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Systematic Literature Review

Effects of Lean Healthcare on Patient Flow: A Systematic Review

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ABSTRACT

Objectives: To assess the effects of lean healthcare (LH) on patient flow in ambulatory care and determine whether waiting time and length of stay (LOS) decrease after LH interventions.

Methods: A systematic review was performed with close adherence to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). We searched for studies of healthcare organizations applying LH interventions within ambulatory care published between 2002 and 2018. Six databases and grey literature sources were used. Two reviewers independently screened and assessed each study. When consensus was difficult to reach, a third reviewer intervened. Finally, a summary of findings was generated.

Results: Out of 5627 studies, 40 were included. Regarding LOS for all patients, 19 out of 22 studies reported a decrease. LOS for discharged patients decreased in 11 out of 13 studies, whereas LOS for admitted patients was reduced in 6 out of 7 studies. Waiting time for patients before seeing a healthcare professional decreased in 24 out of 26 studies. Waiting time to treatment and waiting time for appointments were minimized in 4 and 2 studies, respectively. Patients who left without being seen by a doctor decreased in 9 out of 12 studies. Finally, patient and staff satisfaction were measured in 8 and 2 studies, respectively, with each reporting improvements.

Conclusions: According to our findings, LH helped to reduce waiting time and LOS in ambulatory care, mainly owing to its focus on identifying and minimizing non-value added (NVA) activities. Nevertheless, evidence of the impact of LH on patient/staff satisfaction and the translation of the obtained benefits into savings is scarce among studies.

Keywords: ambulatory care, lean healthcare, length of stay, patient flow, systematic review, waiting time.

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Introduction

Healthcare services face a constant challenge to improve the quality of care, increase efficiency, and ultimately provide more value to patients. In this regard, there is a tacit recognition that internal inefficiencies, such as poor patient flow and inadequate resource utilization, may contribute to delays in care and overcrowding, thereby affecting patient safety, patient/staff satisfaction, and the overall quality of care.[1,2] Patient flow refers to the movement of patients through care settings.[3] It involves the medical care, physical resources, and internal systems needed to get patients from the point of admission to the point of discharge while maintaining quality and patient/provider satisfaction.[4]

Medical services can involve either inpatient or outpatient care. Inpatient care generally refers to any medical service administered to a patient whose condition requires admission into a healthcare facility and the supervision of a nurse or doctor.[5,6] Depending on the region or health system, inpatient care might be considered at least one night of stay.[5]

Conversely, ambulatory care—also known as outpatient care or ambulatory services[7]—refers to those medical services performed on an outpatient basis, without admission to a hospital or any other healthcare facility.[8] Hospitals provide many types of services in their outpatient departments, including emergency and clinic visits, imaging and other diagnostic services, laboratory tests, and ambulatory surgery.[9] Common indicators of patient flow in ambulatory care include patient waiting time[10,11] and length of stay (LOS)[12,13]; however, time frames for patient throughput, and metrics used to monitor throughput, vary widely in both literature and practice.[14]

Conflict of interest: None reported.

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Since the 1990s, in an effort to deal with both quality and cost issues, healthcare providers have looked outside the healthcare sector for inspiration and guidance.[15] In this regard, lean healthcare (LH) emerged as a service strategy for reducing or eliminating waste and activities that did not add value to healthcare processes. The history of the term "lean" is relatively recent. It originates from the Toyota Production System (TPS), a popular system because of the efficiency shown in Japanese manufacturing companies.[16] In turn, the term "lean manufacturing" (LM) was coined by James Womack et al[17]; the concept of lean reached the medical domain in the early 2000s, resulting in the idea of LH.[18,19]

Increasing the efficiency of hospital-based clinical care by applying LH was identified as a potent strategy for lowering costs and improving outcomes.[20] Some areas where LH has been implemented include: intensive care units (ICUs),[21] cardiology,[22] surgery,[23] gynecologic oncology,[24] colonoscopy,[25] pathology,[26] radiology,[27] mental health units,[28] eye hospitals,[29] otolaryngology,[30] ultrasound-otolaryngology,[31] organ transplant centers,[32] and clinical laboratories,[33] to name but a few. In the United States, a national survey found that around 70% of hospitals use LH or related approaches.[34]

LH begins by studying a healthcare process and determining what is of value to the patient; nevertheless, there are many windows into the concept of healthcare value.[35] Value itself is commonly defined as quality divided by costs,[36] yet might include many components (eg, positive patient-provider communication[37] or patient engagement[38]). In a complementary way, values in healthcare are "activities that enhance the quality of healthcare and promote patient well-being so as to achieve better outcome."[11] We used this definition for our research. Conversely, waste is anything other than the minimum amount of equipment, space, or staff time that is essential to add value to a product or service.[39] From this perspective, lean principles categorize activities as either value added (VA) or non-value added (NVA).[40] The former contribute directly to satisfying patient/customer needs, whereas the latter take up unnecessary time, space, or resources and do not meet patient/customer needs.[40,41] Because lean involves improving the way value is delivered to the patient/customer, it is necessary to expose NVA activities and take immediate action to eliminate them.[42]

In an effort to trace the evolution of LH, there have emerged some literature reviews, all of which have taken different approaches. For instance, some reviews focus on care efficiency measures,[43] contextual aspects and change mechanisms,[44] or Lean Six Sigma,[45] whereas others pay attention to lean within emergency departments,[46] quality improvement in surgery,[47] Lean Six Sigma in surgery,[48] lean facilitators,[49] or the positive impacts of LH.[50] Additionally, reviews on LH may present thematic analyses,[51] updates,[19] and operational definitions,[52] or they can focus on Lean Six Sigma in radiology,[53] hospital waste management,[54] a choosing wisely approach,[55] sustainability,[56] leadership and management,[57] safety and patient care,[58] and Lean Six Sigma in Brazil.[59]

From the beginning of LH, there have been difficulties including the need for adjustments in transferring the tools and principles to the new environment[60] in addition to methodological limitations at the implementation stage.[61,62] From a systematic review of 22 articles, Moraros et al found no statistically significant association of LH with patient satisfaction and health outcomes and a negative association with financial costs and worker satisfaction, but potential benefits in process outcomes (eg, patient flow and safety).[63] Despite these efforts, research on the impact of LH on patient flow still remains in the early stages, especially because clarity and structure in the research process is lacking. To address this gap, our study aims to organize, classify, and summarize relevant information regarding the effect of LH on patient flow within ambulatory care.

