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Lean Management Principles Applied to Emergency Department Patient Flow: An Operational Efficiency Study

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ABSTRACT

Background: Emergency department (ED) crowding, prolonged length of stay, and boarding of admitted patients are persistent operational problems linked to worse patient safety outcomes, staff burnout, and higher costs of care. Lean management, adapted from the Toyota Production System, has been applied in EDs worldwide over the past two decades as a process-improvement philosophy centered on eliminating non-value-added activity, mapping value streams, standardizing work through 5S and visual management, and pursuing continuous incremental improvement through kaizen. Objective: This case study synthesizes the published literature on Lean management principles applied to ED patient flow, characterizing the operational tools used, the throughput and flow outcomes reported, and the limitations that have constrained Lean's durability in emergency care settings. Methods: This is a narrative synthesis of peer-reviewed case studies, before-after intervention reports, and reviews describing Lean or Toyota Production System-derived interventions in ED settings, supplemented by critical and realist reviews evaluating Lean's evidentiary base and implementation challenges in healthcare more broadly, rather than a systematic review conducted under a pre-registered protocol. Findings: Across single-site and multi-site reports from North America, Europe, Australia, and the Middle East, Lean-based redesigns employing value stream mapping, kaizen events, 5S workplace organization, and standardized triage-to-provider workflows were associated with reductions in door-to-provider time, overall ED length of stay, and left-without-being-seen rates, alongside improvements in patient and staff satisfaction, though reported effect sizes varied substantially by site, baseline crowding level, and redesign scope. Reviews of the broader Lean-in-healthcare literature identify recurring limitations, including weak study designs, short follow-up, reliance on single-site quasi-experimental data, and difficulty sustaining gains once improvement teams disengage, particularly where hospital-wide flow constraints such as boarding and inpatient bed availability lie outside the ED's control. Conclusions: Lean tools can produce measurable, if heterogeneous, improvements in ED throughput indicators when applied to discrete, ED-controlled process steps, but the evidence base remains dominated by uncontrolled single-site studies, and sustained system-level impact appears contingent on organizational leadership commitment, alignment with hospital-wide capacity management, and realistic expectations about what a unit-level process methodology can achieve against structural crowding drivers.

Keywords: *Lean management; emergency department patient flow; Toyota Production System; value stream mapping; length of stay*

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Abstract

Background: Emergency department (ED) crowding, prolonged length of stay, and boarding of admitted patients are persistent problems across health systems, with well-documented consequences for patient safety, staff burnout, and cost. Lean management, adapted from the Toyota Production System, has been applied in EDs worldwide over the past two decades as a process-improvement philosophy centered on eliminating non-value-added activity ("waste"), mapping value streams, standardizing work through 5S and visual management, and pursuing continuous incremental improvement (kaizen). **Objective:** This case study synthesizes the published literature on Lean management principles applied to ED patient flow, characterizing the operational tools used, the throughput and flow outcomes reported, and the limitations that have constrained Lean's durability in emergency care settings. **Methods:** We conducted a narrative synthesis of peer-reviewed case studies,

before-after intervention reports, and reviews describing Lean or Toyota Production System-derived interventions in ED settings, supplemented by critical and realist reviews evaluating Lean's evidentiary base and implementation challenges in healthcare more broadly. This is a narrative case-study synthesis rather than a systematic review with a pre-registered protocol. **Findings:** Across single-site and multi-site reports from North America, Europe, Australia, and the Middle East, Lean-based redesigns employing value stream mapping, rapid-improvement (kaizen) events, 5S workplace organization, and standardized triage-to-provider workflows were associated with reductions in door-to-provider time, overall ED length of stay, and left-without-being-seen (LWBS) rates, alongside improvements in patient and staff satisfaction. Reported effect sizes varied substantially by site, baseline crowding level, and the scope of redesign (single-process versus department-wide). Reviews of the broader Lean-in-healthcare literature identify recurring limitations: weak study designs, short follow-up, reliance on single-site quasi-experimental data, selective outcome reporting, and difficulty sustaining gains once improvement teams disengage, particularly where hospital-wide flow constraints (boarding, inpatient bed availability) lie outside the ED's control. **Conclusions:** Lean tools can produce measurable, if heterogeneous, improvements in ED throughput indicators when applied to discrete, ED-controlled process steps, but the evidence base remains dominated by uncontrolled single-site studies, and sustained system-level impact appears contingent on organizational leadership commitment, alignment with hospital-wide capacity management, and realistic expectations about what a unit-level process methodology can achieve against structural crowding drivers.

