Lean Performance Indicators and Facilitators of Outcomes in U.S. Public Hospitals

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SUMMARY

Goal: This study investigated the association between Lean and performance outcomes in U.S. public hospitals. Public hospitals face substantial pressure to deliver high-quality care with limited resources. Lean-based management systems can provide these hospitals with alternative approaches to improve efficiency and effectiveness. Prior research shows that Lean can have positive impacts in hospitals ranging in ownership type, but more study is needed, specifically in publicly owned hospitals.

Methods: We performed multivariable regressions using data from the 2017 National Survey of Lean/Transformational Performance Improvement. The data were linked to publicly available hospital performance data from the Agency for Healthcare Research and Quality and the Centers for Medicare & Medicaid Services. We examined 11 outcomes measuring financial performance, quality of care, and patient experience and their associations with Lean adoption. We also explored potential drivers of positive outcomes by examining Lean implementation in each hospital, measured as the number of units using Lean tools and practices; leader commitment to Lean principles; Lean training and education among physicians, nurses, and managers; and use of a daily management system among C-suite leaders and managers.

Principal Findings: Lean adoption and implementation were associated with improved performance in U.S. public hospitals. Compared with hospitals that did not adopt Lean, those that did had significantly lower adjusted inpatient expenses per discharge and

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higher-than-average national scores on the appropriate use of medical imaging and timeliness of care. The study results also showed marginally significant improvements in patient experience and hospital earnings before interest, taxes, depreciation, and amortization margins. Focusing on these select outcomes, we found that drivers of such improvements involved the extent of Lean implementation, as reflected by leadership commitment, daily management, and training/education while controlling for the number of years using Lean.

Practical Applications: Lean is a method of continuous improvement centered around a culture of providing high-value care for patients. Our findings provide insight into the potential benefits of Lean in U.S. public hospitals. Notably, they suggest that leader buy-in is key to success. When executives and managers support Lean initiatives and provide proper training for the workforce, improved financial and operational performance can result. This commitment, starting with upper management, may also play a broader role in the effort to reform healthcare while having a positive impact on patient care in U.S. public hospitals.

INTRODUCTION

Public hospitals are integral to the delivery of healthcare in the United States. They play an important role as safety net providers that allow people from underserved groups to access essential care. Despite their importance, public hospitals are typically underfunded and have fewer resources to support patient care than private nonprofit and for-profit hospitals (Fred, 2018). At the same time, they are held accountable for the quality of care provided while demonstrating positive outcomes (Felland & Stark, 2012).

The financial challenges faced by public hospitals can be a hindrance to their success. Recent attempts at resolving this problem include the passage of the Affordable Care Act (ACA). The ACA provided financial incentives to states to increase Medicaid enrollment, which would increase hospital revenue via Medicaid payments for many previously uninsured patients. However, the ACA also authorized new patient care models, such as patient-centered medical homes and accountable care organizations that emphasize primary care, which were intended to reduce hospital admissions. To address the challenges of maintaining financial viability while improving the quality of care, many public hospitals have adopted Lean management principles and techniques for performance improvement (Griffith, 2017; Toussaint et al., 2020).

Lean was developed in the manufacturing industry by the Toyota Motor Corporation (Spear & Bowen, 1999). It is a sociotechnical system based on a culture of continuous improvement (Soliman et al., 2018) that involves the use of various tools and techniques to enhance work processes. The fundamental objective of Lean is to enhance organizational performance through worker empowerment, thereby increasing value for customers (Womack & Jones, 2015). First adopted in the 2000s by organizations such as the Virginia Mason Medical Center (Nelson-Peterson & Leppa, 2007) and the Thedacare Health System (Toussaint & Berry, 2013), Lean

has steadily grown in U.S. healthcare settings over the past 20 years.

Lean management provides hospitals with a robust set of practices that healthcare professionals can use to identify problems and implement potential solutions (Shortell et al., 2018). The most notable is a daily management system (DMS) that supports the organization's cultural transformation. A DMS specifies practices such as daily work huddles, Gemba (workplace) walks, visual management tools for tracking priorities, analysis tools such as scatter plots, A3 thinking, value stream mapping, plan–do–study–act (PDSA) cycles, and standardization of work processes.

