Lean Thinking in Emergency Departments: A Critical Review

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Emergency departments (EDs) face problems with crowding, delays, cost containment, and patient safety. To address these and other problems, EDs increasingly implement an approach called Lean thinking. This study critically reviewed 18 articles describing the implementation of Lean in 15 EDs in the United States, Australia, and Canada. An analytic framework based on human factors engineering and occupational research generated 6 core questions about the effects of Lean on ED work structures and processes, patient care, and employees, as well as the factors on which Lean's success is contingent. The review revealed numerous ED process changes, often involving separate patient streams, accompanied by structural changes such as new technologies, communication systems, staffing changes, and the reorganization of physical space. Patient care usually improved after implementation of Lean, with many EDs reporting decreases in length of stay, waiting times, and proportion of patients leaving the ED without being seen. Few null or negative patient care effects were reported, and studies typically did not report patient quality or safety outcomes beyond patient satisfaction. The effects of Lean on employees were rarely discussed or measured systematically, but there were some indications of positive effects on employees and organizational culture. Success factors included employee involvement, management support, and preparedness for change. Despite some methodological, practical, and theoretic concerns, Lean appears to offer significant improvement opportunities. Many questions remain about Lean's effects on patient health and employees and how Lean can be best implemented in health care. [Ann Emerg Med. 2011;57:265-278.]

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INTRODUCTION

The need for improvement in emergency departments (EDs) with respect to the cost of care, the speed of service, crowding, and patient safety is now widely accepted.[1-4] In an attempt to achieve broad improvement, health care organizations worldwide increasingly adopt an approach called "Lean thinking" (see Figure 1 for a description of Lean).[5] In a 2009 survey of US hospitals, 53% reported having implemented Lean to some extent; of those hospitals, 60% reported implementing Lean in the ED.[6] Furthermore, some public health care systems, including the UK National Health Service,[7] have adopted or are planning to adopt Lean as a key lever for decreasing costs and improving the quality and safety of care.

Lean thinking is a bundle of concepts, methods, and tools derived from the Toyota Production System, the production philosophy of Toyota Motor Corporation. Lean was first implemented in US auto manufacturing in an attempt to replicate Toyota's success and has subsequently spread to other manufacturers (eg, Boeing), to service industry (eg, Tesco), and to the public sector (eg, UK National Health Service). Key principles of Lean are listed in Figure 1. Chief among them is the need to eliminate unnecessary waste. Waste is anything that does not add value to the customer. For example, if the ED patient is the customer, 2 wastes might be waiting to be seen or undergoing (and paying for) a duplicate test. As waste is eliminated, products (or patients) flow smoothly, continuously, and without errors from one step to another. After work is completed at one step, it is not pushed to the next step; instead, work is pulled when it is ready to be processed at the next step so that work does not pile up. Problems that arise in the process are to be identified immediately, their causes understood, and a solution applied. Both frontline workers and management are responsible for the quality of work, and both are involved in the problem solving process, often by participating in rapid continuous improvement sessions called *kaizen*. Indeed, although the support and participation of leadership is crucial, contemporary prescriptions of Lean insist that workers be involved and empowered to inspect and improve their own work. Workers and management have at their disposal numerous tools and methods to implement the above principles (Figure 1).

The much-celebrated success of Lean in manufacturing[8] and success stories of Lean in the National Health Service and other health care systems[9-12] have resulted in a strong push for introducing Lean to health care[13-16] and more particularly to the ED.[17-21]

Key Principles

Eliminate unnecessary waste, maximize value to the customer.

Achieve smooth, continuous flow of work with minimal delays (*heijunka*).

Just-in-time delivery of products and materials from one step to the next, reducing large stock inventories.

Worker involvement and empowerment to inspect and improve their own work.

Autonomation, or immediate machine-detection of defects in production (*jidoka*).

Solve problems at their source.

Continuous improvement and the never-ending pursuit of perfection.

Tools and Methods

Value stream mapping, a method of diagramming and otherwise describing (eg, timing) current and desired future process steps, including the flow of products, people, information, and materials.

Short-cycle continuous improvement sessions (*kaizen*).

Work standardization based on assessment of the presumed "best way" to do the work (includes standard operating procedures and time-on-task specifications).

Work done by multiskilled work teams.

5S, a method for organizing and standardizing workspaces.

Physical layout improvement to minimize travel time and inventory inefficiencies.

Root cause analysis (5 Why).

Assembly lines and cell-based manufacturing.

A3 report, a standardized organization tool for problem solving.

Mistake-proofing/failure prevention (*poka-yoke*).

Information systems for knowing when products are ready to be pulled to the next step (*kanban*) or when a problem exists (*andon*).

Figure 1. Description of Lean.

Given enthusiasm about Lean as an approach to improving emergency care, this article critically reviews and analyzes the empirical literature on the implementation of Lean in the ED. The present review differs from previous work[9,22-25] in 5 ways. First, it focuses specifically on the ED. Second, it reviews how Lean affects health care employees in addition to patients. Third, it assesses previous studies for evidence of undesirable and null effects of Lean in addition to desirable effects and in general takes a much-needed critical approach.[25-27] Fourth, it analyzes the factors that may contribute to variability in Lean's success. Fifth, this study systematically analyzes each previous study according to an analytic framework, rather than using studies to build a narrative about Lean in health care. That framework, described below, is based on human factors/systems engineering principles and on occupational research on Lean outside of health care.

