org/10.1186/s12913-017-2446-2

White, M., Wells, J.S. and Butterworth, T. (2014a), "The transition of a large-scale quality improvement initiative: a bibliometric analysis of the productive ward: releasing time to care programme", *Journal of Clinical Nursing*, Vol. 23 No. 17-18, pp. 2414-2423, available at: https://doi.org/10.1111/jocn.12585

White, M., Wells, J.S.G. and Butterworth, T. (2014b), "The impact of a large-scale quality improvement programme on work engagement: preliminary results from a national cross-sectional-survey of the 'productive ward'", *International Journal of Nursing Studies*, Vol. 51 No. 12, pp. 1634-1643, available at: https://doi.org/10.1016/J.IJNURSTU.2014.05.002

Whitson, D. (1997), "Applying just-in-time systems in health care", *IIE Solutions*, Vol. 29 No. 8, pp. 32-38.

Williams, S. and Radnor, Z. (2018), "An integrative approach to improving patient care pathways", *International Journal of Health Care Quality Assurance*, Vol. 31 No. 7, pp. 810-821, available at: https://doi.org/10.1108/IJHCQA-07-2017-0132

Womack, J.P. and Jones, D.T. (1997), "Lean thinking – banish waste and create wealth in your corporation", *Journal of the Operational Research Society*, Vol. 48 No. 11, pp. 1148-1148.

Womack, J. and Jones, D. (2003), *Lean Thinking*, Simon and Schuster. London.

Yaduvanshi, D. and Sharma, A. (2017), "Lean six sigma in health operations: challenges and opportunities – 'Nirvana for operational efficiency in hospitals in a resource limited settings", *Journal of Health Management*, Vol. 19 No. 2, pp. 203-213, available at: https://doi.org/10.1177/0972063417699665

Appendix 1

Article	Methodology	Areas	Tools	Improvements	Difficulties
Aleem *et al.* (2015)	AR	A15	T33; T12; T44; T36	I4	D1; D3
Andersen and Røvik (2015)	CS	A19; A3	N/A	N/A	D1
Bal *et al.* (2017)	AR	A1	T41; T29; T9	I3; I4	D6
Barnabè and Giorgino (2017)	AR	A2	T17; T14	N/A	N/A
Barnabè *et al.* (2017)	CS	A3	T41; T30	I3	N/A
Barnabè *et al.* (2018)	CS	A2; A6	T41; T30; T29; T33; T15; T31; T24; T39; T8	I4; I5	N/A
Bittencourt *et al.* (2017)	AR	A3; A6	T17	N/A	N/A
Blouin-Delisle *et al.* (2018)	AR	A12	T41; T15; T4; T12; T44; T6	I1	D2; D4
Boronat *et al.* (2018)	AR	A17	T18; T17; T45; T11	I3; I5	N/A
Chaurasia *et al.* (2017)	AR	A11	T41; T33; T19; T18; T36; T38	I1; I2	N/A
Cheng *et al.* (2015)	AR	A6	T41; T38	I1; I3	D4
Clark *et al.* (2014)	CS	A10	N/A	I3; I4	N/A
Colldén *et al.* (2017)	CS	A17	N/A	N/A	N/A
Costa *et al.* (2017)	CS	A11; A12; A14; A18	T41; T15; T31; T12; T39	I1; I2; I4	D1; D3
Dannapfel *et al.* (2014)	CS	A2; A11	T29; T27; T42; T17; T10	N/A	N/A
Delisle and Freiberg (2014)	AR	A19	T30; T29 T27; T19; T36; T38; T17	I1; I4	N/A
Drotz and Poksinska (2014)	CS	A3; A15; A17	T30; T29; T27; T1; T22	I3	N/A
Efe and Efe (2016)	AR	A1		N/A	N/A
Eiro and Torres-Junior (2015)	CS	A3; A11	T30; T15; T31; T18; T32	N/A	N/A
Fisher *et al.* (2016)	AR	A14;	T41	I2; I3	N/A
Godinho Filho *et al.* (2015)	AR	A12	T41; T30; T29; T27; T15; T4; T1; T2; T6; T10	N/A	N/A
Gupta *et al.* (2018)	AR	A8	T41; T13	I1; I2; I4	D2
Haddad *et al.* (2016)	CS	A6	T41; T30; T27; T24; T39	I1	N/A
Halm *et al.* (2018)	AR	A2	T13	I1; I4	D2
Henrique *et al.* (2016)	AR	A6; A8; A12; A15; A19	T41	N/A	N/A
Hutton *et al.* (2018)	AR	A3	T27; T19; T36; T11	I1; I2; I4;	N/A
Hwang *et al.* (2014)	CS	A2; A6; A17	T42; T29; T28; T20	N/A	N/A
Improta *et al.* (2018)	AR	A1		I1; I3	N/A

