Annotated Bibliography on Lean in Healthcare Organizations
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Overview
This annotated bibliography compiles summaries and findings of systematic reviews and primary research articles focused on lean management’s application in healthcare settings, with the majority of summarized articles published within the last 3 years. All papers were published between 2000 and 2018. Articles were restricted to those that focused on lean, lean-Six Sigma, or Robust Process Improvement in healthcare and addressed outcomes, components, tool development, or barriers/facilitators of lean. Systematic reviews and primary research articles are categorized by organizational unit (e.g. ER, surgery, laboratory) in which lean was implemented.

New additions to the CLEAR annotated bibliography are updated regularly on Zotero, an open source citation software. Researchers are encouraged to check CLEAR's Zotero group library for the latest articles.

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Systematic Reviews

General


This systematic review developed a theoretical model for lean leadership in healthcare based on a general lean leadership conceptual model from researchers Dombrowski and Mielke (2013). The 5 core principles of Dombrowski and Mielke’s model were improvement culture, self-development, qualification (development of qualified employees), gemba (a lean principle that requires leaders to go to the places where value is created), and hoshin kanri (a method of aligning goals with customer focus on all levels). The authors aimed to develop a parallel model to Dombrowski and Mielke’s that was healthcare-specific.

Inclusion criteria were English-language articles of empirical studies or theoretical secondary reviews published in peer-reviewed journals published between 2000-2016. Further, articles were excluded if leadership, leadership attributes, or healthcare were not mentioned. The authors searched the variants of the following terms using MEDLINE/PubMed, EMBASE, and Emerald databases: “attributes,” “lean leadership,” “leadership,” and “health care.” These terms were combined into search syntax using MeSH terms. A total of 32 articles out of 131 potentially relevant articles were included based on the authors’ inclusion criteria.

Results from the 32 articles were then categorized based on Dombrowski and Mielke’s 5 core principles. Selected examples were as follows. Improvement culture: task identity, feedback, autonomy. Self-development: show interest, facilitate resources, emotional intelligence. Qualification: empowerment,
trust, engagement. Gemba: recognition of frontline work, communication, fairness. Hoshin kanri: define and provide value, demonstrate commitment to lean, role adaptation.

The authors concluded that these findings contribute to the development of a new framework for describing lean leadership attributes in healthcare. They noted that several attributes resembled each other, demonstrating the complex relationship between leadership attributes and principles.


This literature review analyzed 107 English language papers focused on lean healthcare to provide an update on previous literature reviews and evaluate lean’s evolution in the healthcare field. Literature searches were conducted in Engineering Village, Web of Knowledge, Scopus, and Google Scholar for the terms ‘lean health,’ ‘lean healthcare,’ and ‘lean hospital,’ and limited to articles published from March 2008 to November 2014. Papers were classified by the following 6 parameters: 1) research method, 2) country, 3) healthcare area (e.g. support activities, ancillary services, entire hospital), 4) lean tools, 5) lean methods, and 6) lean results. They included both modeling studies and empirical studies. All 107 studies were coded based on the above parameters and basic analyses (counts/percentages) were conducted to characterize the state of lean healthcare research.

Among other data points, the authors compared top countries, lean tools, and research methods identified to those found by previous literature reviews. Top countries of publication were similar to those identified in previous literature reviews; the USA had the most articles, comprising 41% of 107 studies, followed by 16% in the UK. A new development was the relatively high number of studies conducted in the Netherlands compared to previous reviews (3rd most common at 8%). Top healthcare areas were also
similar to those previously identified, with moderate heterogeneity and the most common area being clinical and therapeutic operations (42%). Lean tools, methods, and results of studies were additionally similar. The authors noted that lean continues to be used mostly superficially by applying simple tools that are common in the manufacturing industry and that articles rarely discussed difficulties with lean implementation. More studies could provide information that would help managers implement lean more quickly and successfully.

In contrast to previous lean reviews, this literature review found that the majority of papers were applied rather than conceptual. This suggests an evolution in the type of lean health publications over time. Additionally, the number of lean studies evaluating lean application across the entire hospital have increased. However, deeper lean implementation, greater global diversity, and more critical research is needed in the field.


This paper involved a systematic literature review to understand if lean healthcare management (LHM) can support Choosing Wisely (CW), an initiative created by the American Board of Internal Medicine Foundation to help reduce unnecessary care. Utilizing Scopus, PubMed, and Web of Science, a literature review was conducted to create a data source of 16 relevant studies that helped understand the link between LHM and CW.

These studies were selected based on a five step process. Step 1 searched for keywords such as lean management, choosing wisely, care appropriateness, and clinical waste, which resulted in 1177 papers.
These were then filtered down to 897 papers by excluding notes, letters, books and English papers in step 2. In step 3, papers with irrelevant subject areas and not applicable keywords brought the amount of papers down to 561 papers. Among these papers, ones not concerning healthcare sectors, not considering LHM, or omitting CW concepts were excluded. In the final stage, the 97 remaining papers were fully read and filtered down to the final 16 papers that fully referred to LHM or considered LHM in relation to CW and its concepts.

These papers helped answer the following questions: can LHM support CW objectives? If so, how does LHM contribute to these objectives? The group of selected papers were subject to a descriptive analysis; they were then studied intently based on its objectives, methods and results and categorized based on their CW objectives.

Identified studies were conducted mostly in the Netherlands (19%) and the USA (63%). Most of the studies were motivated by the rising and variable costs of healthcare, and aimed to address overuse of resources and inadequate care delivery. These motivations and objectives helped the authors examine the links between LHM and CW objectives. LHM tools were primarily used to map out patient process and then optimize the care process. Some of the specific lean tools used were Rapid Improvement Events, value stream analysis, and Root Cause Analysis. Based on current data LHM is conducive in reducing administrative, operational, and clinical waste. The literature contained limited studies regarding LHM and its use as a facilitator to support CW, but evidence demonstrated the application of LHM as a feasible tool to choose the most cost-effective solution. These results are encouraging to demonstrate how LHM can be adopted to enhance the healthcare goals of CW.

This systematic review looked at lean implementation in Ireland’s healthcare sector: how it is applied, what is it influenced by, and the level of application. This part replication study investigated lean in Ireland by reviewing hospital annual reports and conducting interviews with Irish lean healthcare experts. The first phase, the data collection from reports, consisted of a content analysis of the 2013 annual reports of the seven large, multidisciplinary hospitals in Ireland. From this phase, the researchers identified key words linked with the implementation of lean in Ireland; some of these keywords include innovation, value, productive, and process. Additionally, the seven large hospitals were separated into different levels of implementation; most hospitals fell into the category denoted “few projects,” which means that there was limited implementation of lean in most hospitals.

The second phase, the interviews, contextualized the findings through interviews with 3 leading lean experts. From this phase, researchers concluded that the experts view lean as a systemic and holistic approach to improving care. However, in Ireland, there was no evidence of a systemic implementation of lean. This is common and other literature documents this same partial implementation situation in other care centers around the world. The main explanation is that lean is relatively new to healthcare and thus, these organizations are on a journey of lean development. Another reason for the lack of systemic integration is because financial benefits of lean are often indirect; additionally, senior management at hospitals in Ireland generally has high turnover, so they are often focused on short-term growth. Some limitations on this study were a small sample of hospitals and not being able to examine longitudinal effects of lean implementation.

[https://doi.org/10.1186/s13643-017-0563-y](https://doi.org/10.1186/s13643-017-0563-y)

This systematic review evaluated the effectiveness of value stream mapping (VSM) in lean healthcare on structure, process, and outcome quality in healthcare and social care facilities. The researchers searched the following databases in February 2016: PubMed, EBSCOhost, Academic Search Complete, PSYCInfo, PSYNDX, SocINDEX, Web of Knowledge, and EMBASE ScienceDirect. Quality assessment of selected studies was conducted by 1) evaluating the study design’s level of evidence, 2) assessing risk of bias by an individual study’s design, and 3) noting whether inferential statistics and significance tests were used.

22 out of 903 studies retrieved met inclusion criteria. Large heterogeneity was found in methods and outcomes of studies. All of the studies implemented a pre-post design without control. Based on quality assessment factor #2 specified above, the authors found that none of the 22 studies met all criteria to avoid risk of bias. The researchers looked separately at the 11 out of 22 studies that used inferential statistics and significance tests to evaluate VSM’s impacts.

Overall, the authors found that no studies had high enough methodological quality to make final conclusions on VSM’s effectiveness in care settings. The papers all showed at least 1 positive effect and no negative effects of VSM on quality of care. While recognizing the risk of publication bias, they found that there is a potential association between reduction of non-value-added time and reductions in patients’ length of stay. They also noted that the elimination of non-value-added time can free up time resources for value-adding steps in care processes.

This systematic review compared the problem definitions and proposed interventions of lean thinking, care pathways, relational coordination, and modern sociotechnical design in care organizations. Data were collected using critical and thematic review of selected literature, and the COREQ checklist was used to minimize bias. The authors included 20 conceptual documents and practical guidelines for analysis. They presented a description of each redesign model’s problem definition and proposed interventions in terms of task division and coordination, as well as a comparison of the definitions and interventions.