Many hospitals have used Lean and related approaches (i.e., Lean Six Sigma, Robust Process Improvement) in an attempt to deliver higher-quality care more efficiently (Salah et al., 2010). For example, Po and colleagues (2019) found that Lean adoption was associated with higher earnings before interest, taxes, depreciation, and amortization (EBITDA) margin and a lower percentage of patients leaving the emergency department without being seen. Successful implementation of the various Lean approaches to process improvement may positively affect performance in healthcare organizations, including publicly funded hospitals (Henrique & Filho, 2018; Shortell et al., 2013; de Souza, 2009).

Hypotheses

Despite the increasing number of hospitals implementing Lean nationwide (Toussaint & Berry, 2013; Toussaint et al., 2020), little is known about Lean management in U.S. public hospitals. Recent studies show that although Lean adoption is associated with decreased costs and improved financial performance, as well as improved patient flow (Tlapa et al., 2020), there is a call for stronger evidence demonstrating the relationship between Lean and performance in public hospitals (Fournier & Jobin, 2017; Po et al., 2019). Using the same measures of Lean adoption and implementation used in previous studies of Lean in hospitals of all ownership types combined (Rundall et al., 2021; Shortell et al., 2021), we examined whether public hospitals that adopted a Lean management approach exhibited better financial performance, higher quality of care, and enhanced patient experience compared with public hospitals that did not adopt Lean.

> Hypothesis 1 (H1): U.S. public hospitals that adopted Lean or its related approaches are associated with better performance on financial indicators, quality of care, and patient experience compared with public hospitals that did not adopt Lean, controlling for organizational and market factors.

In public hospitals that reported adopting Lean, we examined the extent of Lean implementation as measured by the number of hospital units using Lean, degree of Lean training/education offered to frontline providers and managers, daily use of Lean practices, and level of leader commitment to Lean principles. Within this subset of hospitals, we hypothesized that a higher degree of Lean implementation would be associated with better performance on outcomes.

> Hypothesis 2 (H2): The extent of Lean implementation in U.S. public

hospitals that reported adopting Lean or its related approaches is significantly associated with improved hospital performance, controlling for length of time of Lean use, organizational factors, and market factors.

METHODS

Measures and Data Sources

The Survey Data Center of the American Hospital Association (AHA) administered the National Survey of Lean/Transformational Performance Improvement (NSL) in 2017. The online survey was sent to 4,500 acute general medical and surgical hospitals throughout the United States, including 934 public hospitals. The response rate among all surveyed hospitals was 27.3%. Topics about Lean adoption and implementation included whether the hospital had adopted Lean or related performance improvement systems, date of adoption, extent of current use of Lean, approach to implementing Lean, leadership commitment to Lean management, use of a DMS, use of Lean tools, number of Lean tools used, and Lean training for managers and clinicians (Shortell et al., 2018).

Study Variables

The independent, dependent, and control variables and their descriptions and data sources built on those used in previous studies are presented in Table 1 (Po et al., 2019; Rundall et al., 2021; Shortell et al., 2018). *Lean adoption* was measured dichotomously based on whether a hospital reported using some form of Lean methodology. Hospitals were coded "1" if they used Lean or its related approaches (i.e., Lean plus Six Sigma, Robust Process Improvement) and "0" if they did not.

The *extent of Lean implementation* was assessed by the number of hospital departments/units—out of a possible 29 that are common to all general medical–surgical hospitals—in which Lean or its related methodologies were used. The extent of Lean implementation was also assessed by using indexes measuring the degree of Lean penetration among leaders and staff members. These variables included an index ranging from 0 to 4 indicating the degree of Lean education and training provided to physicians, nurses, and managers; an eight-item index of leader commitment to Lean practices; a nine-item index pertaining to the use of Lean DMS by C-suite executives; and a nine-item index of DMS use by department managers. The rationale for and validation of all scales are described in more detail elsewhere (Po et al., 2019; Shortell et al., 2021) and in the appendix to this article, published as Supplemental Digital Content at http://links.lww.com/JHM/A101.