Methods

The protocol for our systematic review was prepared and registered on the International Prospective Register of Systematic Reviews (PROSPERO; Ref CRD42019128837).[64] The systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[65,66] and with close adherence to the Cochrane Handbook for Systematic Reviews of Interventions.[67] The resulting PRISMA checklist (Appendix 1 in Supplemental Materials found at https://doi.org/10.1016/j.jval.2019.11.002) and the flowchart (Fig. 1) depict the stages involved in the selection process. The following subsections briefly discuss the methodology.

Data Sources and Search Strategy

The search was conducted from July 2018 to February 2019 on the following databases: PubMed-Medline, the Cochrane Library, CINAHL, Web of Science, Scopus, and EBSCO. Moreover, grey literature was searched on OpenGrey, Grey Literature Report, Google Scholar, and ProQuest. A preliminary search was conducted to develop a search strategy based on the Peer Review of Electronic Search Strategies.[68] The final search strategy is described in Appendix 2 in Supplemental Materials (found at https://doi.org/10.1016/j.jval.2019.11.002). We employed some methodological components of the Effective Practice and Organisation of Care Group's search strategy, combined with selected medical subject headings (MeSH) terms and free text terms related to the PICOS (population, intervention, comparator, outcome and study design) elements. We searched for studies in English published between January 2002 and December 2018; however, we also found studies with the title/abstract in English but the text in Spanish (the authors' native language). Because the literature has emphasized the importance of including non-English studies[69] when appropriate[70] or when the available evidence is of relatively small volume,[71] and bearing in mind the encouragement to include non–peer-reviewed and grey literature,[71] we also collected studies in Spanish. In addition, the reference lists of the retrieved articles were examined to look for further relevant literature. Finally, the search was re-run before the ultimate analysis.

Study Selection

The following criteria were applied to select the relevant studies whose main intervention was LH within ambulatory care and that were focused on improving patient flow.

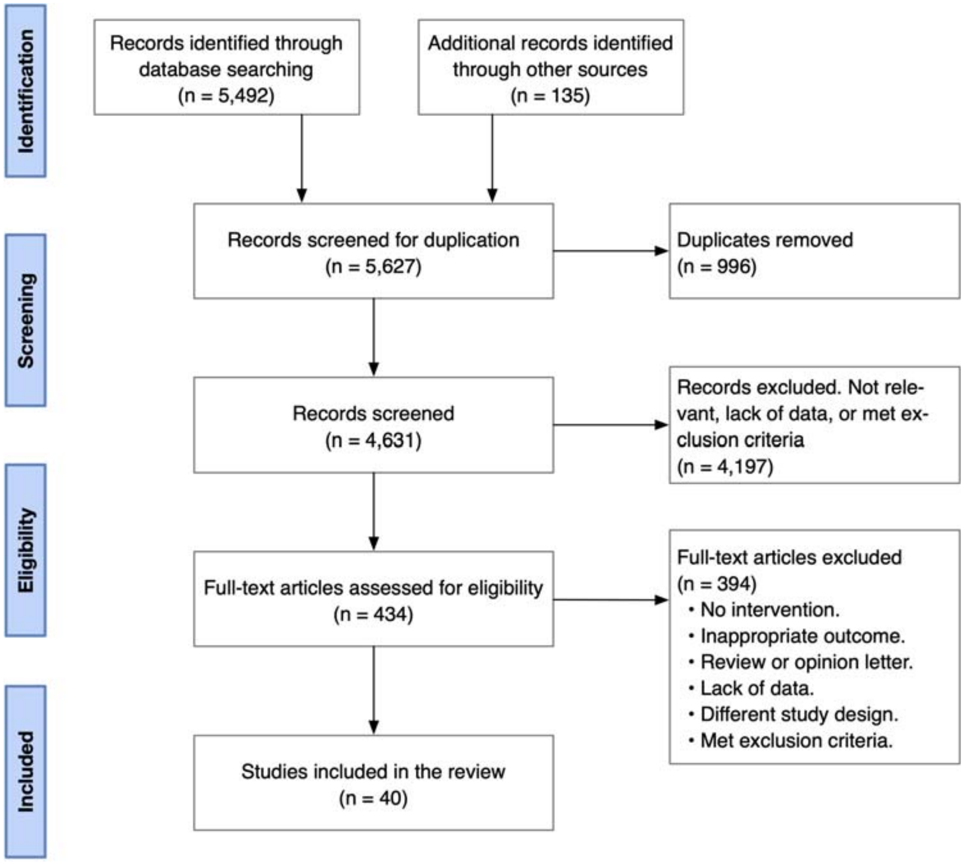
Type of studies

We searched for randomized controlled trials (RCTs), quasi-RCTs, and controlled before-after (CBA) studies. In addition, we searched for case-control, cohort, and pre-post studies. We excluded cross-sectional studies, surveys, abstracts, simulations, and opinion articles.

Participants

We included studies of healthcare units (clinics, teaching hospitals, general hospitals, specialized hospitals, or health centers) applying LH interventions in ambulatory care. This included primary, secondary, tertiary, and quaternary care from both the public and private sectors. As long as the studies were conducted in ambulatory care, we posed no restrictions in terms of type or

Figure 1. PRISMA flow chart.



PRISMA indicates Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

the number of departments in which said studies were conducted (emergency, imaging, diagnostic services, laboratory tests, or ambulatory surgery). We excluded studies focusing on interventions applied in services not directly related to both healthcare and patient flow (eg, financial services or maintenance).

Intervention

The interventions were classified as implementation strategies according to the taxonomy of the Cochrane Effective Practice and Organisation of Care Group,[72] and specifically the subcategory of continuous quality improvement. Given the broad perspective for intervention of interest, we selected those studies that addressed LH applications (also reported as lean methodology or TPS) and LH-related tools and principles. We also selected studies that addressed similar types of interventions on a case-by-case basis, subject to what was reported in the literature. We excluded studies on disease treatments or pharmacologic interventions.