Lean’s problem definition was found to explicitly highlight functional task division and centralized coordination on different organizational levels, which aims at economies of scale and scale efficiency. Proposed interventions were based on creation of service-oriented departments per value stream, multidisciplinary work units, and multi-skilled professionals. The authors noted that mutual adjustments and direct communication are thought to overrule standardization under lean, though there is an emphasis on standardization at the meso and micro level. In comparing all 4 redesign models, the problem definitions were found to be relatively similar. Functional task division was highlighted as problematic by each redesign model, however the suggested interventions differed. Lean thinking and modern sociotechnical design (MSD) were found to be similar in advocating process-oriented task division and decentralized coordination. Additionally, only lean and MSD explicitly considered the macro level of the organization. However, lean differed from MSD in proposing standardization at the meso and micro levels. Finally, due to lean and MSD being the only redesign models that stressed the importance of both task division and
coordination at each level, the authors noted that they can be considered more comprehensive than relational coordination and care pathways.

**Primary Research Articles**

**Acute Care**


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This simple pre-post study sought to improve hospitalist admitting capacity at Virginia Mason Medical Center (VMMC), a 336-bed acute care hospital in urban Seattle, Washington. Administrative data was used to identify mismatches between admitting volume and capacity under the hospitalist group’s pre-existing staffing model. Based on these data, the researchers determined that the department needed to accommodate for 29 admits/day with peak admission volume during the late afternoon and early evening. In contrast, the pre-existing model could only accommodate up to 22 admits. Under this model, hospitalists served in 1 of 4 roles: teaching service, float service, swing shift, or night shift. Each service had caps on how many patients could be admitted, based on the number of available physicians (e.g., swing doctors admitted up to 6 patients/day).

To improve the staffing model, first a 2-day Rapid Process Improvement event was conducted, and then followed by 3 Plan-Do-Study-Act (PDSA) cycles. The team in charge of these events was comprised of hospitalists, medical residents, and administrators. After each PDSA cycle, feedback was collected from providers in the department and changes implemented. The improvement project led to numerous changes in the staffing model. For example, start times for float services were moved to fit peak demand, teaching
service admitting was changed from every other day to daily, and a standard daytime admit sequence was
developed so each team rotated from admitting early in the day to admitting later in the day. These changes
increased capacity to 30 admits/day. Analysis of patient wait times, admission volume, and hospitalist costs
was conducted, finding that admit volume increased from 18.8 admits/day to 22.0 admits/day (p < .001).
Mean wait time from ED bed request to hospitalist admission order fell from 66 mins to 43 mins (p < .001).
Overall costs increased due to adding 2 new physicians during the project, while cost/discharge decreased
from $367 to $187 [CI: $121 - $240].

**Cardiology**

Performance Improvement in Healthcare Projects: An Ethnographic Case Study in U.A.E. *Journal of Medical
and Dental Science Research*, 3, 15–24.

This study explored the value of lean in healthcare; it starts with a literature review and summary of
lean in healthcare, followed by a case study on a successful implementation of lean in a hospital in the
United Arab Emirates. The case study explained in this paper was centered around the Sheikh Khalifa
Medical City in the United Arab Emirates. This study used the personal experiences of the Chief Quality
Officer, Dr. Samer Ellahham, as ethnographic research in demonstrating how system quality and reliability
can be improved. Ellahham explained the various manners in which lean was utilized; the main goal was to
address the Cardiac Door-to-Balloon time in primary angioplasty. This is a critical and life-saving
procedure and the goal was to achieve Door to Optimal perfusion time of less than 90 minutes for all of the
patients. To accomplish this goal, the team mapped the process and identified non-value adding steps which
helped the hospital meet and exceed their target. Additionally, the hospital had the goal of reducing wait
times for the outpatient pharmacy; the team mapped the process and eliminated non-value adding activities.
Results demonstrated a decrease from an average wait time of 40 minutes to 5 minutes. This study was limited by the single site, so it may not be possible to generalize the results. Through this ethnographic case study, the results reinforce the idea that lean adds value to patients and improves their satisfaction; additionally, it can enhance process flow and reduce errors.

**Community Health Clinic (CHC)/Rural**


This study took place in a rural hospital that served a community of roughly 3,000 in Western USA. The improvements of this hospital took place in the context of a student internship program where student engineers were sent to hospitals for two week periods to gather data on the hospitals and offer improvement strategies. To begin this study, the present-state of the hospital was assessed by measuring distance and time required to locate commonly needed items in the emergency department and to analyze the on-hand inventory status. The first test concluded that, on average, a nurses looking for a commonly needed item, traveled 151 feet, took 2 minutes and 7 seconds, and searched 5 rooms. Regarding on-hand inventory, item quantity was compared to usage data from the last 18 months and found that only 8% of the ED inventory had been ordered once a month in the last 18 months. The current par level for each item was 10, which was determined to be too high, as 33% of the on-hand inventory had not been ordered in the last 18 months.

A root cause analysis concluded that a lack of standardized locations for items as well as inappropriately high par levels were the root of the problems that the hospital was encountering. To counter these problems, a 5S strategic approach was used to create countermeasures. In this strategy, the 5S’s are sort, set, shine, standardize, and sustain; this strategy concluded that shelves and cabinets in the 4 emergency rooms should be standardized and that new par levels for items should be created. Each
emergency room was dedicated to a different purpose, but inventory in the cupboards and cabinet was standardized and labeled. The new par levels were based on item usage in the last 18 months. If the item had been ordered 2 times or more in the past 18 months, it was given a par level of 5, while all other items were given a par level of 3. After implementing these changes, travel distance decreased 21% to 119 feet, time decreased 50% to 1 minute and 3 seconds, and nurses searched 4 areas instead of 5. Additionally, total on-hand inventory decreased 52%, from 992 items to 513 items. The number of items in multiple locations within a single room decreased 79% from 14 items to 3 items.

These improvements were supplemented with further recommendations to sustain the results; these recommendations included updating staff on mapping system regularly, matching nurse supply station with ED rooms, clearing tops of supply carts to reduce clutter, and standardizing the IV caddies. These improvements initially led to concerns of limited inventory, but a report showing that a par level of 5 corresponded to 4 months worth of inventory assured hospital staff of the safety of these changes. These improvements reduced nurse search time and distance which allowed for the hospital to treat critical patients more quickly.

**Emergency Department (ED)**


This study sought to prove how lean principles can be implemented to reduce emergency department (ED) length of stay (LOS), which has negative operational consequences such as long waiting times, crowding, and safety concerns. It was conducted in the VA Palo Alto Healthcare System, located in Palo Alto, CA, and served approximately 20,000 ED visits and 5,000 medicine admissions during the study.
time. The study began with a weeklong Rapid Process Improvement Workshop to find the root causes, establish standard phases of the patient’s ED stay, and develop countermeasures to prolonged LOS. There were three root causes found: (1) inability to track delays, (2) prolonged admission processes, and (3) lack of standardized handoffs between nurses.

The major phases of the patient’s stay were divided into three time frames: (1) time from patient triage to ED provider contacting medicine team for admission, (2) time from contacting the medicine team to entering admission orders, (3) and time from admission orders to actual admission in the ward. The next step was to develop countermeasures to each root cause and corresponding time frame of the patient’s stay. A computerized order program that triggered the ED clerk to alert the medicine team automatically was developed to counter the prolonged first time frame. For the second time frame, separate admission orders were created to efficiently triage the patient out of ED. To counter the final time frame, a standard faxed report with time stamps was created to maximize the time of the charge nurse. A Daily Management System (DMS) was created to measure the productivity of the countermeasures; the DMS consisted of a brief meeting with frontline staff each morning to check the progress of the standard work on LOS.

Data was gathered for two periods, pre-intervention (March 2012- Feb 2013) and post-intervention (March 2013-Feb 2016), and compared against similar VA facilities across the same time frame. The results show that at the intervention site, the average ED LOS for medicine admissions decreased from 8.7 hours to 6.4 hours by year 3, a 26.4% reduction, which can be calculated as saving potentially 10,000 patient hours. For combined medical and surgical admissions, ED LOS was reduced from 6.7 hours to 6.0 hours. Although this study was limited by the single intervention site which served a very specific population (veterans) and the fact that baseline LOS was already quite high, this study concluded that lean management significantly reduced ED LOS for medicine admissions.

This prospective pre-post study evaluated the implementation of a new model of ED care using process mapping/value stream mapping (VSM), with the goal to reduce ED length of stay and increase compliance with Australia’s National Emergency Access Target (NEAT). NEAT was a target set by the government in 2012 requiring that all states achieve 90% compliance to a 4 hour limit on ED length of stay (EDLOS) by 2015. Secondary goals included (among others) decreasing referral times, wait times, and ambulance offload times. The study was set at the Royal Brisbane and Women’s Hospital (RBWH): an urban 900-bed adult tertiary referral center serving 74,000 patients/year.

The authors identified inefficiencies such as wasted senior expertise, poor cubicle management, ineffective referrals, and lack of surge management. Custom work sequences designed to address these issues were then tested during an 8-day trial in November 2012. Core to this was a 2-hour evaluation and referral model to reduce turnaround times. Under the novel model, ED patients would be triaged and allocated to 1 of 3 streams based on anticipated workup requirement: 1) Resuscitation/Trauma, 2) FastTrack, and 3) Waiting Room => Acute (“Hot”) zone. Data on all patients presenting to the ED over 26 weeks from February to August 2013 (post-lean) was compared to control data over the same period from 2012 (pre-lean). Time series analyses were conducted for daily NEAT compliance and daily geometric mean EDLOS.

In the post-intervention group, there was an increase in EDSSU admissions (difference between pre- and post- of 3.20% [2.72 to 3.68%]) and decrease in left without being seen/left after treatment commenced rates (-1.24% [-1.42 to -1.06%]). Adjusted NEAT compliance increased by 18.42% [17.73 to 19.11%]) and
adjusted mean EDLOS decreased by 86.83 minutes [-90.10 to -83.55]. The researchers noted that the EDLOS reduction resulted in about 2000 hours of increased ED cubicle availability/week. The associated costs of this change were a decrease of approximately 2 ward admissions and 2 internal transfers/week, without evidence of inappropriate discharge or clinical deterioration.