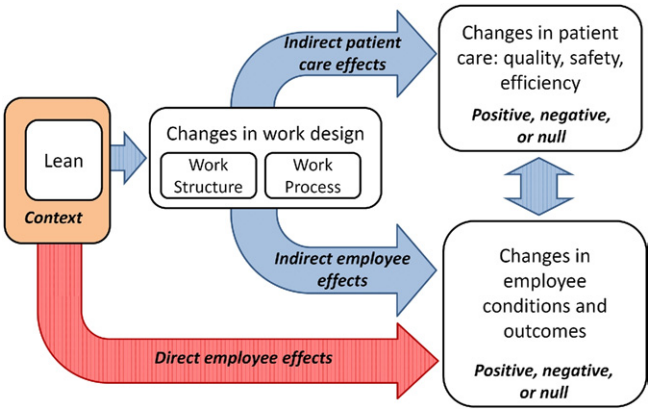

Figure 2. A model of Lean in health care, proposing that (a) Lean affects patient care and employees indirectly by changing work structure and process, (b) Lean affects employees directly, (c) employee and patient care changes can affect one another, and (d) Lean is implemented in a particular context and that the success of Lean is contingent on how a particular Lean implementation fits into the local context.

METHODS

The analytic framework used to generate the core research questions for this review (Figure 2) depicts Lean as having transformative effects on the structure and process of ED work. *Structure* refers to work system elements such as tools and technology, worker factors (eg, education/training, responsibilities), organizational factors (eg, policy, staffing, incentives), communication systems, and the physical environment (eg, spatial arrangement, noise, lighting).[28,29] *Process* refers to the actual activities of patient care and related work[29] and the "flow" of the patient through the ED or broader care delivery system.[30]

Understanding how Lean transforms work structure and process is important because those transformations will determine patient care quality and safety indicators such as length of stay, medication errors, and patient satisfaction.[29,31] How Lean affects patient care, albeit indirectly through structure and process change, ultimately determines the success of Lean.*

By transforming work structures and processes, Lean also affects the employees responsible for carrying out the work, as studies of Lean outside of health care demonstrate.[32-36] A representative finding comes from the study by Sprigg and Jackson[37] of call center employees: the introduction of Lean imposed dialog scripting and performance monitoring; this led to lower job control, task variety, skill use, and role clarity and higher workload and role conflict; those changes in working conditions were then found to relate to employees' job strain

*Arguably, another necessary, perhaps sufficient, indicator of Lean's success is the efficient use of limited resources (eg, financial, material, human resources).

Table 1. List of reviewed studies and descriptions of study sites and Lean project teams.

Study	Study Site	Project Team Composition
Al Darrab et al, 2006[69]	EDs at Hamilton Health Sciences, a 3-site tertiary/quaternary care facility, Canada	Emergency medicine/cardiology leaders and quality improvement facilitators set improvement goals. Project team included pharmacists, staff nurses, managers, educators, residents, nursing program directors, project coleaders from the ED and cardiology, quality improvement facilitators, emergency medical services representatives.
Ben-Tovim et al, 2007,[70] 2008,[71] King et al, 2006[72]*	ED at Flinders Medical Centre, a 500-bed community teaching hospital, Australia	Facilitators worked with senior staff to make initial assessments and then involved multidisciplinary groups of frontline staff to diagnose problems, document the process, and implement and evaluate process redesign. "Participants were drawn from the full range of staff working within the ED, from patient care assistants and clerical staff to junior and senior nursing and medical staff."
Dickson et al, 2008,[73] 2009[74]	Level I trauma center at University of Iowa Hospitals and Clinics, a 700-bed teaching hospital	Improvement team composed of 2 ED physicians, 2 ED nurses, an ED physician assistant, 2 non-ED physicians, 2 radiology technicians, a laboratory technician, 5 industrial engineers, and 5 external participants from a local business council (representing the patient perspective)
Dickson et al, 2009[75†]	Hospital A: ED at a 690-bed teaching hospital, unspecified urban location Hospital B: ED at an 889-bed community hospital, unspecified urban location Hospital C: Level II trauma center at a 461-bed community hospital, unspecified location Hospital D: Level I trauma center at a 700-bed teaching hospital, unspecified rural location	Hospital A: Improvement driven by consultant and focus area leader. "Frontline workers not initially asked to provide ideas for process redesign but in the course of implementation were inspired to suggest incremental process improvements." Hospital B: "Frontline workers," "led by a consultant team" Hospital C: ED management. "Ideas of frontline workers not sought." Hospital D: See Dickson et al, 2008,[73] 2009,[74] above
Eller, 2009[76]	ED at St. Luke's Episcopal Hospital, a 900-bed faith-based teaching hospital	"Staff members"
Ieraci et al, 2008[77]*	ED at Bankstown Hospital, a 400-bed referral hospital, Australia	Intervention developed in "workshop sessions involving key clinical and management staff within the ED"
Jacobson et al, 2009[78]	Level I trauma center at Vanderbilt University Medical Center, a 600-bed teaching hospital	Any physician (resident or attending) wanting to submit an idea, concern, or observation. Although 17% of submissions were from nurses and other staff, the system was initially aimed at physicians.
Kelly et al, 2007[79]*	ED at Western Hospital, a 300-bed community teaching hospital serving adult patients only, Australia	"Collaborative design and implementation process involving all professional groups and grades of staff"
Kulkarni, 2007,[20] 2008[80]	ED at Yale–New Haven Hospital, a 950-bed teaching hospital	Team included "representatives from the emergency department, such as nursing, midlevel staff, staff physicians, resident physicians, greeters, registration, security, and technicians/patient care assistants" and "hospital leadership and representatives from inpatient physician and nursing leadership as well as general hospital departments—such as transport and environmental services."
Ng et al, 2010[81]	ED at Hôtel-Dieu Grace Hospital, a 300-bed faith-based tertiary care hospital, Canada	A Lean consultant and "emergency physicians; nurses; nurse practitioners; porters; clerks; cleaning staff; administrators; the ED director, unit manager and educator; the hospital's senior vice-president; and representatives from diagnostic imaging, laboratory, respiratory therapy, home care and information services."
Parks et al, 2008[82]	Level I trauma center at Parkland Memorial Hospital, a 950-bed community teaching hospital	Project team included hospital administration, trauma surgeons and nursing staff, and performance improvement personnel trained in Lean Six Sigma
Schooley, 2008[83]	ED at Presbyterian Hospital, a 531-bed regional medical center, part of a not-for-profit integrated health care system	At first, Lean consultant and managers only. Later, physician, nurses, and other staff were interviewed and became involved in suggesting and implementing changes. Improvement teams included both supporters of change and resistors who were also social leaders in the organization.