(*continued*)

Table A1.
List of 114 articles

Article	Methodology	Areas	Tools	Improvements	Difficulties
			T41; T30; T27; T1; T8		
			T41; T29; T13;		
Lot *et al.* (2018)	AR	A4	T4; T31; T30	I2; I3; I5	N/A
Mannon (2014)	CS	A2; A3;	T29; T27; T13	I1	N/A
Matt *et al.* (2015)	AR	A2	N/A	I2; I3; I5	D3
Mehdi and Al Bahrani (2017)	CS	A11	T39; T8; T17	I1; I2; I3; I4	N/A
Miller and Chalapati (2015)	CS	A4	T41; T30	I3	D1; D3
Nanda *et al.* (2017)	CS	A3	T31; T22	N/A	N/A
Narayanamurthy *et al.* (2018)	CS	A4; A14	T33; T2; T32; T49; T10	N/A	N/A
Nayar *et al.* (2016)	AR	A2	T12; T44; T36	I3; I4	D5
Simons *et al.* (2017)	CS	A11	T41; T30; T22; T17	N/A	N/A
Pineda Dávila and Tinoco González (2015)	AR	A7	T30; T4; T42	I1; I2; I4; I5	N/A
Poksinska *et al.* (2017)	CS	A15	T41; T30; T27	I2	D2
Rees (2014)	CS	A1	T41; T30; T18	I1; I3	N/A
Regattieri *et al.* (2018)	AR	A14	T29; T32	I2; I4	D5
Régis *et al.* (2018)	CS	A11; A6; A14; A16	T41; T30; T29; T27; T15; T10	I2; I4	N/A
Reijula *et al.* (2016)	AR	A17; A19	T19; T42	I1	D3
Ruohoaho *et al.* (2018)	AR	A12; A17	T41	I2	N/A
Salam and Khan (2016)	CS	A15	T41; T33; T24; T42; T36	I1; I2; I3; I4; I5	N/A
Sánchez *et al.* (2018)	AR	A1	T41; T30; T27; T42	N/A	N/A
Shakoor *et al.* (2017)	CS	A1	T8	N/A	N/A
Steere *et al.* (2018)	AR	A14	T12; T44; T42	N/A	N/A
Tay *et al.* (2017)	CS	A6; A11; A12; A14	T41; T42; T36	I1; I2; I4; I5	D1; D2
Tejedor-Panchón *et al.* (2014)	AR	A1	T41	I1	N/A
Tortorella *et al.* (2017)	AR	A18	T41; T13; T1	N/A	N/A
Trzeciak *et al.* (2018)	AR	A7	T12; T42	I2	N/A
Ulhassan *et al.* (2015)	CS	A1; A17	T29	N/A	N/A
Kanamori *et al.* (2015)	CS	A2	T20	I1	N/A
Holden *et al.* (2015)	CS	A1; A7; A12	T44	I1; I2; I3; I4	D2
Reijula *et al.* (2016)	CS	A3	T20	I1; I2	N/A
Van Leijen-Zeelenberg *et al.* (2016)	CS	A4	T42	I3	D1; D3
Fournier and Jobin (2018)	CS	A2	N/A	I1; I2; I3	N/A
Aij and Teunissen (2017)	TC	–	–	–	–
Aij *et al.* (2015)	TC	–	–	–	–
Al Farsi *et al.* (2014)	TC	–	–	–	–
	TC	–	–	–	–

(*continued*)

Table A1.