This before-after study aimed to investigate the impact of a lean-based ED segmentation on patient mortality and management delays in a French university hospital. ED segmentation consisted of the development of a new patient care geographical layout on a pre-existing site and changing the organization of patient flow. Data were collected through the hospital’s electronic medical record system and compared to matching seasons from the previous year to adjust for seasonal differences in mortality. A total of 83,322 patient visits were analyzed, with 61,118 before and 22,204 after segmentation. Overall, there was a significant decrease in inpatient mortality after segmentation, from 1.5% during summer 2011 to 1.3% during summer 2012 (OR = 0.85, 95% CI: 0.72,0.99).


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corresponded to 4 months worth of inventory assured hospital staff of the safety of these changes. These improvements reduced nurse search time and distance which allowed for the hospital to treat critical patients more quickly.


This simple pre-post study evaluated no-show appointments and overall number of patients referred from a Texas, US county teaching hospital Emergency Room (ER) to the hospital’s Otorhinolaryngology-Head and Neck Surgery (ORL-HNS) clinic (otorhinolaryngology refers to diseases of the ears, nose, and throat). The hospital was a large, publicly funded, safety net institution. The researchers chose to utilize a modified lean-Six Sigma methodology in response to a major budget downturn, and measured no-show appointment rates and number of patient referrals in the 12 months before and after lean implementation.

The Define, Measure, Analyze, Improve, Control (DMAIC) improvement cycle was used to define the following 3 key issues: 1) patients should not be using the ER for non-urgent complaints, 2) patients in the ER with non-urgent otolaryngology conditions should have appropriate and expedited access to the ORL-HNS clinic, and 3) medical residents have restricted duty hours and their time should be used for the most educational opportunities. After defining these issues, the researchers identified and involved key stakeholders and redesigned the referral pathway from the ER to the clinic. To track progress on issues 1 and 2, data on no-shows and referrals were collected. To measure impact on issue 3, an anonymous 10-question survey was conducted of residents who were involved in the referral process both before and after the lean-Six Sigma intervention.
ER referral visits to the clinic increased by 29% in the year after lean-Six Sigma implementation in spite of a 5.4% decrease in annual ER visits that year. A two-sample t-test revealed that average no-show rate decreased by 16.3% from baseline of 12.7% during the first 6 months (p < .02) post-intervention while the average increased by 39.8% from 29% baseline for the last 6 months (p = .002) post-intervention. Comparing the 12 months before and after intervention, the average no-show rate increased by 3.5%, but the change did not reach significance (p = 0.51). In terms of resident experience, the percent of residents who felt unprepared for clinical duty after seeing consults at the hospital at least 1-2 times/month fell from 57% pre-intervention to 14% post-intervention. The percent of residents who had to make an active effort to avoid duty hour violations also fell from 57% to 14% post-implementation.


In this simple pre-post case study, lean value stream mapping (VSM) was utilized with the goal of improving patient flow in a suburban Australian Emergency Department (ED) serving 50,000 patients/year. VSM demonstrated that care processes were difficult to follow and did not match designed processes/procedures. To address this issue, patient flow was restructured, with triage nurses streaming patients who were likely to require hospitalization to the A-side team, and those likely to be discharged directly from the ED to the B-side team. The intervention had support from senior leadership, staff were given very brief training on lean/VSM before the change, and no extra staff were provided. The authors stated that since the intervention’s introduction, this method has been followed continuously.

De-identified hospital data was compared for the 12 months before and after the patient flow changes. Data analysis found that decreases in waiting time to see a doctor and to begin meaningful
treatment were not statistically significant between pre- and post-intervention. Mean time spent in the ED before streaming was significantly reduced by 0.8 hrs ([CI: 0.71-0.89 hrs] and p < 0.001). Additionally, mean time spent in the ED was significantly decreased for both A-side and B-side patients (for A-side, 1.5 hr reduction [1.3-1.7] and p < 0.000; for B-side, 0.3 hr reduction [0.25-0.34] and p < .001). On average, the changes led to 3-4 fewer patients in the ED at any given hour due to improved efficiency. The authors concluded that this streaming method improved patient flow and was well-received by staff and patients.


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The authors aimed to address the gap in knowledge of how and why lean interventions succeed or fail. They utilized a mixed methods design to evaluate an in-depth case study of a Lean-inspired intervention in a Swedish hospital, particularly in its pediatric Accident & Emergency (A&E) Department - the largest of 3 pediatric A&Es in Stockholm. The study aimed to compare performance before and after lean intervention as well as explain how and why lean worked. The hospital’s weekly average data on waiting times and patient volume were collected for 52 weeks before and 104 weeks after Lean implementation for quantitative analysis. Additionally, qualitative data from interviews and documents were retrospectively collected from the intervention-planning phase and prospectively collected during the implementation phase. Analysis of variance (ANOVA) was used to assess differences in performance pre- and post-Lean, revealing an increase in % of patients completing their A&E visit within 4 hours from 67% to 80% [95% CI (65.5, 69.7), (78.2, 82.4)] that was maintained 2 years after the intervention. Average time to first physician consultation also decreased by 24% from 67 to 51 minutes [95% CI, (61.7, 71.5), (46.5,
56.3]) and was sustained 2 years post-Lean at 54 minutes [95% CI, (49.4, 59.2)]. The authors explained that Lean was effective because it reduced work ambiguity, created clear connections between caregivers who were dependent on each other, developed seamless and uninterrupted flow, and enabled continuous improvement through worker empowerment. Barriers to greater improvements from Lean were cited: these were job mismatch, discomfort with being monitored or with inter-professional collaboration, and some employees’ distance from change-related decision-making, leading to a feeling of being inadequately informed. The authors suggested further research into which Lean changes contribute most to performance improvement, claims of contextual conditions critical to further success, and the effects of Lean on employee working conditions.


The authors investigated the effect of Lean quality improvement methods on service reliability and efficiency in an emergency general surgery ward of a university hospital in the UK. It used an interrupted time series study design and determined outcomes by measuring 7 safety relevant care processes. This was based on 969 patients admitted during the 4-month study period before Lean intervention, and 1114 patients admitted during the 4-month study period after Lean intervention was completed. The researchers found that for the 5 process measures targeted for Lean intervention, there were significant relative improvements in compliance, ranging from 28% to 149% with a p-value 0.007. 2 processes measures were not targeted for Lean intervention and did not improve significantly. There was also a significant reduction in new safety events after transfer to other wards (p 0.028), though most adverse events were attributed to delays in investigations and treatment from factors outside of the emergency ward’s control. In conclusion, the
authors found that Lean can substantially improve compliance across multiple safety-related processes at the same time. They noted that given hospital care’s interrelated nature, this may not translate into improvements in safety outcomes unless system-wide approaches are adopted.

General


This case study conducted at a Makkah, Saudi Arabia medical city sought to improve response times in the referral system using lean-Six Sigma. Define, Measure, Analyze, Improve, Control (DMAIC) methodology was used to improve physician response times to the referral system.

In the Define phase, the research team defined 2 parties that influence the response process: physicians and the coordination office. It was identified that the time spent by the coordination office to complete their activities (filling out the form, transferring it for physician consultation, and getting final confirmation) accounted for less than 5% of all process time. Therefore, the research team focused on changing physician activities to decrease late responses to the referral system. The project objective became to improve physician response time from 79% to 95% for urgent requests and from 68% to 90% for normal ones.

Root causes of inefficiency in physician response were identified using a fishbone diagram. These included lack of physician availability due to being out of town, internet connection problems, no follow-up from the coordination office, and incomplete data.

Examples of short-term changes made in response to the root cause analysis were to call physicians directly for all urgent cases, even using the overhead calling system, escalating to the department in case a
delay has exceeded the time limit for response, and calling technical support to check system issues for repair. Some long-term actions included developing a referral acceptance procedure to delegate authority, forming a standing committee for review and acceptance of referrals, and developing an e-referral mobile app. Based on the short-term improvements, physician response time for urgent requests increased to 80.5% and for normal requests to 72.5%. While this did not meet the target, the authors noted that they expected these rates to increase further once long-term improvements were made.


This article gathered data from 11 lean consultants on an in-person panel, asking them to rank the success of 17 lean implementations at a Norwegian, 800-bed university hospital based on lean’s impact on outcomes, sustainability of improvements, and degree of achievement of stated goals. Then potential relationships between rank, team composition, targets for improvement, and time/resource usage were analyzed using a linear mixed model. Surveyed participants were selected by inviting internal lean consultants, project managers, and mentors who worked on 2+ projects to attend the panel. The consultants were separated into 2 groups to reduce bandwagon effect, and they participated in a 6-hour meeting. Inter-rater reliability was calculated to check for bias using relative standard deviation (RSD); RSD ranged from 10% to 36%, with the authors noting that an RSD lower than 15% was considered high inter-rater agreement.