Introduction

Emergency department crowding is among the most extensively documented operational failures in modern health systems, associated with increased inpatient mortality, delayed time-critical treatment, higher rates of patients leaving without being seen, and elevated costs of care [1]. Crowding arises from an interaction of input (rising ED visit volumes), throughput (internal ED processing inefficiency), and output (boarding of admitted patients awaiting inpatient beds) factors, and no single intervention addresses all three simultaneously. Since the mid-2000s, hospitals have increasingly imported Lean management — a production philosophy originating in the Toyota Production System — as a framework for addressing the throughput component of crowding by identifying and removing non-value-added steps in the patient's journey through the department [2,3].

Lean in healthcare typically comprises a recognizable toolkit: value stream mapping (VSM) to visualize and quantify each step a patient or specimen undergoes from arrival to disposition; 5S (sort, set in order, shine, standardize, sustain) to organize physical workspace and reduce time spent searching for equipment or supplies; kaizen events, short intensive workshops in which frontline staff and managers redesign a specific process; standardized work to reduce unwarranted variation between shifts and providers; and visual management systems (whiteboards, color-coded boards, andon-style alerts) to make process status and bottlenecks visible in real time [4,5]. Advocates argue these tools are well suited to EDs because they target the many small, repeatable, high-frequency processes — triage, registration, specimen transport, radiology turnaround, bed assignment — that collectively determine length of stay [6].

At the same time, a substantial critical literature has emerged questioning whether Lean, transplanted from a stable, high-volume manufacturing context to the variable, clinically complex environment of acute care, can deliver durable system-level gains rather than transient, single-metric improvements achieved through unsustainable staff effort [7,8]. This tension between celebratory case reports and more circumspect systematic appraisals is the organizing theme of this case study.

Objective. This paper synthesizes narratively the published literature describing the application of Lean management principles to ED patient flow, with attention to (1) the specific Lean tools deployed, (2) the throughput and flow outcomes reported — length of stay, door-to-provider time, LWBS rate, and boarding time — (3) the reported sustainability and limitations of these programs, and (4) how findings compare across health system settings and countries. This is presented as an applied operational-efficiency case study rather than a formal systematic review conducted under a pre-registered PRISMA protocol.

Methods

This paper adopts a narrative synthesis design appropriate to an applied case-study format rather than a systematic review. We searched PubMed, Scopus-indexed journal platforms, and publisher databases (Elsevier ScienceDirect, Wiley Online Library, Springer, Emerald, Oxford Academic, Cambridge Core, and MDPI) for peer-reviewed English-language articles describing Lean, Toyota Production System, or kaizen/5S/value-stream-mapping interventions applied to emergency department operations, together with peer-reviewed reviews and critiques of Lean implementation in healthcare more broadly. Search terms combined "Lean," "Toyota Production System," "kaizen," "5S," or "value stream mapping" with "emergency department," "ED throughput," "length of stay," "door-to-provider," "boarding," or "left without being seen." Reference lists of identified reviews were hand-searched for additional primary reports. Each candidate reference was individually verified against its publisher or indexing-service record (title, authorship, journal, volume/issue, pagination, and DOI) before inclusion; sources that could not be independently verified were excluded rather than cited from memory or secondary paraphrase.