Outcome

The main outcomes were categorized as either utilization of services or access to services.[73] For the former, we reviewed the change in LOS (time from arrival to departure) for all patients. Additionally, we considered LOS for discharged patients (for this study, that was the time from arrival to departure for discharged patients) and LOS for patients admitted to the hospital (for this study, that was the time from arrival to departure for patients admitted to inpatient status). We reviewed these 2 measures in a similar way, using the timely and effective care measurement described by the US government site for Medicare and the Centers for Medicare & Medicaid Services (CMS).[74] We also reviewed changes in waiting time to see a doctor or health professional (time from door to diagnostic evaluation by a qualified medical professional); waiting time means the time patients spend before being seen by a healthcare professional.[74] We analyzed waiting time for treatment (from the time a patient arrives until the initiation of a meaningful treatment), waiting time for an appointment (from the time a patient asks for an appointment until it is confirmed), and the number of patients who left without being seen (LWBS). As secondary outcomes, we searched for changes in both patient satisfaction and staff satisfaction, which we assessed through scales of validated questionnaires, including but not limited to the Patient Satisfaction Questionnaire, the Hospital Consumer Assessment of Healthcare Providers and Systems survey,[75] the Press-Ganey, and the Picker Patient Experience Questionnaire. We included studies that provided enough data either in the study itself or by email (eg, sample size, means, standard deviations, medians, interquartile ranges, or the full data). We excluded studies that considered inpatient times, studies with lacking data, and studies that did not involve a patient-flow oriented outcome (eg, supplier efficiency, staff efficiency, medical device efficiency, or medical device manufacturing company efficiency).

Data Extraction, Analysis, and Synthesis

Two independent reviewers screened each study to identify the abstract, title, keywords, and concepts that reflected both the study's contribution and the research context. The disagreement rate was close to 12% and was resolved through discussion. Afterward, the full text of the relevant studies was retrieved and assessed by 2 review authors with respect to the inclusion/exclusion criteria. When consensus was difficult to reach (close to 4%), a third review author assessed the study. The data were extracted by one reviewer and checked by a second reviewer. The raw data from each article included authors' names, year of publication, country, title, study setting, length of study, aim of study, study design, study population, participant demographics, details on the intervention and control conditions, recruitment and study completion rates, outcomes and times of measurement, and risk of bias assessment details. For studies reporting different periods of time, the latest reported outcome was considered. Finally, the collected data were organized manually and tabulated using standardized forms. Given the lack of RCTs and the heterogeneity of studies in terms of study design, settings, and outcomes, we were unable to pool the results and conduct a meta-analysis. Instead, we performed a descriptive synthesis of the results, as in similar studies,[47,48,53] and provided a table containing the summary of findings for the main outcomes, using measures of effect (means, medians, or percentages) in the same way as they were reported.

Risk of Bias

We assessed risk of bias (RoB) using the Cochrane's tool Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I)[76,77] because the majority of studies were observational and ROBINS-I is a tool for evaluating RoB in estimates of the comparative effectiveness of interventions from studies that did not use randomization to allocate units.[77] ROBINS-I is based on the premise that an observational study of an intervention should be compared with a hypothetical randomized controlled trial to identify potential biases.[77] This is not free of criticism because RCTs have their limitations.[78]

Bias in a non-randomized study of interventions (NRSI) is the systematic difference between the study results obtained from an NRSI and a pragmatic randomized trial.[79] Our judgment criteria included 5 levels (low, moderate, serious, critical, and no information) for each of the 7 bias domains that the ROBINS-I tool covered.[76] To assess the risk of bias of each study, 2 reviewers independently used the algorithm from ROBINS-I to reach an overall RoB judgment for a specific outcome; when a difference persisted between them, a third reviewer assessed the study and came to an agreement. When RoBs vary across studies, 4 strategies are available to incorporate assessments into the analysis.[80] We followed the strategy of presenting all the studies and providing a narrative discussion of the RoB. The RoB assessment is depicted in Appendix 3 in Supplemental Materials (available at https://doi.org/10.1016/j.jval.2019.11.002).

Results

The literature search yielded 5627 titles in the preliminary phase. Removal of duplicates resulted in 4631 potentially relevant articles. At the screening stage, 4197 studies were removed after applying the exclusion criteria. Four hundred thirty-four LH interventions underwent a full-text review; however, 394 of them were excluded (see Appendix 4 in Supplemental Materials available at https://doi.org/10.1016/j.jval.2019.11.002). In the end, our systematic review included 40 studies on LH interventions (see Fig. 1). Main outcomes, descriptions, and statistics (when available) are presented in Table 1. A complete summary of findings (the aim of the study, all reported outcomes, and the RoB) is provided in Appendix 3 in Supplemental Materials (available at https://doi.org/10.1016/j.jval.2019.11.002), including data from 2 studies that responded to our request for more information.

Regarding settings, 26 of the reviewed studies discussed LH interventions in the emergency department (ED), whereas 4 addressed oncology and 2 addressed both cardiology and radiology, among others. Similarly, early LH interventions focused on patient flow in ambulatory care seem to have arisen in 2006, yet there is an increase after 2011 (see Appendix 5 in Supplemental Materials, available at https://doi.org/10.1016/j.jval.2019.11.002, for further details). Additionally, we found that most of the research was conducted in the United States (n = 18), Australia (n = 6), and Canada (n = 4). The complete list of studies and a geographical map can be seen in Appendix 5 in Supplemental Materials.

In terms of LOS for all patients, 19 studies reported a decrease after LH interventions, with 142 minutes being the longest reduction reported.[81] Conversely, only 2 studies reported no change after the intervention.[11,82] As for the LOS for discharged patients, 11 studies reported a decrease, especially in EDs, where they decreased up to 76 min.[83] On the other hand, 1 study reported a non-significant statistical decrease of time,[84] and another[1] discussed evidence of no clinically important changes but statistically increased LOS around 4 minutes. Finally, 6 studies reported a decrease of the LOS for admitted patients after LH interventions, whereas 1 study reported mixed results for pre-post models and control models.[85]

Regarding waiting time, 24 studies confirmed a decrease in waiting time to see a healthcare professional, whereas merely 2 studies reported no change.[10,86] Waiting time to treatment was reported in 4 studies; meanwhile, waiting time for appointment was assessed in 2, both of which reported a decrease after LH. The number of LWBS patients was reported in 12 studies with mixed results; 9 studies reported a decrease, whereas 3 studies indicated no change.[2,87,88] Table 2 depicts the direction of findings per main outcomes.