Because Lean is a far-reaching approach to operational excellence (Nelson-Peterson & Leppa, 2007), it is important to examine a comprehensive collection of hospital performance measures. We selected 11 hospital performance indicators (i.e., dependent variables), including the following:

- **Financial performance.** EBITDA margin and adjusted inpatient expense per discharge
- **Quality of care.** Appropriate use of medical imaging; patient safety; timeliness of care

TABLE 1

Descriptions of Independent, Dependent, and Control Variables

Variable	Description
Independent variables[a]	
Lean adoption	Binary indicator measure for each hospital. Yes (1) = hospital reported adopting Lean, Lean plus Six Sigma, and/or Robust Process Improvement; No (0) = hospital did not report adoption of Lean, Lean plus Six Sigma, and/or Robust Process Improvement.
Number of years doing Lean	Number of years since Lean adoption (range: 0.25–22.50)
Number of units doing Lean	Number of units in the hospital that have adopted Lean (possible range: 0–29)
Education and training index	Number scale of educational level and training for managers, nurses, and physicians throughout the hospital (possible range: 0–4)
Leadership commitment index	Number scale of leaders' commitment toward Lean throughout the hospital (possible range: 0–8)
Daily management system: C-suite	Number of activities that C-suite incorporated into their daily routine. Includes use of daily huddles, visual management, setting of True North, Gemba walks, visual management, use of analysis tools, A3 thinking, development of standard work, and use of standard work (possible range: 0–9)
Daily management system: managers	Number of activities that managers incorporated into their daily routine. Includes use of daily huddles, visual management, setting of True North, Gemba walks, visual management, use of analysis tools, A3 thinking, development of standard work, and use of standard work (possible range: 0–9)
Dependent variables	
30-day risk-adjusted mortality index[b]	Percentage: 30-day risk-adjusted mortality, averaged across patients with heart failure, pneumonia, AMI, COPD, stroke
Adjusted inpatient expense per discharge[b]	Cost per inpatient discharge adjusted for case mix and area wage indexes
EBITDA margin[c]	Percentage: earnings before interest, tax, depreciation, and amortization/total operating revenue
Severity-adjusted geometric length of stay[b]	Risk-adjusted average length of stay for a patient from admission to discharge
HCAHPS score[b]	Index: Patient responses to the question, "How do patients rate the hospital, overall?" (from a standard survey required by the Centers for Medicare & Medicaid Services), were coded into low, medium, and high categories, and a weighted scoring system was used to create a summary measure ranging from 100 (100% of patients rate the hospital low) to 300 (100% of patients rate the hospital high).

TABLE 1

(Continued)

Variable	Description
30-day readmission rates[b]	Percentage: number of patients readmitted to the hospital within 30 days of discharge/all discharges (adjusted for severity of diagnosis)
Patients who left ED without being seen[b]	Percentage: patients who left the ED before being admitted to the hospital/total patient arrivals in the ED
Patient Safety Indicator 02 death rate in low-mortality DRGs[b]	Ratio: deaths of patients in low-mortality DRGs/total patients in low-mortality DRGs
Composite: appropriate use of medical imaging[b]	1 = better than national average, 2 = same as national average, 3 = worse than national average. Hospital Compare Star Rating calculation based on 5 measures
Composite: patient safety[b]	1 = better than national average, 2 = same as national average, 3 = worse than national average. Hospital Compare Star Rating calculation based on 8 measures
Composite: timeliness of care[b]	1 = better than national average, 2 = same as national average, 3 = worse than national average. Hospital Compare Star Rating calculation based on 5 measures
Control variables	
Region[d]	Categorical: Midwest, Northeast, South, West
Core-based statistical area type[d]	Categorical: metropolitan (urban area of at least 50,000 people), micropolitan (urban areas between 10,000 and 50,000 people), or rural (nonurban area)
Bed size[d]	Categorical: 1–99 beds, 100–399 beds, or ≥400 beds
Market concentration[b]	Categorical: unconcentrated (HHI from 100 to <1,500), moderately concentrated (HHI from 1,500 to <2,500), highly concentrated (HHI ≥2,500); measured at the county level
Percentage Medicaid discharges[b]	Percentage: number of discharges under Medicaid/total number of discharges
Member of Council of Teaching Hospitals[d]	Binary: Yes (1), No (0)
System member[d]	Binary: Yes (1), No (0)

Note. AMI = acute myocardial infarction; COPD = chronic obstructive pulmonary disease; DRGs = diagnosis-related groups; EBITDA = earnings before interest, taxes, depreciation, and amortization; ED = emergency department; HCAHPS = Hospital Consumer Assessment of Healthcare Providers and Systems; HHI = Herfindahl–Hirschman Index.