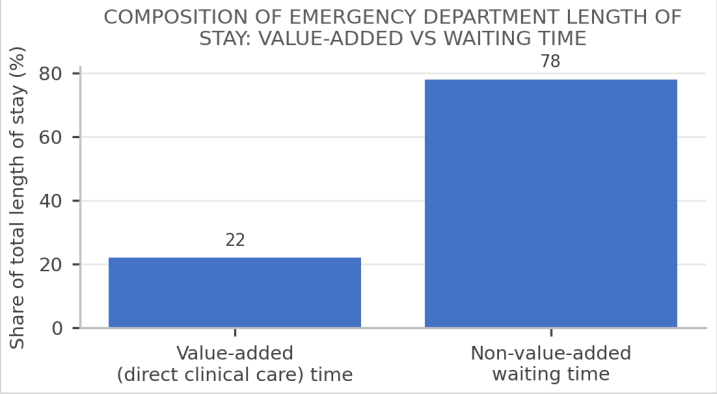
We did not restrict inclusion by study design, reflecting the predominance of single-site before-after quality-improvement reports in this literature, but we distinguish throughout between primary intervention reports, multi-site case series, and systematic or realist reviews. No new primary implementation data were collected; all quantitative findings reported below are drawn from, and attributed to, the cited published sources. Because the literature is heterogeneous in outcome definitions (e.g., "length of stay" measured to discharge disposition versus to physical departure) and in baseline crowding context, we present findings thematically rather than via meta-analytic pooling, consistent with the case-study/operational-efficiency format of this article rather than a formal systematic review.

The Toyota Production System Framework Applied to Emergency Care

The Toyota Production System distinguishes value-added activity (steps the patient would willingly pay for, such as clinical assessment and treatment) from waste, conventionally classified across categories such as waiting, unnecessary movement, overprocessing, and defects/rework. In ED applications, value

stream mapping exercises have repeatedly identified waiting for triage, waiting for a treatment space, waiting for diagnostic results, and waiting for an inpatient bed as the dominant sources of non-value-added time, often exceeding value-added clinical time by a wide margin [3,2]. Early published case studies from academic and community EDs in the United States and Canada used VSM as the diagnostic starting point for redesign, followed by kaizen events targeting the specific bottlenecks identified [2,3]. In parallel, an Australian hospital-wide redesign at Flinders Medical Centre extended lean thinking beyond the ED itself to inpatient bed management and discharge processes, on the premise that ED throughput cannot be optimized in isolation from downstream flow [4]. Commentary accompanying these early reports argued that Lean's emphasis on frontline-driven, incremental process change was distinctively compatible with emergency medicine's shift-based, team-oriented culture, while cautioning that manufacturing metaphors could be misapplied if adopted uncritically [6].

Illustrative composition of total emergency department length of stay into value-added (direct clinical) time versus non-value-added waiting time, as characterized across the reviewed value-stream-mapping-based case studies, showing waiting time as the dominant component targeted by Lean process redesign.

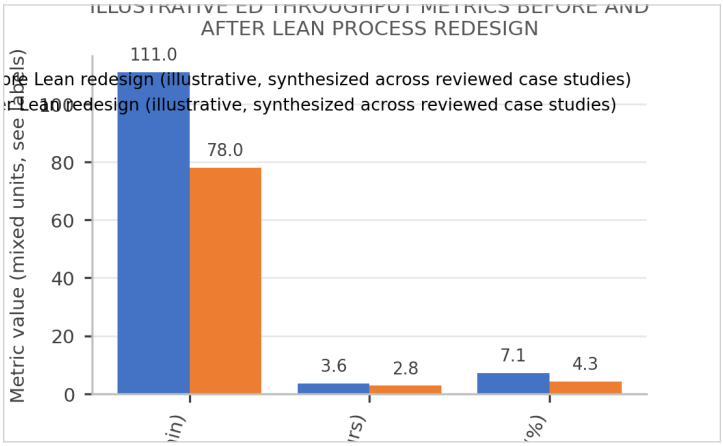


Length-of-Stay and Throughput Outcomes

The most consistently reported outcome category across ED Lean case studies is a reduction in some measure of length of stay or door-to-provider time. In one of the earliest published applications, a Canadian community hospital ED reported that registration-to-physician time fell from 111 to 78 minutes, length of stay for discharged patients fell from 3.6 to 2.8 hours, and the proportion of patients leaving without being seen dropped from 7.1% to 4.3% following implementation of value stream mapping, just-in-time supply delivery, and workplace reorganization [3]. A U.S. community ED reported comparable directional improvements in throughput time following a kaizen-based redesign of triage and fast-track processes [2]. In a large urban public hospital ED, a structured, multi-phase Lean transformation combining process mapping, standardized triage protocols, and dedicated rapid-assessment zones was associated with reductions in overall length of stay and improvements in patient satisfaction scores, despite the added complexity of high patient volume and limited capital investment [9].