We found other important outcomes, including boarding time (the time patients admitted through the ED waited for an inpatient bed) and readmission/revisit rate. Only 1 study discussed boarding time and reported a significant decrease after an LH intervention.[1] As for readmission rate, 3 studies reported this outcome, all with no significant difference after an LH intervention. These results are interesting because readmission rates are an important measure of the quality and costs of healthcare.[111] Moreover, they are generally positively associated with hospital performance.[112]

From the selected studies, only 8 measured patient satisfaction/experience, reporting good results in 7 of them and 1 with mixed results[81] (see Appendix 3 in Supplemental Materials, available at https://doi.org/10.1016/j.jval.2019.11.002). Few studies seemed to use well-known satisfaction assessment surveys.[81,82,89,104,107] Meanwhile, 3 studies reported either a pre-assessment or post-assessment.[25,101,103] Finally, staff satisfaction/experience after LH interventions was only evaluated in 2 studies, with both reporting better results[87,101] (see Appendix 3 in Supplemental Materials, available at https://doi.org/10.1016/j.jval.2019.11.002).

Regarding types of interventions, we found that 30 of the 40 studies were merely lean interventions, 6 were Lean Six Sigma (lean combined with Six Sigma methodology), and the remaining 4 studies combined lean with other strategies. In Lean Six Sigma interventions, we found mixed results. Half of the studies addressing this trend reported improvements combined with no change in some outcomes.

As for the research scope, all the reviewed studies explored LH interventions in a specific department or process, rather than in the

Table 1. Main outcomes of lean healthcare interventions.

First author, year, country	Setting, study design, (n), time frame	Main intervention	Outcomes	Findings
King, 2006, Australia[10]	ED, Pre-post, (n = 99 412), 24 months	Lean	Mean LOS in ED Mean LOS for admitted patients Mean LOS for discharged patients Mean wait time to see a doctor Mean wait time to treatment Percentage of patients LWBS	Reduced 0.8 h, from 5.8 h to 5 h (*P*<.001) Reduced 1.5 h, from 8.5 h to 7 h (*P*<.000) Reduced 0.3 h, from 3.7 h to 3.4 h (*P*<.001) No change (*P*=NS) Reduced from 46 min to 39 min (*P*<.001) Reduced 2.3% from 5.5% to 3.2% (*P*<.001)
Dickson, 2009, USA[89]	ED, Pre-post, (n = 19 100), 7 months	Lean	Mean LOS in ED, all patients	Reduced from 161 min to 148 min
Hseng-Long, 2011, Taiwan[22]	Cardiology department, Pre-post, (n = 46), 15 months	Lean and Six Sigma	Mean wait time to see a doctor (door-to-balloon process time)	Reduced 58.4%, from 139.2 min to 57.9 min
Mazzocato, 2012, Sweden[90]	Accident and ED, Case study, (n = 104), 36 months	Lean	Mean wait time to first assessment by a doctor.	Reduced from 67 min to 54 min (*P*<.05)
Pinto, 2013, Brazil[91]	Radiation unit, Pre-post, (n = 714), 10 months	Lean	Median wait time for daily treatment Median wait time for appointment	Reduced 75%, from 2 h to 30 min Reduced 80%, from 4 months to 8 days
Ulhassan, 2013, Sweden[92]	Cardiac ED, Case study; 48 months	Lean	Mean LOS in cardiac ED	Decreased from 206 min to 153 min
Vermeulen, 2014, Canada[85]	ED, Cohort study with control, (n = 10 912 834), 50 months	Lean	Median LOS, all patients Median LOS for discharged Median LOS for admitted Patients LWBS (relative risk)	Before-after group; control group Decreased 15 min; decreased 13 min Decreased 14 min; decreased 17 min Decreased 137 min; increased 109 min 0.82; 0.77
Rutman, 2015, USA[93]	ED, Pre-post, (n = 98), 7 months	Lean	Median wait time to see a provider Mean LOS in ED	Reduced from 43 min to 7 min Decreased by 30 min
Duska, 2015, USA[24]	Gynecologic Oncology clinic, Pre-post, (n = 39)	Lean	Mean LOS in chemotherapy (overall wait time)	Decreased from 119 min to 82 min (*P*=.001)
Damle, 2016, USA[25]	Colonoscopy unit, Pre-post, (n = 217), 7 months	Lean	Mean LOS in colonoscopy (colonoscopy time)	Decreased from 134 min to 121 min (*P*=.01)
Beck, 2016, USA[1]	ED, Retrospective pre-post, (n = 6906), 25 months	Lean and Six Sigma	Median LOS for discharged (non-admitted patients)	Increased from 2.47 h to 2.54 h (*P*=0.001)
Narayanamurthy, 2014, India[94]	Scheduling and Pharmacy, Pre-post study, and Case study.	Lean	Mean waiting time to provider Mean LOS for discharged patient (total lead time	Decreased 62.5%, from 80 min to 30 min Decreased 70%, from 115 min to 35 min
Sanchez, 2018, Spain[2]	ED, Prospective interventional, Pre-post study, (n = 24 431), 12 months	Lean	Median LOS in ED Median wait time to see a professional (nurse preparation) Percentage of patients LWBS Median process time of discharged	Reduced from 389 min to 329 min (*P*<.001) Reduced from 71 min to 48 min (*P*<.001) No change (*P*=.45) Reduced from 182 min to 160 min (*P*< .001)
Chan, 2014, China[11]	ED, Pre-post, (n = 594), 13 months	Lean	Mean wait time to see a doctor (door to diagnostic evaluation) Mean LOS in ED	Reduced from 16.9 min to 14.3 min (*P*<.05) Increased from 117.7 min to 157.7 min (*P*<.05)