A 5-point Likert scale was used to rank each intervention. An example of this scale for lean’s impact on outcomes is as follows: (1) ‘no impact on work processes,’ (2) ‘minimal impact,’ (3) ‘moderate impact,’ (4) ‘substantial impact,’ (5) ‘comprehensive wide-ranging impact.’ The authors conducted linear regression to analyze associations.
Employee and safety-staff representation, executive management attendance, and patient-related goals were significantly positively associated with a higher ‘impact’ ranking. Cross division interventions were negatively associated with ‘sustainability’ rankings, while employee and safety-staff representation, comprehensive project organisation, and patient-related goals were positively associated with sustainability. Finally, ‘effectiveness’ rankings tended to be lower for interventions that ranged across divisions, but higher among interventions with comprehensive project organisation, employee and safety-staff representation, executive management attendance, a multi-disciplinary team composed of several professions, and patient-related goals. The authors noted that 5 out of 17 interventions (30%) were ranked highly successful, 10 as moderately successful (60%), and 2 (10%) ranked minimally so.

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In this simple pre-post study, researchers utilized lean value stream mapping (VSM) to eliminate waste and improve timely and reliable provision of durable medical equipment and supplies at a US Midwestern children’s hospital. VSM was led by a 5-member improvement team comprised of staff from each of the relevant departments within the hospital.

The improvement team spent 60 days learning lean principles and conducting a pilot improvement program using 5S lean principles. Lead time and process time were identified as likely causes of delays, with VSM conducted on the processes’ current states and identified work areas to apply continuous improvement practices. Baseline and post-implementation data was collected using paper data collection sheets attached to request forms for medical equipment/supplies. Of the 10 vital process steps and 9 in-between steps identified in the request process by VSM, 1 new step was added and 2 old steps were
removed. Pickup of completed request forms by the health information management department was additionally changed from batch processing (weekly) to daily pickup.

Results showed that median lead time for processing requests decreased from 50 days to 3 days post-lean ($p < .0001$). Median processing time also decreased from 14 min to 9 min ($p < .0001$). Finally, estimated annual cost of completing requests fell from $29,000 to $18,000. The authors perceived that the lean intervention additionally led to boosted morale among employees processing requests, increased recognition of these employees’ work, and decreased conflict for staff members.


This study sought to improve patient satisfaction by reducing the time patients spend in the system at a local hospital, specifically targeting the ophthalmology department. This objective was carried out through the use of the DMAIC model. The DMAIC model consists of five phases: defining the goals, mapping the process, identifying customers and high impact characteristics, measuring data, and controlling implementation. In this case study, the define phase sought to identify the project scope and objectives. Utilizing an ABC analysis which classified the hospital practices based on frequency, the team discovered that eye surgeries were the most frequent operation; eliminating wasteful time associated with these operations became the primary goal. Additionally a SIPOC diagram was created to understand the scope of the project. A SIPOC diagram is a visual tool that helps to map out the overview of the process by defining suppliers, inputs, process, outputs, and customers.
At the end of the define phase, the hospital top management specified length of stay targets for cash paying customers and insurance utilizing customers: 95 minutes and 100 minutes, respectively. In the measure phase, a detailed process map was created, which divided the day case surgery into three main phases. These phases included admission, pre-operation, and post-operation. Baseline measurements were conducted for the times consisting of the admission stage, pre-operation phase, operation, and discharge time. Results indicated an average time of 158.68 minutes for cash paying patients and 190.37 minutes for insured patients. In the analyze phase, the team sought to find non-value adding steps and track the root causes of the time delays in the admission, pre-operation, operation, and post-operations phases; non-value adding steps accounted for about 48% of the total time in the system. In the improve phase, the DMAIC team generated solutions to the delays. The proposed improvement initiatives included a full time resident doctor at the day case department, improved information transfer with insurance companies, shared databases of network associated departments, revision of registration forms, and new scheduling processes to enhance flexibility at the pre-operation department. As a result of these proposed solutions, some of these improvement strategies were implemented in the control phase. The study concluded by finding that having a full-time doctor at the day case department decreased patient cycle time by over 25 minutes, from around 48 minutes to slightly over 20 minutes. Other solutions like collaborating with insurance companies and standardized work also helped reduced delays.


This paper involved the development of a lean readiness assessment tool and a case study applying the developed tool to different hospital departments. The researchers worked with a lean implementation
team from a healthcare group to develop the framework, and used fuzzy-based input to create an overall ranking. Fuzzy technique is a method for overcoming imprecise/vague responses by using degrees of truth as a mathematical model of vagueness; it was utilized by the authors in codifying interview responses. The researchers also conducted a literature review on over 130 case studies of lean healthcare implementation to inform tool development.

The lean readiness assessment tool asked respondents to rank both readiness level and importance of numerous elements: leadership and executive team, frontline management team, lean sensei and team, patients and other customer groups, supplier groups, and healthcare institution attributes. These elements were further divided into sub-elements (e.g., within leadership and executive team, “job security policies” and “lean positions instituted”). An example of a description for “leadership and executive team” is as follows: “Healthcare unit needs to have high commitment and push from the top management to implement lean.”

The authors implemented this tool in a case study of a healthcare organization, collecting data from a physician, nurse, executive team member, member of the lean team, and staff of the primary care clinic. They found that the organization was “average ready” in the realms of leadership and executive team, frontline management team, and lean sensei and team. It ranked as “low ready” in patients and other customer groups, with a need to improve “knowledge of its patients on ‘end to end’ process pathway.” Similarly, it ranked “low ready” on healthcare institution attributes due to low “capacity and demand matching efforts,” which the authors stated could be addressed by using data from existing systems. On the other hand, the tool also identified strengths in sub-elements of healthcare institution attributes, such as the case organization’s patient and employee safety policies. Finally, the assessed primary care clinic ranked
“not ready” in the supplier groups element, with a need for greater collaboration with key suppliers and a measurable service quality system.


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This article involved content validation of the Employee Perception to Assess Lean Implementation Tool (EPLIT) in Portuguese and English, as well as regional validation in Brazil, the US and UK. EPLIT was adapted from a manufacturing to a healthcare setting. The Delphi technique was used for validation, which involved generating consensus of a number of professionals who work or research in lean healthcare. The researchers invited clinicians, managers, and academics from all levels to participate in the validation process. Two Delphi rounds were completed, with the first round involving reading the instrument, scoring each item from 0 (did not understand item) to 5 (completely understand and have no doubts about the item), and adding comments. After revision of items that received scores between 1-3, a second round of scoring and comments was completed.

Validation in Brazil, the UK, and the US was conducted by a small number of professionals in varied lean healthcare roles including hospital employees, consultants, and researchers. The number of participants who completed both rounds of validation in Brazil was 9 and in the UK was 7. For the English EPLIT version, the Delphi method was first applied to validate a British English version. Then the researchers recruited a new group of healthcare management professionals to validate a final version of the EPLIT that could be applied to both the US and UK.
The authors noted differences in the validation process for the US and UK versus Brazil. In particular, due to lean healthcare’s more recent emergence in Brazil, it was more difficult to recruit professionals that worked in lean healthcare, and more explanation of lean terminology was needed. Identified issues were inadequate vocabulary of lean or healthcare-related terms as well as translation issues. The authors concluded that the instrument was now valid in both Portuguese and English.


4 case studies of lean implementation were conducted at University of Pittsburgh Medical Center (UPMC), a large urban, academic U.S. health system. Process mapping/root cause analysis (RCA) was run to identify root causes of issues. Based on RCA, expected performance was determined, work redesigns developed, and daily monitoring enacted to identify deviations from expected performance.

Results from 4 case studies were as follows. In Experiment 1, RCA found time-consuming workarounds in intravenous (IV) antibiotic push procedures. The Five Whys were asked and a countermeasure tested. Experiment 1 resulted in 4 minute/dose reduction in preparation time and decreased discomfort for patients. Authors estimated total annual savings of 5,000 RN hours/year from this experiment. Experiment 2 was held in the surgery unit. RCA found that nurses spent 49 minutes/day per unit searching for keys to access pain medication. The developed countermeasure was to provide each nurse with his or her own key and at the end of each shift, pass the key on to the next RN. Result was savings of 2,895 RN hours and improved ability of patients to receive pain relief. Experiment 3 was conducted at a pharmacy with the goal of minimizing oversupply/undersupply of drugs. The pharmacy determined it would create a redesigned picking station and Kanban inventory system to reduce wasted time, motion, and excess drugs while providing for patient needs. This led to a 60% reduction in trips to
multiple locations, 85% reduction of stock-outs, 14 days of zero stock outs, and cost savings of approximately $210,000. Finally, Experiment 4 involved improving medication administration timeliness. RCA/Five Whys found that late administration was due to lack of specificity in the process of filling and delivering medication orders. To resolve this, filling of 24-hour doses was rescheduled to later in the morning and the on-duty pharmacist would arrive earlier to assist with medication checking. This resulted in an 88% decrease in missing medications after 2 weeks.

Lessons learned were the need for substantial leadership time commitment and resources devoted to lean. Additionally, dedicated team leaders were needed for each ‘learning line’ (work process to be improved) and the authors recommended that no other work redesign occur simultaneously with lean. Team preparation, a ‘no layoff policy,’ and active employee involvement were similarly required.


This case-control study evaluated the effect of the UK’s Productive Ward (PW) program, a lean healthcare program, on work engagement over time in Ireland. The researchers surveyed ward-team members at 9 PW sites in acute Medical/Surgical, Rehabilitation, and Elderly services using the Utrecht Work Engagement Scale questionnaire (UWES-17) and compared scores to those of ward-team members at a cohort of matched control sites. The survey was conducted at two time intervals: T1, up to 3 months after PW commencement (sample size: 253 case | 249 control), and T2, 12 months later (sample size: 233 case | 236 control).
Overall, the authors found that ward-team members at the case sites had higher engagement scores both at T1 and T2 in comparison to controls, controlling for employment grade and specialty. While the total engagement score and its 3 dimensions (dedication, absorption, and vigour) were all significantly higher among cases at T1, this changed at T2, with only scores in the ‘vigour’ dimension remaining significantly higher (p = .006). The authors found these results to indicate that the Productive Ward program had a moderately positive impact on work engagement.