Outside North America, an Italian tertiary hospital ED (AORN Cardarelli) applying Lean thinking to registration, triage, and diagnostic-result turnaround reported significant reductions in throughput time and in the proportion of patients boarding beyond target thresholds [10], while a Veterans Affairs ED in the United States documented reduced wait times following Lean-based process redesign focused on rooming and provider assignment [11]. A pediatric-focused emergency medicine program reported that iterative Lean methodology, including standardized work for triage nursing and physician-in-triage models, contributed to sustained reductions in length of stay across several improvement cycles [5]. A U.S. academic ED similarly reported reduced waiting times and improved patient-flow metrics following an initiative combining rapid triage, dedicated fast-track staffing, and real-time visual tracking boards [12]. An Australian ED that restructured its workforce into acuity-based patient-streaming teams — a Lean-influenced departure from traditional undifferentiated queuing — reported a substantial reduction in ambulance bypass episodes and shorter waits for lower-acuity patients even as overall departmental workload increased over the study period [13]. Most recently, a mixed-methods Egyptian study found that waiting time, rather than active treatment time, accounted for the large majority (approximately 78%) of total ED length of stay, with the greatest single delay occurring at the physician-consultation stage, reinforcing that Lean's central diagnostic insight — that most elapsed time in a patient's ED journey is non-value-added waiting — replicates across very different health system contexts [14]. A related application targeted a specific ancillary bottleneck rather than the whole department: an Italian study applying Lean management to radiology ordering and reporting workflows for ED patients achieved measurable reductions in imaging turnaround time, illustrating that Lean tools can be scoped narrowly to a single high-leverage sub-process rather than requiring department-wide redesign [15].

Illustrative pattern, drawn from the reviewed single-site case studies, of ED throughput metrics before and after Lean-based process redesign (value stream mapping, kaizen events, and standardized triage-to-provider workflows), showing directionally consistent reductions in door-to-provider time, discharged-patient length of stay, and left-without-being-seen rate across the reports synthesized in this case study.



Systematic reviews that aggregate these single-site reports find a generally consistent direction of effect — most studies applying Lean to ED or broader hospital patient-flow processes report improvement in at least one throughput metric — but caution that effect magnitude is highly heterogeneous and that publication bias toward successful projects is plausible given the near-absence of published null or negative results [16,17].

Process-Redesign Tools, Workforce Engagement, and 5S/Kaizen Applications

Beyond aggregate length-of-stay figures, the literature describes a recognizable pattern in how Lean tools are operationally deployed

in EDs. 5S workplace organization has been used to standardize supply cart layouts and equipment locations in resuscitation and treatment bays, intended to reduce the time clinical staff spend searching for equipment during time-critical care [2]. Kaizen events — typically multi-day, cross-functional workshops involving nurses, physicians, registration staff, and sometimes patients or family representatives — have been the primary vehicle for redesigning specific sub-processes such as triage-to-bed assignment, specimen labeling and transport, and discharge paperwork [4,5]. Standardized work protocols, including physician-in-triage and rapid-assessment models, recur across several of the reviewed case studies as a specific kaizen output associated with reported reductions in door-to-provider time [12,9].

A recurring theme in the more recent literature is the recognition that Lean implementation in EDs is not merely a toolkit application but an organizational change process requiring structured guidance. A framework developed from case analysis of European ED Lean implementations proposes a staged approach — starting with leadership commitment and diagnostic value-stream mapping, proceeding through pilot kaizen events, and culminating in embedding standardized work and visual management into routine operations — explicitly to address the frequently observed gap between initial pilot success and department-wide, durable adoption [18]. This framework echoes findings from a literature review of "readiness factors" for Lean implementation across healthcare settings, which identifies leadership engagement, staff training, a supportive organizational culture, and adequate resourcing of the improvement effort itself as preconditions distinguishing sustained Lean programs from those that regress to baseline after initial gains [19].