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Table 1. Continued

First author, year, country	Setting, study design, (n), time frame	Main intervention	Outcomes	Findings
Hitti, 2017, Lebanon[12]	ED (Radiology), Pre-post, (n = 11 047), 14 months	Lean	Mean LOS in ED	Decreased 0.92 h, from 4.6 h to 3.6 h (*P*<.0001)
Murrel, 2011, USA[13]	ED, Retrospective pre-post study, (n = 64 907), 13 months	Lean	Mean LOS in ED Mean wait time to see a doctor (arrival to physician start time) Percentage of patients LWBS	Reduced 0.6 h, from 4.2 h to 3.6 h (*P*=<.001) Reduced 20.3 min, from 62.2 min to 41.9 min (*P*=<.001) Reduced 3%, from 4.5% to 1.5% (χ^2=<.001)
Kelly, 2007, Australia[87]	ED, Pre-post, (n = 63 085), 24 months	Lean and task analysis	Median wait time for all triage Median LOS in ED (ED time for all triage) Percentage of patients LWBS	Reduced 3 min (*P*<.003) Reduced 12 min (*P*<.005) No change (*P*=NS)
Naik, 2012, USA[95]	ED, Pre-post, 31 months	Lean	Median login to provider time	Reduced from 2.1 h to 1.6 h (*P*<.001)
Weaver, 2013, USA[28]	Mental health clinic, Pre-post, quasi-experimental, pre (n = 200), 24 months	TPS	Mean wait time for appointment (days)	Reduced 3 days, from 11 days to 8 days (*P*=.03)
Ford, 2012, USA[96]	ED, Pre-post, (n = 264), 39 months	Lean	Media door-to-needle time for patients with acute ischemic stroke	Reduced from 60 min to 39 min (*P*<.0001)
Ieraci, 2008, Australia[97]	ED, Pre-post, (n = 34 662), 18 months	Lean and Patient complexity	Mean wait time to see a doctor Percentage of patients LWBS Mean LOS for discharged (patient treatment time)	Reduced from 54.5 min to 31.7 min (*P*<.001) Reduced from 6.2% to 3.1% (*P*<.001) Reduced from 240.6 min to 194.1 min (*P*<.001)
Eller, 2009, USA[98]	ED, Pre-post, 25 months	Lean	Mean LOS for no RAD patients Mean LOS for RAD patients Percent of patients LWBS	Reduction of 45 min Reduction of 208 min Reduction of 28%
Migita, 2011, USA[99]	ED, Pre-post study	Lean	Median LOS for admitted patients	Reduced from 289 min to 257 min
Rutman, 2015, USA[100]	ED, Cohort controlled, Pre-post study (n = 98)	Lean and IRD	Median time to see a doctor (provider) Median LOS in ED	Decreased from 43 min to 7 min Decreased from 168 min to 153 min
Ciulla, 2018, USA[101]	Ophthalmology clinic, Pre-post, (n = 3149), 7 months	Lean Six Sigma	Mean LOS from clinic (Patient flow)	Decreased by 20 min (*P*<.05)
Ben-Tovim, 2008, Australia[102]	ED, Cohort study, 60 months	Lean	Mean LOS for discharged patients Mean LOS for admitted patients	Reduced from 3.7 h to 3.4 h Reduction from 8.3 h to 7.0 h
Lingaratnam, 2013, Australia[103]	Chemotherapy day unit (CDU), Pre-post, 11 months	Lean	Median waiting time to see a professional on the day (time from appointment to treatment commencement)	Reduced 38% from 32 min to 20 min (*P*<.01)
Skeldon, 2014, Canada[84]	Uro-oncology, Pre-post, (n = 216), 7 months	Lean	Median LOS for discharged Mean wait times for registered nurse Mean wait time for Doctor assessment	Reduced from 46 min to 41 min (*P*<.051) Reduced from 23 min to 5 min (*P*<.001) Reduced from 9 min to 11.5 min (*P*=.052)
Dickson, 2009, USA[81]	ED, Pre-post, (n = 32 490), Hospital A (24 months), B (48 months), C and D (36 months)	Lean	Mean LOS in ED Percentage or number of patients LWBS	A) Reduced from 459 min to 376 min B) Reduced from 426 min to 284 min C) Increased from 201 min to 212 min D) Reduced from 160 min to 156 min A) Decreased from 8% to 5% B) Decreased from 512 to 310 patients