Table 1. Continued.

Study	Study Site	Project Team Composition
Stephens-Lee, 2006[84]	ED at Dartmouth General Hospital, a 131-bed community hospital	Lean consultant and "nurses and clerks from the ED and inpatient units, the bed manager, an inpatient Health Services manager, chief of staff and engineers."
Woodward et al, 2007[85]	ED at Seattle Children's Hospital, a 250-bed pediatric teaching hospital	Not described

*Reviewed in Cooper and Mohabeersingh.[24]
†Hospital A likely refers to Eller[76] and Hospital D to Dickson et al.[73,74]

outcomes (job-related anxiety and depression). The effects of Lean on employees may also be desirable ones.[38,39]

Apart from the employee effects of Lean-related changes to the actual work, there may also be a direct path by which Lean affects employees. For example, 2 intended effects of implementing Lean are to shift employees from merely doing their work to looking for ways to improve it and the empowerment of workers to suggest and implement changes.[40] Similarly, changes in motivation, information, and social standing, to give 3 examples, might result from the mere involvement of workers in Lean projects, independent of the work changes brought about by the actual projects. Another possible direct effect of Lean is the anxiety brought about by fears of losing one's job or having a less satisfying job after clinical work is made more efficient.

If workers are affected by Lean, resulting in higher or lower motivation, satisfaction, anxiety, task control, and more, it is reasonable to suggest that patient care, and thus patient outcomes, will improve or suffer. Following this logic, the Mehta and Shah[41] model of employee effects of Lean proposes that employee outcomes both affect and are affected by "organizational outcomes" such as "productivity" and "performance." In the health care setting, however, the relationship of interest is between employee conditions and outcomes on one hand and the quality, safety, and efficiency of patient care on the other.[28]

"Lean production is . . . not a single unitary production concept, either in its design or in its implementation."[33] Instead, organizations select among numerous principles, tools, methods, and philosophies.[42] Generic Lean principles are interpreted and adapted for each organization's unique local context.[43] This has led researchers to propose that the effects of Lean are contingent on how and where Lean is implemented.[33,37,41]

The components of the analytic framework discussed above yield 6 study questions that guided the analysis of reviewed studies of Lean in the ED:

- How does Lean transform work structures and work processes?
- How does Lean affect patient care (quality, safety, efficiency)?
- How does Lean affect employee working conditions (eg, autonomy, workload) and outcomes (eg, motivation, satisfaction) indirectly by transforming work structures and processes?
- How does Lean affect employee outcomes directly, independent of changes to work structures and processes?
- How are patient care effects and employee effects of Lean linked?
- How are patient care and employee effects of Lean contingent on the features of (a) the organization implementing Lean and (b) the design and implementation of Lean?

The scholarly literature spanning January 2005 to January 2010 was searched for articles describing Lean implementation in the ED. Three database searches were conducted: (1) the medical database PubMed, using the search string "Lean OR Toyota Production System;" (2) the business/management database ABI/INFORM (Scholarly Journals) using "Lean OR Toyota Production System" and a collection of health care terms (eg, hospital*, patient*, health care, clinic*, emergency department*); and (3) the interdisciplinary database Google Scholar using "emergency room OR emergency medicine OR accident & emergency OR emergency department AND Lean production OR Lean thinking." Twelve specific journals, including *Annals of Emergency Medicine*, *Journal of Emergency Medicine*, *Emergency Medicine Journal*, *American Journal of Emergency Medicine*, and *International Journal of Emergency Medicine*, were searched using the terms "Lean" and "Toyota." Finally, the references of retrieved articles and of existing articles from a broad literature collection on Lean in health care were searched for other relevant articles.

Nonempirical articles and articles reporting on work design or improvement projects not identified as Lean[44-46] were excluded from the review. Conference abstracts[47-56] and similar condensed publications[57,58] were excluded because they provided insufficient information. Larger-scale (eg, hospital-wide) studies that included the ED were excluded because of space limitations and difficulty extracting ED-specific content.[10,59-67] Studies of pre-ED triage only were also excluded.[68] Finally, studies not published in the English language were excluded.

RESULTS

Eighteen articles describing Lean initiatives in 15 EDs met inclusion criteria (Table 1).

Table 2. Work process and work structure changes resulting from implementation of Lean.