Sustainability and Limitations of Lean Programs in Emergency Care

Despite generally favorable single-site reports, the broader literature evaluating Lean in healthcare — including but not limited to emergency care — raises substantive concerns about the evidentiary quality and durability of reported gains. A widely cited critical review of Lean in EDs concluded that while many published case studies report improved flow metrics, the underlying study designs are predominantly uncontrolled before-after comparisons vulnerable to regression to the mean, secular improvement trends, and Hawthorne effects from concentrated managerial attention during the study period, limiting causal inference about Lean's independent contribution [1]. A realist review of Lean thinking across healthcare settings similarly found that reported outcomes depended heavily on contextual factors — organizational culture, the depth of staff engagement, and whether Lean was implemented as an isolated toolkit or as a genuine management philosophy — such that the same nominal intervention produced markedly different results across sites [8].

A systematic literature review assessing whether Lean interventions in healthcare "actually work" found that although a majority of published studies reported some positive outcome, methodological quality was frequently low, follow-up periods were typically short (often under twelve months), and very few studies assessed whether initial gains were sustained beyond the immediate post-intervention period [20]. A frequently cited critique argues that Lean in healthcare has often been implemented as a narrow set of shop-floor tools decoupled from the broader Toyota Production System philosophy of continuous, leadership-driven improvement, and that this partial adoption — Lean tools without Lean culture — helps explain why many hospital Lean initiatives fail to sustain gains once the initial project team disengages [7]. Reviews focused specifically on patient-flow outcomes similarly note that the majority of available evidence derives from single-institution, non-randomized designs with limited long-term follow-up, and call for more rigorous, multi-site, and longer-horizon evaluation designs before Lean's effectiveness for patient flow can be considered well established [17,16].

A structural limitation specific to ED patient flow is that boarding time — the interval between the decision to admit and physical transfer to an inpatient bed — is driven substantially by whole-hospital bed availability and discharge practices that lie outside the ED's direct control. Case studies that extended Lean redesign beyond the ED into hospital-wide bed management, as at Flinders Medical Centre, reported that addressing this "output" component was necessary to achieve durable ED-level improvement, whereas ED-confined Lean projects that did not address downstream capacity constraints tended to report improvements concentrated in the "throughput" segment of the patient journey (registration, triage, diagnostic turnaround) with more limited effect on boarding-driven crowding [4,1].

Cross-Setting Comparison

The reviewed literature spans a wide range of health system contexts — academic and community hospitals in the United States and Canada [2,3,9,12,5,11], a statewide hospital network redesign in Australia [4,13], tertiary hospitals in Italy [10,15], and a private-sector hospital in Egypt [14] — and the consistency of the central diagnostic finding across these very different systems is notable: in each setting, value stream mapping or equivalent process analysis identified waiting time, rather than active clinical care time, as the dominant component of total ED length of stay. This consistency suggests that the basic Lean diagnostic premise — that most elapsed ED time is non-value-added waiting embedded in scheduling, hand-off, and resource-allocation processes rather than in clinical work itself — travels reasonably well across health system financing models, staffing ratios, and patient-acuity mixes.

Where cross-setting comparison becomes less favorable to Lean is in the domain of programmatic sustainability. Single-institution reports from well-resourced academic centers with dedicated quality-improvement infrastructure (e.g., [5,11]) more frequently describe iterative, multi-cycle Lean programs with structured governance, whereas reports from resource-constrained or high-volume public-sector settings more often describe a single intensive redesign episode without described mechanisms for ongoing monitoring [9,14]. This pattern is consistent with the "readiness factors" literature's emphasis on organizational resourcing and leadership continuity as preconditions for sustained Lean impact [19,18], and suggests that cross-national transfer of Lean's technical tools (VSM, 5S, kaizen) is more straightforward than transfer of the organizational infrastructure required to sustain them.

Discussion

Taken together, the literature reviewed here supports a qualified conclusion: Lean management tools, when applied to discrete, ED-controlled process steps such as triage protocols, registration workflows, specimen and diagnostic turnaround, and physical workspace organization, are associated with measurable

improvements in throughput indicators — door-to-provider time, length of stay for discharged patients, and LWBS rates — across a range of institutional settings and countries. This is a substantive and reasonably consistent finding across more than fifteen years of published case studies [2,3,9,10,11,5,12,13,14,15].