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Table 1. Continued

First author, year, country	Setting, study design, (n), time frame	Main intervention	Outcomes	Findings
Ng, 2010, Canada[104]	ED, Pre-post, 24 months	Lean	Mean wait time to see a physician Mean LOS for discharged patients Percentage of patients LWBS	Decreased from 111 min to 78 min Decreased from 3.6 h to 2.8 h Decreased from 7.1% to 4.3 %
Tejedor, 2014, Spain[105]	ED, Quasi-experimental pre-post study, (n = 256 628), 36 months	Lean	Mean LOS in ED (time spent in the examination area) Mean wait time to see a physician. Percentage of patients LWBS	NUC, reduced from 80.4 min to 61.6 min (*P*<.001); TC, reduced from 137.8 min to 123.8 min (*P*<.05); MSC, Decrease from 219.7 min to 209.3 min (*P*=.108) Reduced from 58 min to 49.1 min (*P*<.001) Decreased, from 2.8% to 2.0% (*P*<.001)
Piggott, 2011, Canada[106]	ED, Pre-post, pre (n = 1666), 10 months	Lean	Median wait time to physician Median wait time to first 12-lead electrocardiogram after triage	Reduced from 82 min to 49 min Reduced from 53 min to 11 min.
Sayed, 2015, Lebanon[88]	ED, Pre-post, (n = 387), 20 months	Lean	Mean wait time to see a doctor Mean LOS for admitted Mean LOS for discharged Percentage of patients LWBS	Decreased from 40.0 min to 25.3 min (*P*<.001) Dropped from 2.6 h to 2.0 h (*P*<.001) Dropped from 9.0 h to 5.5 h (*P*<.001) No statistical change (*P*=.15)
Kane, 2015, USA[107]	ED, Pre-post, 23 months	Lean	Median LOS all patients Median time to see a doctor Percentage of patients LWBS	Reduced 17% from 282 min to 243 min Reduced 73% from 49 min to 13 min Reduced from 2% to 0.65%
Bost, 2015, Australia[86]	ED (mental health), Retrospective pre-post study, (n = 3037), 12 months	Lean and patient flow strategy	Median wait time to see a doctor Median LOS in ED (Total)	No change, from 48 min to 48 min (*P*=.29) Reduced from 296 min to 255 min (*P*=.64)
White, 2014, USA[108]	ED, Prospective controlled, pre-post study, (n = 59 687), 17 months	Lean, Six Sigma, QT, and TOC.	Median LOS for discharged patients	Intervention group reduced 15 min from 158 to 143 (*P*<.0001). No change in control group from 265 min to 267 min (*P*=0.69)
Improta, 2018, Italy[109]	ED, Pre-post, (n = 33 710), 18 months.	Lean	Mean LOS in emergency room Mean waiting time I triage – II triage Mean waiting time I triage – taken into care Mean waiting time Taken into care–dismissal Mean waiting time I triage – dismissal	Red reduced from 72 min to 71 min Yellow reduced from 151 min to 147 min Green reduced from 164 min to 163 min White reduced from 160 min to 158 min Reduced from 22:54 min to 21:24 min (*P*<.001) Reduced from 01:47:55 h to 1:41:55 h (*P*<.001) Reduced from 2:31:02 to 2:19:12 (*P*<.001) Reduced from 04:18:57 to 4:01:07 (*P*<.001)
Lin, 2013, USA[82]	Otolaryngology outpatient clinic, Prospective pre-post study, (n = 329), 12 months	Lean and Six Sigma	Mean wait time to see a doctor LOS in clinic (patient overall time)	Decreased from 41 min to 36 min (*P*=0042) No significant increase, from 61 min to 63 min
Mcdermott, 2013, Ireland[110]	Diabetes Day Centre, Pre-post, (n = 73), 6 months	Lean	Mean LOS in clinic (patient journey) Mean time to see doctor (door to doctor)	Reduced from 118 min to 58 min (*P*<.001) Reduced from 61.26 min to 38.38 min (*P*=.005)

continued on next page

Table 1. Continued

First author, year, country	Setting, study design, (n), time frame	Main intervention	Outcomes	Findings
Wiler, 2017, USA[83]	Emergency care delivery, Pre-post, Department A and B, 28 months	Lean tools, Six Sigma and Plan-do-study-act cycle. Rapid Process Optimization	Wait time to see a doctor (door-to-physician) LOS all patients (overall LOS) LOS for discharged LOS for admitted to hospital Percentage of patients LWBS	A reduced from 54 min to 12 min; B reduced from 20 min to 8 min. A reduced from 228 min to 184 min; B reduced from 202 min to 192 min. A reduced from 216 min to 140 min; B reduced from 179 min to 167 min. A reduced from 249 min to 217 min; B reduced from 325 min to 306 min. A reduced from 5.5% to 0.0%; B reduced from 4.1% to 0.5%

Note. ED indicates emergency department; h, hour; IRD, model for improvement to rapidly redesign; LOS, length of stay; LWBS, patients left without being seen; min, minute; MSC, medical-surgical circuit; NS, not significant; NUC, non-urgent circuit; QT, queuing theory; TC, trauma circuit; TFT, total fast track; TOC, theory of constraints; TPS, Toyota Production System.

entire organizational structure. Moreover, according to our results, EDs accounted for the largest number of LH interventions in patient flow (in 26 out of 40 studies), followed by oncology with 4 studies.

We also found that 36 out of 40 studies worked with multidisciplinary teams, which were composed of members from at least 2 different areas and involved mainly physicians and nurses.

Interestingly, meeting national or local standards regarding patient flow was discussed in only 4 studies. Among the LH interventions included, 3 reported case studies, 2 discussed cohort studies, and 35 introduced before-after studies. None of the research involved RCT. As for RoB, 24 studies were evaluated as moderate, 15 as serious, and 1 as critical. Finally, we found 6 studies[81,82,84,87,95,108] that reported the “Hawthorne effect,” in which there may be changes in a person’s behavior owing to the presence of an observer.[82]

Discussion

The purpose of this systematic review was to assess the effects of LH interventions on patient flow in ambulatory care. We found that most of the reviewed studies reported improvements regarding shorter LOS and shorter waiting times after a LH intervention. These measures were the most common process-related outcomes of LH interventions. In this sense, our results are consistent with those reported in Costa and Godinho.[19]

Our results also indicate that lean interventions may be combined with other methodologies. We identified 6 studies of Lean Six Sigma interventions in ambulatory care. Whereas lean aims to reduce waste, Six Sigma uses a DMAIC (Define, Measure, Analyze, Improve, and Control) framework to reduce process variation, mainly with statistical tools. Lean Six Sigma also provides useful frameworks to help hospital staff identify causes of delays in their own institutions.[113] This combination outperforms the use of only one other methodology; however, this combination tends to be composed of larger, private hospitals with more resources for quality improvement.[114] Our review also found that most of the studies mapped their activities to describe and understand flows and patient care processes; to this end, healthcare organizations mainly relied on value stream mapping, thereby being the most important tool in LH. This finding is consistent with other research.[115] Studies also reported other frequent tools used such as standard work (which is considered one prerequisite for flow);[93] the 5 steps of sort, set in order, shine, standardize, and sustain (the 5S, which are used to eliminate clutter and organize workstations);[33] and Kaizen (which is used for intensive team-based improvement projects[95] and for the engagement of key stakeholders[12]). Such findings are consistent with those reported in other studies[19,44] and support the claim that most LH applications focus more on assessment and improvement tools and less on process-monitoring tools after LH interventions.