Process Changes	Specific Examples
New processes and related operating procedures	Rapid assessment and disposition process[76]
	Separate express care track for patients to be treated more quickly during high-volume times[83]
	Fast track process for low-complexity patients[77]
	Separate streaming of likely-admitted versus likely-discharged patients[72,79,81] and likely-discharged patients treated in order of arrival[72]
	Streaming of patients into 3 "pods" (complex, medium, and fast)[85]
	Script for calling ambulance[69]
	Immediate rooming of patients and bedside registration, when possible[74]
	Test orders[74] or other work (eg, identifying need for home care)[81] conducted earlier in the process
	Involvement of other services conducted earlier in the process[74]
	Workflow improvement for disposition, ancillary services, and documentation[78]
	Patient sees triage nurse first, completes other processes (eg, registration) later[80]
	Eliminating or combining steps in process[80,81]
	Eliminating of outdated policies[80]
	New specific guidelines for "medical holds"[80]
	Physicians and nurses encouraged to complete discharge procedures as quickly as possible[81]
	Standardized medication storage and labeling process[71]
	New process for "pulling" patients into inpatient wards[71]
System Changes	**Specific Examples**
Data collection and monitoring	Daily monitoring and monthly reporting of patient and process data[76]
	Weekly review and public posting of outcome metrics[81]
	Performance benchmarking and feedback[69]
	Quality improvement measurements taken and shared with staff[73]
	Charts and diagrams of unit performance publicly displayed[83]
	Quarterly audits (Hospital B)[75]
Education/training	Brief orientation to new process[70]
	Training on new rapid assessment and disposition process[76]
	Posting of process map in public areas[73]
	Education day on specific areas of improvement[69]
	Residents encouraged to attend cardiology rounds for educational reasons[5]
	Training of nurse to coordinate communications[85]
Tools/technologies	Communication tools[76]
	Automated telephone system[85]
	Patient chart combining documentation from nurses and physicians[85]
	Checklists[69]
	Standardized forms[69]
	Exploring new medical technology (out-of-hospital 12-lead ECG)[69]
	New equipment (eg, thyroid shields) and maintenance on existing equipment (eg, fixing computer order problem)[78]
	Marked locations for returning equipment to right place[81]
	New procedure for moving charts served as a workflow-facilitating technology[81]
Communication and teamwork	Communication tools[76]
	Use of voicemail dictation system instead of paging[80]
	Telephone hotline to heart investigation unit[69]
	Communication center and dedicated nurse coordinator for communication about patient arrival, care, and disposition[85]
	Team assessment of patient history[74]
	Improved communication with radiology department[80]
	Rerouting of laboratory results to different printers[81]
Staffing reassignment/new roles/new responsibilities	Physicians and nurses reassigned to match peak patient volume[76] or arrival rates, generally[73]
	Allocation of dedicated fast track medical and nursing staff[77]
	Division of medical and nursing staff to work on different patient streams[72,79,85]
	Dedicated ECG and laboratory technician in ED[69]
	New screening nurse position[76]
	New communication specialist position[85]
	Increased radiology staff availability on nights and weekends[82]
	Adding technicians and transport staff[82]
	Staff with cardiopulmonary resuscitation and automated external defibrillation skills to transport patients[69]
	Triage nurse made responsible for determining assignment of patients to streams[72,81]
	Redefined responsibilities of nurse, nursing assistant, and intake coordinator[74]
	Triage nurse limited to doing triage and other staff assigned to do work previously done by triage nurse (eg, checking on treatment space availability)[80]
	Ambulatory patients encouraged to self-porter[81]

Table 2. Continued.

Process Changes	Specific Examples
Reassignment/reorganization of space	Dedicated spare bed[69]
	Space reallocated for rapidly assessing and holding patients[76]
	Reorganization of ED space to create a centrally located fast track treatment area[77] or 3 separate areas for different tracks[81]
	Design of new ED space divided into 3 pods[85]
	Dedicated express area where patients were treated sitting in chairs, not separate rooms[83]
	Use of all examination rooms[74]
	Redesigned staff work areas (Hospital B)[75]
	Designated physician examination rooms (Hospital B)[75]
	Space created for housing transport staff in ED[80]
	Some processes (eg, registration) conducted in patient treatment area, using mobile workstations[80]
	Stocking of all physician-required material to the patient's right[81]
	Reorganizing and standardizing stock carts so that commonly used items were most easily accessible[81]
Other	Stocking conducted more on as-needed basis rather than bulk deliveries[81]
	Hallway signs to direct ambulance crew traffic[69]
	Improved signs to direct patients[74]
	"Pelvic Exam in Progress" signs[78]
	Celebrations when goals achieved[83]
	Contests/incentives[69]

Study sites tended to be larger teaching hospitals in the United States, Australia, or Canada. Project team composition varied among sites, but with one exception (Dickson et al[75]), all Lean involved frontline staff in some way. The staff involved ranged from clinicians to clerks, assistants, engineers, and representatives of the patient community. Their involvement ranged from providing suggestions to designing and implementing changes. Usually, a quality improvement facilitator or Lean consultant was involved, and management or senior staff were often involved throughout Lean initiatives.

In most cases, Lean was the sole approach used. Three studies[69,82,83] combined Lean with Six Sigma, a quality improvement method based on minimizing variability. Another "borrowed from many other manufacturing philosophies."[71] In other studies, changes such as new leadership,[83] increased staffing,[77] or other ongoing quality improvement projects[78] were concomitant with Lean.