This doctoral dissertation involved the creation and use of a new literature-based survey instrument for assessment of contextual factors in lean healthcare. The author tested the instrument by surveying quality improvement (QI) practitioners at a large New Zealand District Health Board who had recently completed a small-scale lean improvement project or had participated in lean training programs. Contextual factors assessed in the survey based on literature review were as follows: human resource capability (subdivided into teamwork and respect for people), lean actions, positive or negative motivation, and previous experience. These factors were evaluated for their impact on self-reported success of lean.

Results from the survey administration showed that contextual factors of teamwork, respect for people, lean actions, and negative motivation were significantly associated with self-reported success. Meanwhile, previous experience and positive motivation were not significantly associated with success (p > .05). A final regression model found a statistically significant adjusted R² = 0.58. The author concluded that these results validated the results of a previously developed model, the Model for Understanding...
Success in Quality. Proposals for further research included identifying more detailed causal mechanisms and testing predictive models for contextual factors.

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With the rising age of Turkey’s population, as the percentage of 65 year olds is expected to rise to 21% of the total population by 2050, there is a growing need to reduce healthcare costs. This study took place at the Ataturk Rehabilitation Application and Research Center of Uludag University in Bursa, Turkey. It aimed to use lean methodology to shorten invoice processing times in order to create a highly efficient institution and reduce the high operative costs. This intervention site sees an average of 120 patients per day. 85% of the hospital’s budget comes from the day to day payments by patients, while 14% and 1% come from the Social Security Institution (SSI) and donations, respectively. The Social Security Institution is the state healthcare provider and the medical center obtains reimbursements by processing invoices and sending them to the SSI. However, the processing times at this site often took longer than the maximum SSI reimbursement period of 2 months, so the site was often unable to obtain reimbursements.

To begin the study, a value stream map was used to depict existing process flow; this map found an average time of 67.69 days to process the invoices (SD= 4.05). The team then conducted an analysis of the value and non-value adding steps of the invoicing process; prior to the study, there were 16 possible routes of action, but after removing and consolidating steps in the process, 4 primary routes of invoice processing were left. Time improvement reduced invoice processing time to an average of 11.11 days (SD=2.61, p<0.001). Other improvements in this intervention include the standardization of tasks by updating the job descriptions for all personnel in the invoicing process as well as root cause analysis. Some of the root
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causes include lack of signatures on documents, mistakes on treatment dates, and mistakes on patient codes. Finally, a Kaizen approach was used to maintain the success of the intervention which included regular meetings, training all hospital personnel on invoice control, and updating forms to maintain accordance with SSI.

In order to determine the impact of lean on patient satisfaction, a 9 question survey was distributed before and after the implementation. Using a 5 point scale as a measure of satisfaction, this survey was distributed to 117 and 91 patients before and after the implementation, respectively. The significant change was an improvement in satisfaction for the statement “The time spent in the facility was what I expected.” As a result, the researchers concluded that lean does not have any adverse effects on patients while lowering costs. Some limitations include the single intervention site and the small sample size in patient surveys.

Instrumentation/Technology


This study focused on pediatric inguinal hernia repair (PIHR), a surgery conducted by both pediatric surgeons and pediatric urologists. The researchers specifically focused on reducing the number of instruments by 25% through a single, standardized tray for both surgeons and urologists. Taking place at the Hospital for Sick Children in Toronto, this study took place between October 2014 and June 2015. This observation and implementation research took the form of two phases: pre and post-standardization. Phase I included baseline measurements; four independent researchers observed all PIHRs performed to count the number of instruments used. Instruments were considered used if the surgeon held it at least once, even if
this instrument was not used in the surgery. The data was compiled to propose a standardized tray of instruments that were used in greater than 50% of the observed surgeries. In this phase, 44 procedures by surgeons and 12 procedures by urologists were observed. For the surgeries performed by surgeons, 51 instruments were in the original tray: 16 were used in over 50% of the cases, 18 were used less than 50% of the time, and 17 were never used. For the surgeries performed by urologists, 96 instruments were in the original tray: 16 were used in over 50% of cases, 11 were used less than 50% of the time, and 68 were never used.

In Phase II, researchers used these results to create a standardized tray of the 28 instruments that were used over 50% of the time. While this tray was the primary tray, the old sets were available as back-ups in all surgeries. Data was collected for cycle time to observe the time to rinse, sterilize and re-pack each tray. Cycle time data was collected on 10 non-standardized urologist trays, 10 non-standardized surgeon trays, and 10 standardized trays. Additionally, the amount of non-standardized trays opened and used was measured. In Phase II, 52 cases were observed, but only 4 non-standardized, back up trays were opened; one was by accident, one was opened and not used, while 2 were opened and used. Cycle time was reduced from 11 minutes for the old urologist tray and 8 minutes for the old surgeon tray to 5 minutes for the standardized tray. Additionally, the weight decreased from 13.5 lbs for the old urologist tray and 11.2 lbs for the old surgeon tray to 8 lbs for the standardized tray. Prior to Phase I, a survey was conducted to understand the perception of surgeons and nurses on the standardization proposal; 87% of nurses and 59% of surgeons thought that the standardization would improve patient care. After the implementation, 91% of nurses though the new tray was better, while 3% saw no difference, and 6% thought it was worse. 60% of surgeons thought that the standardized tray was better, 33% saw no difference, and 7% thought it was worse. Whe primary aim of this study was fulfilled, the study was limited by a variety of factors. Some of these factors include not specifically studying the cost impact, including only a single study site, not
measuring long-term sustainability, and not validating the survey. Additionally, there was a discrepancy in the number of survey participants before and after the implementation of countermeasures, providing the opportunity for a response bias. In conclusion, the study standardized the work of PIHRs and improved efficiency in a variety of ways.

**Laboratory**


This article described “Lean Enablers for Clinical Laboratories (LEfCL),” a checklist of 136 best practices for clinical laboratories that was developed by regional laboratory directors at Kaiser Permanente (KP), a large US Health Maintenance Organization, based on 6 lean principles: value, value stream mapping (VSM), flow, pull, perfection, and respect. This work to identify Lean Enablers was completed as project-based master’s coursework for the first two authors. Additionally, this article documents the results of a lean intervention in a US, Southern California KP regional clinical laboratory over 2014-2016. This laboratory performs over 30 million tests per year ranging from routine to highly specialized clinical laboratory tests.

The authors defined Lean Enablers as lean-based best practices that minimize waste, test result turnaround time, cost, and frustrations of providers/patients, while maximizing test quality and work satisfaction. Enablers were solutions that came about as the product of identified clinical laboratory Challenges. Lean Enablers were typically one sentence statements e.g. “reduce batch sizes,” with some Enablers that required further explanation being described in a few sentences or paragraphs. Examples of Challenges were siloed departments, laboratory specimens not sorted upon receipt, and uneven flow of
work due to large amount of specimens received at irregular times. Examples of Enablers are routinely and frequently conducting team huddles, placing specimens directly into racks for sorting and processing, and placing sample pick-up locations near the laboratory’s truck parking lots.

The authors described quantitative and qualitative results from lean improvements conducted between 2014-2016, and provided a list of lean improvements made based on the LEfCL Lean Enablers. In the molecular genetic pathology laboratory, average turnaround time was reduced from 10 days to 5 days in 2 years. In the automated chemistry laboratory, consolidation of tubes led to a $42,000 cost reduction over 2 years. Additionally, in the bacteriology laboratory, capacity for lab tests increased by 6% from about 1.4 million to 1.5 million samples. The authors suggested that LEfCL could be most helpful for planning new laboratories and training new hires.

**Ophthalmology/Optometry**


This simple pre-post study utilized lean-Six Sigma tools at a midwest outpatient ophthalmology clinic in the US to reduce patient flow times (time between check-in and check-out) and wait times. Data on all patient visits at the clinic were collected for 3 months of baseline assessment from October to December 2014, resulting in data for 2,078 visits and 1,250 unique patients. 6 weeks of data was then collected 3 months post-lean, from March to April 2015, on 1,071 visits and 871 unique patients.

Root cause analysis was performed with a fishbone diagram to identify causes of potential increased patient flow time. 16 contributing factors (e.g., patient language fluency, employee training level, facility
capacity) were identified as leading to long throughput time. Additionally, through VSM, the researchers identified that nearly all patients took 1 of 5 routes through the clinic. The identification of these paths led to process redesign under which staff members immediately started patients into 1 of the 5 pathways to reduce waiting time. The clinic then adjusted staffing to address high demand tasks, such as technician work-up, and changed scheduling based on root cause predictors of patient flow times. Separate resources and schedules were allocated to each of the 5 pathways (e.g., injection path) to decrease time variation and minimize potential for bottlenecks.

After the intervention, mean patient flow time decreased by 20 mins (18%, p < .05). For the injection pathway, patient flow time dropped by 43 mins (36%, p < .01). The authors found that lean-Six Sigma can be applied to other clinics where waiting times are a problem.