Article	Methodology	Areas	Tools	Improvements	Difficulties
Al-Balushi *et al.* (2014)					
Alshahrani *et al.* (2018)	S	–	–	–	–
Andersen *et al.* (2014)	TC	–	–	–	–
Anuar and Sadek (2018)	TC	–	–	–	–
Anuar *et al.* (2018)	TC	–	–	–	–
Booker *et al.* (2016)	TC	–	–	–	–
Bruno (2017)	TC	–	–	–	–
Chakraborty and Gonzalez (2018)	TC	–	–	–	–
Costa and Godinho Filho (2016)	TC	–	–	–	–
Crema and Verbano (2015)	TC	–	–	–	–
Crema and Verbano (2017)	TC	–	–	–	–
D'Andreamatteo *et al.* (2015)	TC	–	–	–	–
Daultani *et al.* (2015)	TC	–	–	–	–
DiGioia *et al.* (2015)	TC	–	–	–	–
Ferreira *et al.* (2018)	TC	–	–	–	–
Filser *et al.* (2017)	TC	–	–	–	–
Gershengorn *et al.* (2014)	TC	–	–	–	–
Habidin *et al.* (2015)	TC	–	–	–	–
Habidin (2017)	S	–	–	–	–
Habidin *et al.* (2014)	S	–	–	–	–
Hallam and Contreras (2018)	TC	–	–	–	–
Jiang and Malkin (2016)	S	–	–	–	–
Jorma *et al.* (2016)	TC	–	–	–	–
Kahm and Ingelsson (2017)	S	–	–	–	–
Kasivisvanathan and Chekairi (2014)	TC	–	–	–	–
Knapp (2015)	S	–	–	–	–
Kovacevic *et al.* (2016)	TC	–	–	–	–
Li and Johnson (2015)	TC	–	–	–	–
White and Waldron (2014)	TC	–	–	–	–
White *et al.* (2017)	S	–	–	–	–
White *et al.* (2014a, 2014b)	TC	–	–	–	–
Maijala *et al.* (2018)	TC	–	–	–	–
White *et al.* (2014a, 2014b)	S	–	–	–	–
McCann *et al.* (2015)	TC	–	–	–	–
Moraros *et al.* (2016)	TC	–	–	–	–
	TC	–	–	–	–

Table A1. (*continued*)

Article	Methodology	Areas	Tools	Improvements	Difficulties
Narayanamurthy and Gurumurthy (2018)					
Simons *et al.* (2015)	TC	–	–	–	–
Patri and Suresh (2018)	TC	–	–	–	–
Ponanake *et al.* (2014)	TC	–	–	–	–
Rees and Gauld (2017)	TC	–	–	–	–
Rewa *et al.* (2015)	TC	–	–	–	–
Richards and Mellott (2014)	TC	–	–	–	–
Romano *et al.* (2015)	TC	–	–	–	–
Sarantopoulos *et al.* (2017)	TC	–	–	–	–
Schonberger (2018)	TC	–	–	–	–
Stelson *et al.* (2017)	S	–	–	–	–
Swartz *et al.* (2015)	TC	–	–	–	–
Terra and Berssaneti (2018)	TC	–	–	–	–
van Rossum *et al.* (2016)	S	–	–	–	–
Vavrušová (2015)	S	–	–	–	–
Vitásková (2015)	S	–	–	–	–
Williams and Radnor (2018)	TC	–	–	–	–
Yaduvanshi and Sharma (2017)	TC	–	–	–	–

Table A1.

Corresponding author
Rui M. Lima can be contacted at: rml@dps.uminho.pt