The typical approach to Lean began with process mapping, wherein the current process steps were diagramed. Time consumed for each step was measured[73,75,82,84] or estimated,[81] and in one study the location of staff at each step was diagrammed.[80] Some type of analysis typically followed, wherein bottlenecks, waste, or other problems were identified and causes or correlates of those problems were sought. After brainstorming and sometimes future-state mapping of possible improvements, project teams undertook process redesign. Often, changes were evaluated and adjusted in an iterative way; such iteration is a vital component of the plan-do-study-act cycle adopted by some studies[69,72,83] and of the *kaizen* rapid process improvement workshops reported in other studies.[73,78,81,85] *Kaizen*, or "small, low-cost, low-risk improvements that can be easily implemented,"[78] is a cornerstone of Lean and is not surprisingly the chief and sometimes sole Lean tool used in health care.[75] Other components of Lean included education on Lean,[72,75,78,81] goal setting,[79,81,83] formal root cause analysis,[69,79,82,83] and various types of data collection.[82-84]

Table 2 depicts how Lean changed work structure and process in the studied EDs. Process redesign was a formal component of all EDs' Lean initiatives except in one ED in which redesign was planned but not yet implemented.[84] Table 2 lists examples of process change, many of which involved some separation of patients into "streams" or "tracks." New or transformed processes were accompanied by new standard operating procedures, consistent with the focus of Lean on creating standard work. As depicted in Figure 2, Lean does not simply alter the process of work: numerous work structure changes accompanied process change. These included (a) new data collection and monitoring systems, (b) education and training, (c) changes to tools and technologies, (d) new systems for communication and teamwork, (e) changes in staffing, roles, and responsibilities, and (f) reassignment or reorganization of physical space. Table 2 provides examples of work system changes within each category.

Figure 3 depicts how Lean affected patient care in the studied EDs. Four trends can be seen. First, improvements were consistently reported (Figure 3). After Lean, most EDs observed reductions in length of stay, proportion of patients leaving without being seen, and waiting times. This sometimes resulted in better compliance with national standards. Second, patient outcomes often improved as well, but such improvements were rarer, and patient outcomes were less commonly measured compared with process improvements. Changes in average patient health outcomes from pre- to postLean were never measured, even though timelier care would be expected to result in better outcomes. Patient safety changes were measured in only one study, and

Improved Care Process

- Decreased ED length of stay[72,73,75,76,79-81,83,85]
  - Especially for admitted patients[72]
  - Especially for less urgent patients[76,79,81]
  - Often despite increased patient volume[73,75]
- Decreased proportion of patients leaving ED without being seen[72,75-77,81,83]
- Decreased waiting time to be seen[72,77,79-81]
  - Especially for less urgent patients[77,79]
- Increased compliance with national waiting time recommendations[72] or benchmarks[77]
  - Especially for less urgent patients[72,77]
- Increased proportion of bed requests made within 4 h of presentation[79]
- Decreased number of patients in ED at one time[72]
- Decreased variability in waiting times[72]
- Decreased time between decision made to admit patient and actual admission to hospital[80]
- Decreased proportion of time spent on hospital diversion[76]
- Decreased number of ambulance bypasses[79]
- Increased proportion of discharged patients[79]
- Staff perceived improvements in ED operation[79]

Improved Patient Outcomes

- Increased patient satisfaction[73,75,81,83,85]
- More stabilized patient satisfaction[81]
- Decreased proportion of patients re-presenting to the ED after discharge[77]
- Reduced number of hospital-wide adverse event notifications[71]
- Patients more tolerant of waiting when informed of their queue position (based on discussion with patients)[72]
- Decreased patient frustration (assumed but not measured)[77]

Worsened Care Process or Lack of Improvement

- No change in waiting time to see physician[72]
- No change to number of patients leaving ED without being seen[79]
- Decreased compliance with national waiting time recommendations for higher-acuity patients[72]

Worsened Patient Outcomes or Lack of Improvement

- Decreased patient satisfaction[75]
- No change in perceived patient safety or mortality rate[72]

Other

- Measures of improvement not yet available or not reported[69,78,82,84]

Figure 3. Effects of Lean on patient care.

even then only indirectly.[71] Third, studies predominantly reported improvements, and there were few reported decrements in patient care or failures to achieve improvement. Fourth, not every study adequately reported pre- and postmetrics. In some cases, "measures of success" (eg, door-to-balloon time, door-to-needle-time) were taken but not reported.[69] In others, measures such as patient satisfaction were not described,[83] statistical tests were not used to test pre-post differences,[20,75] or no numeric data were given to support reported changes.[83]

Indirect effects of Lean, those resulting from the types of process and structure changes described in Figure 3, were not consistently measured or discussed (Table 3). Some studies, however, observed that after changes were made, staff were less prone to aggression, more courteous, more satisfied with their job and less likely to leave, and faced lower workloads. Further, better utilization of staff, including more time available for supervision and education, communication improvements, (perceived) loss of autonomy because of standardization, and an increased sense of control were among reported working conditions resulting from Lean-driven changes.

Direct employee effects resulted from the mere presence of, and employees' participation in, the Lean initiative, quite apart from any operational changes made through Lean (Table 3). By participating in Lean sessions, process mapping, and process redesign, employees became better aware of their work and the problems therein, gained new values, and were more eager to participate in and to accept changes created by Lean. Consistent with the claims of Lean experts, some studies indeed reported that their employees became empowered to suggest future changes[72] and to control the design of their own work[75]; the high participation rates in process improvement described in one study are a testament to such empowering effects of Lean.[78] Indeed, some studies suggested that Lean may have even brought about a new participative, continuous improvement culture, leading frontline staff to take control of their own work and to participate more in shared governance.[76,78,83] In turn, managers learned to defer to their frontline staff and to value their input. Less commonly, the introduction of Lean was associated with at least initial resistance and concern over possible changes.