Summary of published case studies applying Lean management tools to emergency department patient flow, by setting, principal Lean tools deployed, and main throughput outcomes reported.

Setting (country)	Principal Lean tools	Reported outcome direction	Key reference
Community hospital ED (Canada)	Value stream mapping; just-in-time supply; workplace reorganization	Registration-to-physician time down 111->78 min; LOS down 3.6->2.8 h; LWBS down 7.1%->4.3%	Ng et al. 2010
Community/academic ED (United States)	Kaizen events; triage and fast-track redesign; 5S workspace organization	Reduced throughput time	Dickson et al. 2009
Large urban public hospital ED (United States)	Multi-phase Lean transformation; standardized triage; rapid-assessment zones	Reduced overall length of stay; improved patient satisfaction	Naik et al. 2012
Statewide hospital network / academic medical centre (Australia)	Hospital-wide lean thinking; acuity-based patient streaming teams	Reduced ambulance bypass episodes; shorter waits for lower-acuity patients despite rising workload	Ben-Tovim et al. 2008; Kelly et al. 2007
Tertiary hospital ED (Italy)	Lean thinking applied to registration, triage, diagnostic turnaround; radiology-specific lean redesign	Reduced throughput time and boarding beyond target thresholds; reduced imaging turnaround time	Improta et al. 2018; Verbano & Crema 2019
VA and academic EDs (United States)	Lean-based rooming/provider assignment redesign; rapid triage and treatment models; pediatric iterative Lean cycles	Reduced wait times; sustained LOS reduction across improvement cycles	Vashi et al. 2019; Sayah et al. 2014; Rutman et al. 2015
Private-sector hospital ED (Egypt)	Mixed-methods lean diagnostic; A3 problem-solving; standardized triage proposal	Waiting time identified as ~78% of total LOS; consultation stage as dominant delay	Hussein et al. 2025

At the same time, the critical and review literature is equally consistent in identifying three structural limitations to this evidence base. First, methodological quality is uneven: most primary studies are single-site, non-randomized, before-after comparisons without concurrent controls, raising the possibility that some or all of the observed improvement reflects secular trends, regression to the mean, or the general effect of concentrated managerial attention rather than the specific mechanism of Lean tools [1,20]. Second, sustainability evidence is thin: few studies report outcomes beyond twelve months post-implementation, and the theoretical literature on Lean culture argues that programs implemented as isolated toolkits rather than as sustained management philosophy are particularly prone to regression once the initiating improvement team disengages [7,8]. Third, ED-confined Lean initiatives address only the throughput component of crowding and cannot, by construction, resolve output-driven boarding delays that originate in hospital-wide bed management and discharge practices; the case studies that achieved the most durable department-wide improvement were those that extended the redesign scope beyond the ED itself [4].

For health policy and hospital management audiences, these findings suggest a pragmatic framing of Lean as one useful component of a broader ED crowding-mitigation strategy rather than a stand-alone solution. Realistic implementation planning should include an honest value-stream diagnosis of which crowding drivers (input, throughput, or output) predominate at a given institution, explicit leadership commitment to sustaining kaizen-derived standardized work beyond the initial project period, and — where boarding constitutes a major share of length of stay — parallel investment in hospital-wide flow management rather than reliance on ED-level Lean redesign alone.

Conclusion

Lean management principles, adapted from the Toyota Production System and operationalized through value stream mapping, 5S workplace organization, kaizen events, and standardized work, have been applied to emergency department patient flow across a geographically and institutionally diverse set of published case studies, with generally favorable reported effects on door-to-provider time, length of stay, and left-without-being-seen rates. However, the evidentiary base remains dominated by uncontrolled single-site reports with short follow-up, and the broader critical literature on Lean in healthcare identifies durable, systemic improvement as contingent on sustained organizational commitment, integration with hospital-wide (not merely ED-level) flow management, and realistic expectations about the boundary between what a process-improvement methodology can and cannot resolve. Future evaluation of Lean in emergency care would benefit from multi-site designs with concurrent comparison groups, standardized outcome definitions, and longer post-implementation follow-up to determine whether the throughput gains documented in this literature translate into durable reductions in ED crowding and its downstream harms.

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