Although the lean theory adopts a holistic view,[44] none of the reviewed studies were conducted in the entire healthcare organization, but rather in a specific department or process, which is consistent with what D’Andreamatteo et al[51] report. The rationale is that small, focalized improvements help organizations maintain momentum and any early achievement is important to keep people from becoming dispirited.[116] More experienced organizations might implement broader and longer projects. In contrast, if the goal is to maximize quality improvements and cost savings, then LH interventions or similar methodologies (eg, the Virginia Mason Production System) must occur throughout the institution (ie, in both ambulatory care and inpatient settings).[20]

Most of the reviewed studies that involved professionals from different areas in the lean team—whether multidisciplinary teams,[93] improvement teams,[85] cross-functional teams,[101] or Kaizen teams[89]—reported better performance in patient flow indicators. In fact, lean teams are vital in getting “buy in” from all the stakeholders involved,[116] mainly because lean continues to support a multidisciplinary problem-solving approach, as evidenced by the joint ownership of performance measures.[103]

Contrary to our expectations, patient satisfaction was reported in merely 8 of the 40 selected studies. This is quite contradictory because LH is considered a factor for improving patient flow and thus positively related to patient satisfaction.[11,84,117–119] Furthermore, the literature suggests that doctors, nurses, employees, and staff perceive LH benefits as an increase in their satisfaction, motivation,[91,120] and empowerment[39,92]; however, few studies measured staff satisfaction.[87,101] In fact, the lack of evidence on the assessment of staff satisfaction or experience after LH interventions is worrisome and might suggest that creating the ideal staff experience has been missing from many lean transformations.[121] Unfortunately, it is well

Table 2. Direction of findings per main outcomes.

Author	LOS for all patients			LOS for discharged patients			LOS for admitted patients		
	-	NC	+	-	NC	+	-	NC	+
(Dickson, 2009)[89]	✓								
(Ulhassan, 2013)[92]	✓								
(Chan, 2014)[67]			✓						
(Lin, 2013)[82]		✓							
(Vermeulen, 2014)[85,*]	✓			✓			✓		✓
(Rutman, 2015)[93]	✓								
(Duska, 2015)[24]	✓								
(Damle, 2016)[25]	✓								
(Sánchez, 2018)[2]	✓			✓					
(Hitti, 2017)[12]	✓								
(Murrell, 2011)[13]	✓								
(Kelly, 2007)[87]	✓								
(Eller, 2009)[98,†]	✓								
(Rutman, 2015)[100]	✓								
(Dickson, 2009)[81]	✓								
(Tejedor, 2014)[104]	✓								
(Kane, 2015)[107]	✓								
(Beck, 2016)[1]						✓			
(Bost, 2015)[86]		✓							
(Improta, 2018)[109]	✓								
(McDermott, 2013)[110]	✓								
(Wiler, 2017)[83,‡]	✓			✓			✓		
(King, 2006)[10]	✓			✓			✓		
(Narayanamurthy, 2014)[94]				✓					
(Naik, 2012)[95]									
(Ciulla, 2018)[101]				✓					
(Ben-Tovim, 2008)[102]				✓			✓		
(Skeldon, 2014)[84]					✓				
(Ng, 2010)[104]				✓					
(Sayed, 2015)[88]				✓			✓		
(White, 2014)[108]				✓					
(Migita, 2011)[99]							✓		
(Hseng-Long, 2011)[22]									
(Mazzocato, 2012)[90]									
(Ford, 2012)[96]									
(Ieraci, 2008)[97]				✓					
(Lingaratnam, 2013)[103]									
(Piggott, 2011)[106]									
(Pinto, 2013)[91]									
(Weaver, 2013)[28]									
TOTAL	19	2	1	11	1	1	6	NR	1

Note. Ticks indicate studies reporting an outcome. For the direction of the outcome (-) indicates that an outcome decreased, NC no change in outcome, and (+) outcome increased. BSHP indicates before seeing a healthcare professional; LOS, length of stay; LWBS, left without being seen; NR, Not reported.
[*]Two studies (before-after study and differences model study), [†]two groups (RAD and no RAD patients), and [‡]two departments (A and B). Only the last name of the first author and the year of publication are shown.

Table 2. Continued

Waiting time for patients BSHP			Waiting time to treatment			Waiting time for appointment			LWBS		
-	NC	+	-	NC	+	-	NC	+	-	NC	+
✓											
✓											
✓											
✓											
✓										✓	
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24	**2**	**NR**	**4**	**NR**	**NR**	**2**	**NR**	**NR**	**9**	**3**	**NR**

known that disengaged healthcare workers are by far the biggest reason for lean failure.[121] Therefore, monitoring and enhancing lean team experience and satisfaction should be an important consideration for further interventions because LH draws heavily on staff involvement and commitment.

Regarding follow-up time (ie, an accountability and continual evaluation of the effectiveness of the implemented changes[122,123]), around a third of the studies reported follow-up results of less than one year, which makes it difficult to confirm the sustainability of the improvements. This may have a bearing on "project fatigue" in hospitals because so many problems within their facilities need attention[124]; thus a short follow-up analysis might not be a proper indicator of achievement. Some other aspects that might compromise the sustainability of LH improvements include poor understanding of the organizational context,[125] less time for lean teams, and increased patient volume.[92] Conversely, the successful implementation of lean or any other improvement framework requires that the hospital and medical leadership are all strong supporters of the methodology, speak the same process improvement language, and are able to generate support and resources for an operation-wide forward movement.[93] Furthermore, when lean is correctly implemented and is owned by the frontline workers, it can produce care metric improvements.[81]

In a time when service efficiency and cost reduction drive many decisions worldwide, health services are being pressured to find better compliance strategies without compromising quality of care. Standards, targets, and benchmarks are being developed to serve as a reference for healthcare improvement. For example, patients in ED are discharged, admitted, or transferred to another hospital within 4 hours in Australia,[126] and there is a 4- to 8-hour province target for low-high urgencies for non-admitted patients in Ontario, Canada,[127] and a 4-hour target to treat, admit, or transfer emergency patients in the UK,[128] although nowadays The National Health Service [NHS] in England is moving to a more specific set of new standards).[129] In the United States, different quality of care measures, including those regarding operational performance, are being monitored and collected (eg, by the CMS).[74] As a reference point for the results in this research, in terms of LOS in ED, the US national median for the second quarter of 2018 for time from arrival to departure for discharged patients was 134 minutes[130] and 251 minutes for patients admitted to the hospital.[131] In terms of target or standard compliance while implementing LH, only a few of the reviewed studies indicated a local or national standard[1,22,85,97]; instead, the stated goal was usually to improve performance.[95]