Unfortunately, most of the employee effects described above were not systematically assessed and were either implied or based on anecdotal evidence. For example, only 1 study actually measured staff satisfaction (using surveys) and even so did not report numeric values or statistical tests.[83]

Given the lack of information on employee effects, it was not surprising that no study measured the relationship between Lean-related patient outcomes and employee outcomes, or the reverse. However, the authors of one study wrote, "quality improvement is intimately linked to how individual providers . . . interact with patients, on a day-to-day basis in the outpatient clinic and inpatient unit frontlines."[73] Because of this vital interaction, it is possible that patient and employee outcomes influenced one another in the reviewed studies. One way that this influence might play out was suggested by another study: "Patients' irritation with delays can result in displaced anger

Table 3. Indirect and direct effects of Lean on employees.

Study	Indirect Effect of Lean		Direct Effect of Lean	
Al Darrab et al[69]	None measured or discussed	○	None measured or discussed	○
Ben-Tovim et al,[70,71] King et al[72]	Stabilized ED staffing ED regained a feeling of control Decreased verbal and physical aggression, especially at triage desk Standardization created by Lean a possible threat to autonomy	◐	Initial reluctance but eventual acceptance of change Lean sessions "created a shared awareness of how chaotic the care processes had become and generated support to change processes" Possible resistance from management to a bottom-up process for discovering and solving problems	◐
Dickson et al[73,74]	Increase in patient-rated physician and nurse courtesy	◐	With Lean, workers took on extra responsibility to improve own work, increasing workload Management came to acknowledge frontline staff's superior insight into their own work process Involvement in Lean led staff to accept and sustain changes Staff empowered to make further suggestions for change	◐
Dickson et al[75]	Hospital A: Other units eager to try Lean after evidence of improvement Hospital B: None measured or discussed Hospital C: None measured or discussed Hospital D: Increase in patient-rated physician and nurse courtesy	◐ ○ ○ ◐	By learning about Lean and participating in Lean improvement projects, participants gain new values Lean can empower workers to become designers of their own work Managers may be loath to relinquish control over process design to frontline workers In Hospital D, workers took ownership of the Lean process and demonstrated teamwork	◐
Eller[76]	None measured or discussed	○	Lean may fostered a culture of accountability Lean enhanced employee engagement in process change	◐
Ieraci et al[77]	Anecdotal improvement in work experience and job satisfaction of medical staff Better use of advanced nursing staff Increased time on supervision and teaching Improved communication with certain inpatient units	◐	None measured or discussed	○
Jacobson et al[78]	None measured or discussed	○	New culture created as a result of Lean Repeated Lean projects created positive attitudes toward future projects	◐
Kelly et al[79]	Increase in time spent directly supervising junior medical staff Staff satisfaction measured but not reported	◐	None measured or discussed	○
Kulkarni[20,80]	None measured or discussed	○	None measured or discussed	○
Ng et al[81]	None measured or discussed	○	Involvement in Lean led staff to better see process inefficiencies Involvement in Lean led staff to accept and sustain changes	◐
Parks et al[82]	None measured or discussed	○	None measured or discussed	○
Schooley[83]	Increased employee satisfaction Decreased staff turnover Initial resistance and opposition to changes Nurses perceived more manageable workload Better use of employees' skills	●	Initial concern that Lean consultant would "try to shake up the department immediately and make changes overnight" Involvement in Lean led staff to accept changes Staff became eager for further Lean improvements, and nurses started new improvement projects of their own initiative Lean led staff to value collecting data to guide change New culture created as a result of Lean After Lean, some staff became more involved in shared governance Lean changed leaders (eg, more focused toward continuous improvement)	◐
Stephens-Lee[84]	None measured or discussed	○	None measured or discussed	○
Woodward et al[85]	None measured or discussed	○	None measured or discussed	○

Empty circle, employee effects not measured or discussed; half-filled circle, employee effects discussed but assessed indirectly or anecdotally; filled circle, employee effects discussed based on standardized measures.

Prior to Lean

Readiness for change/acknowledgement of need for change[71,72,79]

Poor baseline conditions, allowing more profound improvements[75]

Management Involvement

Strong clinical leadership[71,79]

Leadership support of Lean[75]

Management defers to frontline staff's insight into their work and takes subordinate role in identifying problems and suggesting solutions[74]

Management undergoes a paradigm shift, refocusing on flow and quality[74]

Frontline Staff Involvement

Frontline staff participation in the design and implementation process[77,79,81,83]

Frontline staff engagement[75] and empowerment[73]

Frontline staff ownership of change process[78]

Frontline staff flexibility to change[75]

Frontline staff motivation to improve own work[74]

Lean Process

Easy to use, not requiring large time commitment[78]

Multidisciplinary project teams[69]

Open, iterative process[79,81]

Communication with staff[77]

Tracking and feedback of all worker suggestions for change[78]

Funding for data collection[69]

Greater focus on flow rather than on efficiency[74] or diagnosis[81]

Lean Change Initiatives

Multiple small process enhancements, not large breakthroughs[74]

Lean principles adapted to local working conditions and demographic environment[72,73]

Following Change

Skill of staff to carry out new work processes[77]

Standardize and sustain most efficient and effective way of work[71]

"Hold the gains" (ie, sustain initial improvements) and continuously improve[69,71]

Initial success encourages persistence[73]

*Factors suggested or inferred from reviewed studies.