**Pharmacy**


This study was conducted at a private hospital in Ipoh, Malaysia that, on average, sees 926 patients per month. The goal of this study was to determine the factors causing long waiting times in this medical center and create effective improvement procedures against these causes. The improvement process occurred in four main steps. In stage 1, the team was tasked with determining the department or clinic with highest patient volume by analyzing patient volume statistics. The team found that consultant physician specialists see the highest volume of patients; more specifically, the geriatrician physician specialist has the most patients. On average, the hospital processes 926 patients a month. Following this, during stage 2 the team measured the initial waiting times using a stopwatch to determine where most waste occurred.
team measured 300 patient’s medical process flow and found 6 main hospital flow groups based on which centers the patients visited. The team identified the medical services that involved the most wasted time: physician clinic, pharmacy, X RAY, CT SCAN, and electrocardiogram. Utilizing a main effects plot, the team was able to determine the specific medical service that caused the highest waiting time, which turned out to be the pharmacy. In stage 3, a value stream map was created to analyze patient flow and understand the value or non-value adding steps. The pharmacy sees an average of 5000 patients per month; the current standard time for obtaining 1 or 2 medications is 15 minutes and 25 minutes for 3 or more medications. The team found that idle time in the pharmacy accounted for 33.54% of the total time in the pharmacy. In the pharmacy, payment and order entry were deemed non-value adding if an integrated IT system could be implemented that would make multiple registrations unnecessary and simplify pharmacy workflow. Finally, in stage 4, via group discussions about hospital policy and procedures, the team proposed improvement plans to counter these delays. After conducting root cause analyses, the team proposed several countermeasures in addition to the integrated IT system. These proposals included rearranging the pharmacy, obtaining a new printer, and a larger pill cutter. Finally, a new urgency initiative was proposed, where one worker was placed in charge each day to encourage more urgency and improve efficiency in the pharmacy. Based upon all these initiatives, the team estimated that the total time spent in the pharmacy could be reduced by 21% from 705.2 seconds to 557.1 seconds. The team concluded that the application of lean concepts can be useful in identifying non value adding workflow and reducing waiting times.

This simple pre-post study utilized the lean-Six Sigma DMAIC (Define, Measure, Analyze, Improve, and Control) framework in order to improve drug administration efficiency and reduce interruptions of drug rounds in a large 600-bed teaching hospital in Ireland. The intervention involved pharmacy staff, nursing staff, and healthcare assistants in a single 20-bed orthopedic ward; focus was placed on the 8:00am drug round, which was the busiest round of the day. Based on value stream mapping, 3 sources of disruption were identified: 1) direct interruptions to nursing staff during the medication round from staff members, patients, and relatives; 2) drug supply issues (e.g., medication not available in utility room, requiring nurses to search and retrieve it); 3) drug charting issues (e.g., drug chart contains omissions or errors that nurses must clarify or correct before drug administration). Key outcome measures evaluated were average number of interruptions, average drug round time, and variation in time taken to complete drug round.

Root cause analysis was used to identify suggested areas for improvement. The intervention then involved training to ensure that all nursing and pharmacy staff would be involved in the project and a formal feedback process. Solutions implemented included designating one nurse to unpack and restock medications on arrival from the pharmacy each day, redesigning the drug order communications board, and adding “Do not interrupt” signs to drug trolleys.

Tally sheets were used to capture data on frequency of interruptions during and length of each 8am drug round over a 2-week period before and after the lean-Six Sigma intervention. Mean drug round duration fell from 125 (SD = 50 min) to 95 minutes (SD = 23 min), a 24% reduction in time. Additionally,
average number of interruptions/drug round fell from 12 interruptions at baseline to 11 post-intervention. The authors noted that these changes equated to a 6 hour/week savings.


4 case studies of lean implementation were conducted at University of Pittsburgh Medical Center (UPMC), a large urban, academic U.S. health system. Process mapping/root cause analysis (RCA) was run to identify root causes of issues. Based on RCA, expected performance was determined, work redesigns developed, and daily monitoring enacted to identify deviations from expected performance.

Results from 4 case studies were as follows. In Experiment 1, RCA found time-consuming workarounds in intravenous (IV) antibiotic push procedures. The Five Whys were asked and a countermeasure tested. Experiment 1 resulted in 4 minute/dose reduction in preparation time and decreased discomfort for patients. Authors estimated total annual savings of 5,000 RN hours/year from this experiment. Experiment 2 was held in the surgery unit. RCA found that nurses spent 49 minutes/day per unit searching for keys to access pain medication. The developed countermeasure was to provide each nurse with his or her own key and at the end of each shift, pass the key on to the next RN. Result was savings of 2,895 RN hours and improved ability of patients to receive pain relief.

Experiment 3 was conducted at a pharmacy with the goal of minimizing oversupply/undersupply of drugs. The pharmacy determined it would create a redesigned picking station and Kanban inventory system to reduce wasted time, motion, and excess drugs while providing for patient needs. This led to a 60% reduction in trips to multiple locations, 85% reduction of stock-outs, 14 days of zero stock outs, and cost savings of approximately $210,000. Finally, Experiment 4 involved improving medication administration timeliness. RCA/Five Whys found that late administration was due to lack of specificity in the process of
filling and delivering medication orders. To resolve this, filling of 24-hour doses was rescheduled to later in the morning and the on-duty pharmacist would arrive earlier to assist with medication checking. This resulted in an 88% decrease in missing medications after 2 weeks.

Lessons learned were the need for substantial leadership time commitment and resources devoted to lean. Additionally, dedicated team leaders were needed for each ‘learning line’ (work process to be improved) and the authors recommended that no other work redesign occur simultaneously with lean. Team preparation, a ‘no layoff policy,’ and active employee involvement were similarly required.

**Primary/Preventive Care**

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This study sought to prove how lean healthcare improves patient satisfaction in primary-care centers by investigating 2 qualitative case studies and a quantitative analysis based on the Swedish National Patient Survey. For the case studies, the researchers selected centers that had successfully implemented lean, meaning that they had used lean for 5 years and documented improvements. The data for improved patient satisfaction was collected in interviews and document reviews. The purpose of the case studies was to determine how primary-care centers defined value from a patient’s perspective and which lean tools were helpful in the improvement. The researchers mapped the sequence of activities of the patients and the activities of the staff to determine the value-adding steps. Results from the qualitative case studies showed increased availability by phone, shorter waiting times, decreased stress and improved staff satisfaction, indicating that the implementation of lean was successful.
In the quantitative study, the researchers used data from the Swedish National Patient Survey (NPS) from 2009, 2011, and 2013. They analyzed the 23 (out of 50 total) questions on the survey that were expected to be positively impacted by lean implementation. The test group (“lean group”) included data from primary care centers that had been using lean for at least 3 years, while the control group (“non-lean group) included primary care centers that were not working with lean. The analysis investigated the difference in patient satisfaction between the lean and non-lean group. Results were first analyzed by time frame. In 2009, there were no significant differences in patient satisfaction. However, in 2011, the lean group patients were less satisfied with physicians listening to what they had to say. Additionally, they were less satisfied with physicians paying sufficient attention to the patient's experience. In 2013, no significant difference were found. Results were then analyzed over time. Significant decreases were found in patient satisfaction between 2009 and 2011, as well as between 2009 and 2013. The results imply a negative impact over time for the lean primary-care centers. However, this study was limited by multiple factors. Such limitations include small mean differences in the tests, difficulty in obtaining even distribution of responses, and lack of understanding of how lean was implemented in the lean groups. The study concluded that although literature suggests that lean healthcare improves patient satisfaction, the research demonstrated that primary-care centers utilizing lean did not have more patient satisfaction than non-lean groups.

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This study was a controlled before-after study of how lean-Six sigma can reduce parenteral medication administration. The goal of this study was to obtain a 50% reduction in medication administration errors associated with parenteral medication administration, which is a very common source of high risk adverse drug events. The first step of this study was to obtain baseline measurements of parenteral medication administration errors in a control ward and intervention ward. The errors were classified by type (wrong patient, drug, time, duration, dose, dose form, and route of administration) and by medical severity.

When an error was observed, the disguised observer was allowed to intervene. During the baseline period in the control ward, 19 medical administrations were observed, and in 14 (74%) of these administrations at least one error was made, with a potential risk of harm in 6 (32%). For the intervention ward, 13 medical administrations were observed, and in 6 (46%) of these administrations at least one error occurred, with a potential risk of harm in only one (8%). These measurements were made between August and October 2015. A DMAIC-cycle was established to find improvement strategies; these included substituting bolus injections with infusions, increased education of nursing staff, more availability of instruction leaflets and reimplementing drug round tabards to reduce interruptions. The effects of these improvement strategies were measured from March to April 2016 in the same manner of the baseline test. In the post intervention measurement, 100 medication administrations were observed in the control ward and 59 in the intervention wards. In the control ward, 76 (76%) administrations had at least one error, with a potential risk of harm in 14 (14%). In the intervention ward, 40 (68%) administrations had at least one
error but no potential risk of harm in any of them. The differences between baseline and post intervention measurements did not reach statistical significance, but the study power was limited by the low quantity of baseline measurements. Other limitations included having only a single control and intervention ward and not measuring sustainability. However, the results are encouraging and lean-Six Sigma appears to be a promising improvement strategy for reducing administration errors with a risk of harm.