Additional operational indicators associated with LH include increased service capacity,[132,133] increased productivity,[134,135] lower costs per case/service,[23,136] reduced inventory/space,[93,135] minimized transit/transportation time,[27,137] boarding time,[1] lead time in radiology,[138] and time increase for nurses to care patients,[139] among others. These efforts seem to be a war on waste, which would be justified by the need to reduce costs that are not essential for patient care.[140] Despite the inherent relationship between LH and costs reduction/revenue increase, we only found a few studies reporting this outcome.[22,82] This might indicate that, unlike lean manufacturing, LH in ambulatory care still struggles to translate the obtained benefits to savings and measure them. In this sense, to ensure the real impact of LH on costs and savings, multidisciplinary teams involving healthcare, finance, and administrative staff might be required for further interventions.

In this research, the majority of the reviewed studies were the before-after type. This could be related to the fact that lean implementation occurs in the real world and is contingent on people who interact in a manner that cannot be isolated and controlled.[81] The majority of observational studies in lean interventions is consistent with Frieden, who stated that many other data sources can provide valid evidence for clinical and public health action, such as observational studies, including assessments of results from the implementation of new programs and policies, which remain the foremost source.[78] Indeed, for many public health interventions, randomized trials are difficult or impossible to conduct on an area-wide basis.[77] Moreover, RCTs have their limitations in terms of the selection of the population, external validity of the results,[78] and increasingly high costs.[141] Therefore, if the aim is to use empirical evidence, any credibility advantage that RCTs have in estimation is no longer operative.[142]

In terms of bias, 24 studies were evaluated as moderate, 15 as serious, 1 as critical, and none as low risk (because only in exceptional circumstances will an NRSI be assessed as low risk owing to confounding).[76,77] Our results are similar to Sterne et al,[76] who anticipated that most NRSI will be judged as at least at moderate overall RoB. Our relative large number of studies with high RoB might be controversial; however, it represents our decision to include all the studies that met the inclusion criteria to provide a general perspective of the LH phenomenon while simultaneously following one of the strategies recommended when RoB varies across studies.[80]

Studies conducting meta-analysis can yield different results. For instance, including all eligible studies may produce a result with high precision but can be seriously biased. On the other hand, including only the studies at low RoB may produce a result that is unbiased but imprecise.[80] In addition, studies at high RoB should be given reduced weight, yet methodologies for weighting studies according to their RoB are not sufficiently well developed.[80] Ultimately, researchers can conduct statistical analyses to reduce bias, and propensity scores can be used for bias due to confounding,[143,144] Heckman selection models for selection bias,[145,146] and fixed effect models for time-invariant confounding.[147]

In this research, we did not conduct a meta-analysis, yet we highlight the importance of assessing RoB. Moreover, because our research provides a descriptive synthesis, our results do not have an effect on statistical tests, as used in quantitative synthesis.

Regarding the domains of bias, 3 out of 7 were common among the studies: bias in selection of participants, bias in selection of the reported results, and bias owing to confounding; the latter consisted of baseline and time-varying confounding,[76] whereas the first two related to some participants, follow-up times, or outcomes excluded at the beginning or end of the studies.

Finally, around two-thirds of the studies provided statistical analyses to test for significant changes in outcomes. This number represents an increase when compared with the one-third reported by an early review[45]; however, the lack of statistical analyses implies a limitation and might drive the bias as well.

Limitations

Our research has several limitations. First, most studies were observational pre-post designs; as a result, the absence of matched comparison groups, the potential presence of confounding variables, and the lack of randomization prevent the reported outcome improvements from being causally linked to the lean interventions. Second, the multi-component nature of LH, along with the heterogeneity of the data (differences in time for low and high acuity, settings, triage systems, patient volume, and data collection/processing approaches) make it difficult to generalize results. Third, the heterogeneity of the studies and RoB prevented us from conducting a meta-analysis and thus determined causal relationships.

There is also the likely occurrence of the "Hawthorne effect" or "observer effect" in which there may be changes in a person's behavior owing to the presence of an observer,[82] which is often mentioned as a possible explanation for positive results in intervention studies,[147] although efficiency changes, as evidenced in the statistical tests of each study, suggest that improvement results are more likely due to the LH interventions. Finally, some of the reviewed studies reported follow-up results of less than one year, yet longer follow-up performance metrics (eg, 3 to 5 years) are required to evaluate the sustainability of LH and the improvement strategies of similar processes.[122] Additionally, longer follow-up times might help decrease the likely occurrence of the Hawthorne effect.[81]

Conclusions

In light of the rapidly growing literature on lean healthcare, this research contributes by summarizing the main results obtained from LH interventions on patient flow in ambulatory care. As noted by most of the study authors, lean encouraged improvement and efficiency of service by identifying NVA activities and acting to reduce them. Considering the dimensions of quality of care,[148] this review presents evidence that LH reduces patient waiting time and length of stay, thus contributing to the provision of accessible and efficient service. In addition, when LH projects are properly supported, they can help healthcare organizations comply with standards or targets related to timely and effective care (throughput), and the stakeholders may recognize such improvements in the short and medium terms. Likewise, our results highlight that understanding the relationship between capacity and demand is key to improving patient flow, and, in this regard, lean is an essential support. Moreover, because Six Sigma focuses on reducing variation, combining lean and Six Sigma can help smooth patient flow and solve more complex problems, as long as the entire organization provides extraordinary support. Finally, despite the improvement in patient flow measures, evidence of the impact of LH on patient/staff satisfaction and the translation of the obtained benefits from LH into savings is scarce among studies.

Notwithstanding the mostly positive findings of LH intervention, we advise caution when generalizing owing to the relatively weak study designs. Ultimately, further research is needed, involving either high quality observational studies, which can reduce the bias related to unmeasured confounding or selection issues, or randomized controlled trials.

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Supplemental Material

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.jval.2019.11.002.

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