Figure 4. Contingency factors affecting success of Lean thinking efforts.*

aimed at nurses and physicians, which deflates staff morale."[83] This suggests that reductions in delays can improve employees' quality of work life. In turn, when staff carry out improved work processes, they may exhibit increased courtesy toward patients.[73]

Only one study, Dickson et al,[75] included multiple Lean implementations across multiple EDs, and therefore only this study was able to directly address contingency factors. Dickson et al[75] wrote that "Lean is not a panacea, but rather a tool that may or may not succeed, according to the efforts surrounding its use" and more formally proposed that Lean's variable success could be understood as "context + mechanism = outcome," in which context refers to the local context of the ED and mechanism refers to Lean.[75] Based on a comparison of 4 EDs, Dickson et al[75] proposed that the 2 key contextual contingencies were (a) the involvement of frontline staff in Lean initiatives, and (b) leadership commitment to Lean. Although no other study compared EDs or hospitals (but see other comparative studies of Lean in health care[15,62]), many of the reviewed studies proposed some of the contingency factors on which their success was based (Figure 4).

DISCUSSION

Five years have passed since the first well-publicized Lean initiatives in US health care at Virginia Mason Medical Center.[11,15,86] In that time, many EDs, among other health care delivery units, have begun to apply Lean as a way to fight problems such as errors, delays, and crowding. This review revealed robust opportunities for improvement in EDs and hospital-wide using Lean but also revealed considerable limitations in Lean implementations and in reports thereof.

Lean is often characterized as a process improvement approach. Thus, not surprisingly, process change was a key component of Lean in the ED. Some process changes resembled those already advised or attempted for EDs, such as "fast-track" streaming.[87] This is indicative of Lean's role as a philosophy and an approach to change rather than as a specific process solution.[88] Perhaps this is why some EDs reported improvements with Lean but not with earlier change efforts.[71,83] Process changes and accompanying protocols served to standardize care. In routine situations anticipated by protocols, standardization can be of great benefit, but safety scientists contend that overstandardization can make a system brittle and less able to adapt to unexpected variation.[89,90] Further work must investigate the extent to which individual providers and EDs as a unit can be resilient after work standardization.

In addition to process change, work structures were modified as a result of Lean. The implication is that implementing Lean is not simply a matter of changing the way things are done. Problematic work structures are also identified and rectified through Lean, even if the focus is on process. Further, resources (eg, staffing, technology, communication) often need to be allocated to support new processes. Practitioners will need to be aware of the possibility of changing structures and not just processes, and researchers will need to measure structural changes, intended and unintended.

Patient care typically improved as a result of Lean-driven process and structure changes, implying the possible value of Lean. One would expect improvements in length of stay, waiting times, and other commonly reported efficiency

Be Ready for Change

Before implementation, there should be a shared recognition that problems exist and that improvements are needed. Failing this, Lean may be viewed as a wasted effort or as dubiously motivated ("Are they trying to make us work faster?" "Are they cutting costs?").

Take a Human-Centered Approach

Recognize the value of people (eg, workers, patients) and involve them in Lean initiatives to the extent possible. Consider the employee effects of Lean alongside patient care effects. Attend to people's needs (eg, workers' need for control, patients'/families' need for information). Address concerns such as "How will increased efficiency and performance measurement affect my job?" Practitioners will need to make time and effort for Lean projects, even when they are nonmandatory and uncompensated.

Secure Expertise

An external expert on Lean, change management, or quality improvement can educate internal stakeholders and help to facilitate initial efforts. However, over time internal stakeholders (eg, clinicians), and not consultants, will need to use their expertise to translate Lean from general tools and principles to their local context. Efforts should be undertaken to provide internal stakeholders with expertise in Lean and to ensure Lean activities can continue after the external expert departs.

Obtain Top Management Support and Resource Allocation

Without the material and nonmaterial resources needed to do a thorough job, Lean will not succeed. Lean participants will need the authority to obtain information, undertake changes, and make decisions. Budgetary needs will include worker time participating in Lean, payments to consultants and internal coordinators, education costs, and the costs of implementing, evaluating, and fine-tuning changes. Managers not only provide unique perspectives (eg, on how multiple units or services are integrated) but also build motivation and legitimate Lean as a worthwhile activity through their support and involvement.

Secure Leadership

A person or group of people will need to act as visible leaders of Lean initiatives. These leaders need not be formal leaders, although project champions who are well respected in their social group will best motivate their peers. Leaders will not only motivate but also lead improvement projects.

Aim for Culture Change

Experts on Lean argue that to implement Lean, it is not sufficient to apply a few tools. A successful Lean implementation will aim for and achieve culture change.[88] One culture change that Lean can facilitate that future implementers should perhaps strive for is the incorporation of the scientific method into organizational problem solving. Likewise, Lean can be a mechanism for establishing evidence-based decisionmaking or a learning culture.

Adapt Lean to the Local Context

Each of the 15 EDs reviewed here interpreted and implemented Lean in a distinct way. There must be no misconceptions that Lean is a program that can be purchased off the shelf and thus installed. Many decisions are required (eg, who are our internal/external customers? What tools do we use and how?), many generic concepts will need to be adapted for local use, and many adjustments will be needed over time, and all this will require resources.

Improve Continuously

Lean does not conclude after the first wave of projects. Plans should be made to sustain Lean and to continuously evaluate and adjust previous changes and to plan further change. Part of this should include establishing the architecture (eg, education, budget, top management commitment) necessary to sustain Lean in the face of evolving needs, staff turnover, and other disruptions.