**Radiology**


External beam radiation therapy requires processes that are difficult to contain within a 15 minute treatment slot; this study sought to streamline the underlying workflow processes using the Kaizen approach to enhance efficiency and increase safety. The project took place at the Center for Advanced Medicine at the Hofstra-Northwell School of Medicine where on average, 100 patients are seen daily to be treated with external beam radiation therapy. The metric used to observe the changes was the average time for completion of tasks, noted by digital time stamps as the patient went through the system. The study was organized into 4 distinct phases. In the first phase, the team drew up a process map of 90 tasks and took baseline measurements of each task. 66.1% of tasks were completed within the normal duration of 15 minutes, 30.6% were completed in 15-30 minutes and 3.2% of tasks took over 30 minute. In phase 2, the team created a list of issues that had a potential impact on efficiency and safety. Then (phase 3), researchers organized the issues by the level of effort required to fix them as well as the benefit that may be reaped if implemented. In phase 4, the researchers targeted initiatives toward the high benefit, low cost issues, and implemented them. There were four countermeasures implemented. In the first measure an extra monitor
was installed in the treatment room to reduce the distance therapists had to walk. Other initiatives included reworking automation processes to reduce errors, implementing software to export and retrieve documents rather than manually obtaining them, and standardizing the therapist’s role.

Before these implementations, average time to complete a task was 13.6 minutes, but was reduced by 10% to 12.3 minutes in the 6-month follow up period after these measures were implemented (p=0.001), demonstrating statistical significance and improving efficiency. 77.2% of the tasks were completed in the normal duration, 20.3% were completed within 15-30 minutes, and 2.5% took longer that 30 minutes. These results demonstrate the increase in efficiency due to the Kaizen approach. The average saving of 1.3 minutes per task translates to an average of 15.2 weeks saved annually. Additionally, the increase in efficiency allowed for improvements for patient safety via improved peer review. Some limitations of this study include missing timestamp data from some patients and not interviewing therapists on their perceptions of the culture before and after the countermeasures were implemented.


In this longitudinal time series study conducted in an Italian radiotherapy clinic, researchers utilized lean-Six Sigma tools of DMAIC (Define, Measure, Analyze, Improve, Control), Poka-Yoke, and visual management to decrease errors in the 2D-2D whole breast radiotherapy (WBRT) repositioning process. These projects were led by an interdisciplinary team of 2 radiation oncologists, 2 medical physicists, 3 radiotherapy technicians, and 2 lean experts.

A retrospective analysis of repositioning shifts was applied over 30 months of clinic data (July 2014 - December 2016) to identify potential cause-effect relationships in errors. A fishbone diagram was created
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Digital Reconstructed Radiography parameters were reviewed and optimized to improve tissue visualization, and radiotherapy technicians began visually reporting cases of large median shifts in order to help technicians on the next shift. The monthly percentage of almost zero shifts was chosen as a good outcome to monitor stability due to its monthly variation prior to the lean-Six Sigma intervention (despite its low clinical significance).

The researchers found that the monthly percentage of almost zero shifts decreased from 13.2% [CI: 7.1% - 19.3%] to 4.8% [4.2% - 5.4%] during the control period after lean-Six Sigma implementation and remained stable for the following 5 months. Standard deviation of almost zero shifts decreased significantly, indicating an effect of increased process standardization. Distribution symmetry also improved (skewness decreased from 1.4 to 1.1). The authors concluded that lean-Six Sigma implementation successfully improved the WBRT repositioning process.

Surgery


This study sought to improve the quality and efficiency of instrument availability within operating rooms by reducing the number of instruments. Conducted at the Virginia Medical Center, an urban hospital that on average performs 17,000 surgeries per year, this center processes over 5.2 million instruments annually, with an average of 300 instruments per case.

In the planning of this intervention, the existing operating room instrument flow was measured; this flow consisted of tray setup, room preparation, details of the procedure, cleaning up after the procedure and...
reprocessing the instruments. A Kaizen event focused on the inability to track actual instrument usage and the inability to remove instruments from the tray even if the utility diminished, and a 5S approach was used to improve the quality of the instrumentation process. In the sort phase, the instruments were sorted based on their usage and their necessity. After observing 20 cases by a variety of surgeons, the instruments that had not been used were identified for removal in the simplify phase. In the sweep phase, team members and surgeons were allowed to include any instruments they felt necessary and block any removals. In the standardize phase, new trays were developed that contained only necessary and emergency instruments. In the final self-discipline phase, a new instrument tracking process was implemented to ensure maintenance of success.

To evaluate the effect of the lean 5S approach, the primary measure compared the number of instruments for the same surgeries performed by the same surgeons before and after the intervention. Additional measurements included the lengths of surgeries. The study focused on the 885 patients who had minimally invasive spine surgery and the 156 who had deep brain surgery. Instrument availability fell 70% from 197 to 58 instruments for minimally invasive spine surgery. Similarly, deep brain surgery instrument availability fell 78% from 134 to 30. Additionally, setup times for minimally invasive spine surgeries decrease from 13.1 minutes to 8.2 minutes (p=0.0015). For minimally invasive spine surgeries, mean surgery time decreased from an average of 74 minutes to 66 minutes (p<0.001) and from 55 minutes to 48 minutes for open spine surgeries (p=0.0019). However, the decrease in surgery times was similar for both intervention and control groups (p=0.679), which indicates that the lean intervention may not be solely responsible for the reduction. An expenditure savings report was conducted and using these results, found an elimination $60,000 in wasteful instrument processing expenditure in 2012, with the potential to save up to $2.8 million per year. Based on these results, lean methodology can lower costs by reducing waste and improve quality by reducing setup times and simplifying instrumentation. This study was limited by a

This case study focused on reducing hospital acquired infections (HAIs) in general surgery departments at an Italian university hospital using lean-Six Sigma (LSS). The authors used DMAIC (Define, Measure, Analyze, Improve, Control) as a framework for implementation. The dependent variable that the organization sought to minimize was the number of patients with at least 1 positive sample of sentinel bacterium as reported by the hospital’s microbiology department. Data on independent variables were collected via the hospital database and descriptive analyses conducted using Fisher’s and chi square tests.

Correlations between independent variables (e.g., age, sex, hospitalization days, number of surgical procedures) and HAI status were calculated in order to identify root causes of risk. The only statistically significant correlation was between number of procedures and HAI risk, and this became the focus of the improvement efforts. The following causes were identified as impacting HAI risk: 1) information about procedures to reduce HAIs, 2) information about HAI risk factors, 3) information systems to collect infection data, and 4) standardized safety procedures. A quality control plan was implemented to address these causes, including more careful data collection and early identification of colonized patients. These changes resulted in a reduction in HAIs from 0.36% to 0.19% of patients. The authors noted that a multihospital study could be useful in testing LSS efficacy in different environments.

This simple pre-post study evaluated no-show appointments and overall number of patients referred from a Texas, US county teaching hospital Emergency Room (ER) to the hospital’s Otorhinolaryngology-Head and Neck Surgery (ORL-HNS) clinic (otorhinolaryngology refers to diseases of the ears, nose, and throat). The hospital was a large, publicly funded, safety net institution. The researchers chose to utilize a modified lean-Six Sigma methodology in response to a major budget downturn, and measured no-show appointment rates and number of patient referrals in the 12 months before and after lean implementation.

The Define, Measure, Analyze, Improve, Control (DMAIC) improvement cycle was used to define the following 3 key issues: 1) patients should not be using the ER for non-urgent complaints, 2) patients in the ER with non-urgent otolaryngology conditions should have appropriate and expedited access to the ORL-HNS clinic, and 3) medical residents have restricted duty hours and their time should be used for the most educational opportunities. After defining these issues, the researchers identified and involved key stakeholders and redesigned the referral pathway from the ER to the clinic. To track progress on issues 1 and 2, data on no-shows and referrals were collected. To measure impact on issue 3, an anonymous 10-question survey was conducted of residents who were involved in the referral process both before and after the lean-Six Sigma intervention.

ER referral visits to the clinic increased by 29% in the year after lean-Six Sigma implementation in spite of a 5.4% decrease in annual ER visits that year. A two-sample t-test revealed that average no-show rate decreased by 16.3% from baseline of 12.7% during the first 6 months (p < .02) post-intervention while
the average increased by 39.8% from 29% baseline for the last 6 months (p = .002) post-intervention. Comparing the 12 months before and after intervention, the average no-show rate increased by 3.5%, but the change did not reach significance (p = 0.51). In terms of resident experience, the percent of residents who felt unprepared for clinical duty after seeing consults at the hospital at least 1-2 times/month fell from 57% pre-intervention to 14% post-intervention. The percent of residents who had to make an active effort to avoid duty hour violations also fell from 57% to 14% post-implementation.


This study focused on pediatric inguinal hernia repair (PIHR), a surgery conducted by both pediatric surgeons and pediatric urologists. The researchers specifically focused on reducing the number of instruments by 25% through a single, standardized tray for both surgeons and urologists. Taking place at the Hospital for Sick Children in Toronto, this study took place between October 2014 and June 2015. This observation and implementation research took the form of two phases: pre and post-standardization. Phase I included baseline measurements; four independent researchers observed all PIHRs performed to count the number of instruments used. Instruments were considered used if the surgeon held it at least once, even if this instrument was not used in the surgery. The data was compiled to propose a standardized tray of instruments that were used in greater than 50% of the observed surgeries. In this phase, 44 procedures by surgeons and 12 procedures by urologists were observed. For the surgeries performed by surgeons, 51 instruments were in the original tray: 16 were used in over 50% of the cases, 18 were used less than 50% of the time, and 17 were never used. For the surgeries performed by urologists, 96 instruments were in the
original tray: 16 were used in over 50% of cases, 11 were used less than 50% of the time, and 68 were never used.