Learn From Previous Experiences

No amount of advice here can substitute for learning from previous experiences with Lean—one's own and one's colleagues'. There is now a growing literature describing how health care units, organizations, and health systems have implemented Lean and, to a lesser extent, the lessons they learned. There may even be shareable "lessons learned" available from other units in the same organization or from earlier similar changes within the unit.

Figure 5. Practical suggestions for successful Lean implementation.

measures to be accompanied by improved patient health, fewer errors, or more appropriate care. Indeed, a recent study found a link between ED crowding and medication errors.[91] However, reviewed studies lacked measures of quality and safety outcome indicators, something that will need to be rectified to determine the whole effect of Lean on patients.[92]

Desirable patient care effects of Lean dominate both in the presently reviewed ED literature and in Lean health care more generally.[93] One reviewed ED study observed, "there is a current trend of reporting bias toward publishing positive—and more often than not immediate—results because hospitals who failed to achieve the intended behavioral changes do not come forward to openly analyze the reasons for their failure."[75] It is possible that a publication bias, not universally positive effects of Lean, is behind the lack of null and negative results.[22] Full disclosure by study authors and formal inclusion of the

possibility of undesirable and null effects of Lean (eg, as in Figure 2) should characterize future reports of Lean in health care. Closely related is the need for better reporting of findings, including lists of all measures with descriptions of each, numeric values (central tendency, variability), and appropriate statistical tests.[22] Other methodological needs are more longitudinal research,[22,75] the use of comparison groups,[22] the inclusion of covariates to control for secular changes besides Lean,[77] and more attention to the possibility of selection bias.[75]

Employees can be affected in 2 distinct ways, indirectly and directly, but most reviewed studies tended to avoid measuring those effects or even discussing their possibility. Improving employee outcomes was not typically a goal of Lean; as one study put it, "the purpose of this Lean initiative was to improve the care of patients who visited our emergency department."[76] When another study found that Lean allowed senior physicians to spend more time on direct supervision, study authors referred to this as "a by-product of the initiative."[79] Only 1 study repeatedly mentioned the aim to improve employees' working conditions, and this was the only study to systematically measure changes in job satisfaction.[83] Disregard of Lean's employee effects reveals an underestimate of the power of Lean to empower workers and to improve working conditions. The improvements listed in Table 3, although sporadic and poorly assessed, should inspire systematic attempts to achieve employee benefits of Lean. In parallel, Lean implementers and researchers should be aware that Lean can increase workload, threaten autonomy, and bring about anxiety. These undesirable employee effects are well documented in the broader Lean literature[32-39,94-97] but may not show up in reports on Lean in health care either because of how Lean is implemented in health care or because studies in health care simply do not measure employee effects. Measures of such effects are generally available to implementers and researchers in compendia of work measures[98,99] and individual validated questionnaires for perceived working conditions, organizational culture, job satisfaction, empowerment, fear of job loss, and more. Additionally, implementers can devise measures—observational, surveys, interviews—that assess specific employee effects of Lean (eg, the extent to which workers think they are able to suggest or initiate changes, acceptance of Lean). Once employee effects are appropriately measured, it will be possible to assess links between employee effects and patient care effects of Lean.

The possibility of direct employee effects, those related to "mere exposure" to Lean, is reminiscent of the Hawthorne effect, the phenomenon that change efforts bring about positive effects in workers merely because more interest is paid to the workers. Considering the Hawthorne effect can be instructive for understanding Lean in the ED in 3 ways. First, the Hawthorne effect is typically regarded as a confounder, meaning that the improvements listed in Figure 3 and those reported in other Lean studies may not be the result of better-designed work; as the spotlight on Lean fades, so may the improvements. Second, the Hawthorne effect is a nontrivial way to improve work. It inspired the Human Relations movement, which promoted paying greater attention to the human element of work, addressing workers' psychological needs, and letting workers feel involved; thus, according to the Human Relations school of thought, Lean can achieve real improvements if it is worker centered. Third, the major criticism of the Human Relations movement was that it disproportionally attempted to make workers feel special without substantially altering the design of work. Subsequent work, for example that of Sociotechnical Systems theorists and macroergonomists, demonstrated that the most successful change efforts are ones that attend to both humanistic needs and the operational needs for well-designed work. By implication, it is important to attend to both direct ("Hawthorne-like") and indirect ("operational") effects of Lean.

Finally, EDs in this study differed in their characteristics and they implemented Lean in different ways. For example, studies differed in which components of Lean were implemented, the nature of worker involvement and management support, and the types of changes implemented. Further work will need to assess more closely how those context differences relate to variability in Lean's patient care and employee outcomes. Such investigations will yield a better understanding of the "critical success factors" for Lean.[100] Nine success factors, derived from this review and a broader (unpublished) review of Lean in hospitals, are hypothesized here and may be of practical value to Lean implementers (Figure 5).

In conclusion, Lean appears to offer significant improvement opportunities in the ED. The EDs implementing Lean in this review reported generally favorable effects (as do studies of hospital-wide initiatives including the ED, not reviewed here). However, more work remains in understanding Lean in the ED and in health care more generally, including better assessment of Lean's effects on patient safety and quality outcomes and on employees, as well as identifying the factors on which Lean's success depends. Other questions remain as well, including how Lean can best be adapted to health care, the effect of Lean on resilience, whether Lean is sustainable in the long term, whether Lean is more effective than other approaches, and the "Karen question" (after "Karen," who seemingly single-handedly coordinated Lean improvements at Western Pennsylvania Hospital's presurgery unit[9]): Who shall do the herculean task of coordinating the massive change effort that is Lean? In sum, much remains to be learned about this promising approach.

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