In Phase II, researchers used these results to create a standardized tray of the 28 instruments that were used over 50% of the time. While this tray was the primary tray, the old sets were available as back-ups in all surgeries. Data was collected for cycle time to observe the time to rinse, sterilize and re-pack each tray. Cycle time data was collected on 10 non-standardized urologist trays, 10 non-standardized surgeon trays, and 10 standardized trays. Additionally, the amount of non-standardized trays opened and used was measured. In Phase II, 52 cases were observed, but only 4 non-standardized, back up trays were opened; one was by accident, one was opened and not used, while 2 were opened and used. Cycle time was reduced from 11 minutes for the old urologist tray and 8 minutes for the old surgeon tray to 5 minutes for the standardized tray. Additionally, the weight decreased from 13.5 lbs for the old urologist tray and 11.2 lbs for the old surgeon tray to 8 lbs for the standardized tray. Prior to Phase I, a survey was conducted to understand the perception of surgeons and nurses on the standardization proposal; 87% of nurses and 59% of surgeons though that the standardization would improve patient care. After the implementation, 91% of nurses though the new tray was better, while 3% saw no difference, and 6% thought it was worse. 60% of surgeons thought that the standardized tray was better, 33% saw no difference, and 7% thought it was worse. Whe primary aim of this study was fulfilled, the study was limited by a variety of factors. Some of these factors include not specifically studying the cost impact, including only a single study site, not measuring long-term sustainability, and not validating the survey. Additionally, there was a discrepancy in the number of survey participants before and after the implementation of countermeasures, providing the opportunity for a response bias. In conclusion, the study standardized the work of PIHRs and improved efficiency in a variety of ways.

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In this simple pre-post study, a 12-month lean quality improvement (QI) project was conducted at a large academic US medical center to increase usage of evidence-based tobacco use treatment (TUT) for hospitalized neurosurgical patients who indicated current tobacco use (usage within 30 days prior to admission). With this aim in mind, the improvement team utilized A3 problem-solving to guide the QI process and increase adherence to a TUT consult protocol for neurosurgery inpatients. This protocol involved both nicotine replacement therapy (NRT) and counseling referrals. Solutions to increase adherence included adding tobacco use to the RN manager’s daily checklist and adding counseling and NRT to common neurosurgery post-op order sets.

Data was collected on utilization of TUT practices before and after intervention to assess impact. Counseling referral rates increased from 31.7% to 62% post-intervention. Inpatient NRT prescription rates increased from 15.3% to 28.5% and discharge NRT prescription rate increased from 9.0% to 19.3%. Additionally, patient satisfaction surveys and follow-up calls were administered to patients with current tobacco use who were referred for counseling. 89% of respondents to the patient satisfaction surveys indicated that they were satisfied with the counseling provided (38.4% response rate). Intent-to-treat analysis was used and follow-up calls found that the quit rate was 15.2%.

4 case studies of lean implementation were conducted at University of Pittsburgh Medical Center (UPMC), a large urban, academic U.S. health system. Process mapping/root cause analysis (RCA) was run to identify root causes of issues. Based on RCA, expected performance was determined, work redesigns developed, and daily monitoring enacted to identify deviations from expected performance.

Results from 4 case studies were as follows. In Experiment 1, RCA found time-consuming workarounds in intravenous (IV) antibiotic push procedures. The Five Whys were asked and a countermeasure tested. Experiment 1 resulted in 4 minute/dose reduction in preparation time and decreased discomfort for patients. Authors estimated total annual savings of 5,000 RN hours/year from this experiment. Experiment 2 was held in the surgery unit. RCA found that nurses spent 49 minutes/day per unit searching for keys to access pain medication. The developed countermeasure was to provide each nurse with his or her own key and at the end of each shift, pass the key on to the next RN. Result was savings of 2,895 RN hours and improved ability of patients to receive pain relief.

Experiment 3 was conducted at a pharmacy with the goal of minimizing oversupply/undersupply of drugs. The pharmacy determined it would create a redesigned picking station and Kanban inventory system to reduce wasted time, motion, and excess drugs while providing for patient needs. This led to a 60% reduction in trips to multiple locations, 85% reduction of stock-outs, 14 days of zero stock outs, and cost savings of approximately $210,000. Finally, Experiment 4 involved improving medication administration timeliness. RCA/Five Whys found that late administration was due to lack of specificity in the process of filling and delivering medication orders. To resolve this, filling of 24-hour doses was rescheduled to later in
the morning and the on-duty pharmacist would arrive earlier to assist with medication checking. This resulted in an 88% decrease in missing medications after 2 weeks.

Lessons learned were the need for substantial leadership time commitment and resources devoted to lean. Additionally, dedicated team leaders were needed for each ‘learning line’ (work process to be improved) and the authors recommended that no other work redesign occur simultaneously with lean. Team preparation, a ‘no layoff policy,’ and active employee involvement were similarly required.

**Tool Development Articles**


This paper involved the development of a lean readiness assessment tool and a case study applying the developed tool to different hospital departments. The researchers worked with a lean implementation team from a healthcare group to develop the framework, and used fuzzy-based input to create an overall ranking. Fuzzy technique is a method for overcoming imprecise/vague responses by using degrees of truth as a mathematical model of vagueness; it was utilized by the authors in codifying interview responses. The researchers also conducted a literature review on over 130 case studies of lean healthcare implementation to inform tool development.

The lean readiness assessment tool asked respondents to rank both readiness level and importance of numerous elements: leadership and executive team, frontline management team, lean sensei and team, patients and other customer groups, supplier groups, and healthcare institution attributes. These elements were further divided into sub-elements (e.g., within leadership and executive team, “job security policies”
An example of a description for “leadership and executive team” is as follows: “Healthcare unit needs to have high commitment and push from the top management to implement lean.”

The authors implemented this tool in a case study of a healthcare organization, collecting data from a physician, nurse, executive team member, member of the lean team, and staff of the primary care clinic. They found that the organization was “average ready” in the realms of leadership and executive team, frontline management team, and lean sensei and team. It ranked as “low ready” in patients and other customer groups, with a need to improve “knowledge of its patients on ‘end to end’ process pathway.” Similarly, it ranked “low ready” on healthcare institution attributes due to low “capacity and demand matching efforts,” which the authors stated could be addressed by using data from existing systems. On the other hand, the tool also identified strengths in sub-elements of healthcare institution attributes, such as the case organization’s patient and employee safety policies. Finally, the assessed primary care clinic ranked “not ready” in the supplier groups element, with a need for greater collaboration with key suppliers and a measurable service quality system.


This article described “Lean Enablers for Clinical Laboratories (LEfCL),” a checklist of 136 best practices for clinical laboratories that was developed by regional laboratory directors at Kaiser Permanente (KP), a large US Health Maintenance Organization, based on 6 lean principles: value, value stream mapping (VSM), flow, pull, perfection, and respect. This work to identify Lean Enablers was completed as project-based master’s coursework for the first two authors. Additionally, this article documents the results of a lean intervention in a US, Southern California KP regional clinical laboratory over 2014-2016.
laboratory performs over 30 million tests per year ranging from routine to highly specialized clinical laboratory tests.

The authors defined Lean Enablers as lean-based best practices that minimize waste, test result turnaround time, cost, and frustrations of providers/patients, while maximizing test quality and work satisfaction. Enablers were solutions that came about as the product of identified clinical laboratory Challenges. Lean Enablers were typically one sentence statements e.g. “reduce batch sizes,” with some Enablers that required further explanation being described in a few sentences or paragraphs. Examples of Challenges were siloed departments, laboratory specimens not sorted upon receipt, and uneven flow of work due to large amount of specimens received at irregular times. Examples of Enablers are routinely and frequently conducting team huddles, placing specimens directly into racks for sorting and processing, and placing sample pick-up locations near the laboratory’s truck parking lots.

The authors described quantitative and qualitative results from lean improvements conducted between 2014-2016, and provided a list of lean improvements made based on the LEfCL Lean Enablers. In the molecular genetic pathology laboratory, average turnaround time was reduced from 10 days to 5 days in 2 years. In the automated chemistry laboratory, consolidation of tubes led to a $42,000 cost reduction over 2 years. Additionally, in the bacteriology laboratory, capacity for lab tests increased by 6% from about 1.4 million to 1.5 million samples. The authors suggested that LEfCL could be most helpful for planning new laboratories and training new hires.

This article involved content validation of the Employee Perception to Assess Lean Implementation Tool (EPLIT) in Portuguese and English, as well as regional validation in Brazil, the US and UK. EPLIT was adapted from a manufacturing to a healthcare setting. The Delphi technique was used for validation, which involved generating consensus of a number of professionals who work or research in lean healthcare. The researchers invited clinicians, managers, and academics from all levels to participate in the validation process. Two Delphi rounds were completed, with the first round involving reading the instrument, scoring each item from 0 (did not understand item) to 5 (completely understand and have no doubts about the item), and adding comments. After revision of items that received scores between 1-3, a second round of scoring and comments was completed.

Validation in Brazil, the UK, and the US was conducted by a small number of professionals in varied lean healthcare roles including hospital employees, consultants, and researchers. The number of participants who completed both rounds of validation in Brazil was 9 and in the UK was 7. For the English EPLIT version, the Delphi method was first applied to validate a British English version. Then the researchers recruited a new group of healthcare management professionals to validate a final version of the EPLIT that could be applied to both the US and UK.

The authors noted differences in the validation process for the US and UK versus Brazil. In particular, due to lean healthcare’s more recent emergence in Brazil, it was more difficult to recruit professionals that worked in lean healthcare, and more explanation of lean terminology was needed.
Identified issues were inadequate vocabulary of lean or healthcare-related terms as well as translation issues. The authors concluded that the instrument was now valid in both Portuguese and English.