[a]*Source.* 2017 National Survey of Lean/Transformational Performance Improvement in Hospitals (Shortell et al., 2018).

[b]*Source.* 2018 CMS Hospital Compare (the methodology for star rating groups was used for the composite measures: https://www.rand.org/content/dam/rand/www/external/health/projects/hospital-performance-report-card/StrRtgDec16PrevQUS_rept_110416.pdf).

[c]*Source.* 2018 Medicare Cost Report posted at https://www.cms.gov/research-statistics-data-and-systems/downloadable-public-use-files/cost-reports/cost-reports-by-fiscal-year

[d]*Source.* 2017 AHA Annual Survey Database posted at www.ahadata.com/system/files/media/file/2020/04/2017%20AHA%20Survey%20File%20Layout.pdf.

- **Patient outcome.** The 30-day risk-adjusted mortality; 30-day readmission rates; percentage of patients who left the emergency department without being seen; death rate in low-mortality diagnosis-related groups; severity-adjusted geometric length of stay
- **Patient experience.** Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) score

The dependent variables are shown in Table 1. All dependent variables were based on their inherent importance to hospital performance and the availability of widely accepted data from the Centers for Medicare & Medicaid Services for 2018, a year after the NSL data on Lean adoption and implementation were collected. The performance measures include composite indexes for appropriate use of medical imaging (based on five measures), patient safety (based on eight measures), and timeliness of care (based on five measures). These data were linked to the NSL by IBM Watson Health, providing deidentified data for analysis.

Control variables from the 2017 AHA Annual Survey were included in all analyses, serving as both a partial adjustment for survey respondents versus nonrespondents and as potential confounders in the analysis of hospital performance. Based on previous research, we identified variables that are associated with various measures of hospital performance and output (Goldman et al., 2007; Ly & Cutler, 2018; Shortell et al., 2018; Sloan et al., 2001; Taylor et al., 1999). For example, hospitals with higher non-Medicaid reimbursement that joined a hospital system may demonstrate increases in operating margins that can then be spent on process improvement initiatives (Tlapa et al., 2020). The other control variables are similar to those included in previous research (i.e., location type [urban, suburban, rural], bed size, market concentration, hospital ownership, and whether the hospital is a system member; Womack & Jones, 2015), with the addition of U.S. region in which the hospital is located.

Data Analysis

We first conducted bivariate analyses of all study variables according to Lean adoption status in U.S. public hospitals. We then conducted two sets of multivariable regression analyses to investigate our study hypotheses, as described earlier. The first set of regressions examined associations between Lean adoption and each of the 11 performance outcomes reflecting quality of care, patient experience, and efficiency/financial indicators. The primary independent variable was a binary variable that measured whether the hospital had adopted some form of Lean management for performance improvement (e.g., Lean only, Lean Six Sigma, and Robust Process Improvement). We noted outcomes that showed significantly higher performance in Lean hospitals than in non-Lean hospitals and included them in our second set of regressions.

In this second set of regressions, which focused only on public hospitals that had adopted Lean, we examined associations between the extent of Lean

implementation (number of Lean units, leadership commitment, DMS use, and Lean training) and the subset of significantly higher performance outcomes identified in the first set of regressions. This approach was used to identify specific aspects of Lean implementation that may be drivers of improved outcomes in public hospitals. Four hospitals provided no information in the NSL for each variable measuring Lean implementation and thus were excluded from the analysis. All analyses were performed using statistical software (IBM SPSS, version 27).

RESULTS

Our analyses included 280 U.S. public hospitals that responded to the NSL. Of the public hospital respondents, 143 reported adopting some form of Lean, representing slightly more than half (51.1%) of the relevant sample.

Lean Adoption in Public Hospitals

Table 2 shows bivariate relationships between Lean adoption among public hospitals and hospital performance outcomes, as well as hospital characteristics serving as control variables. Of all the control variables, only region ($p = .389$) did not differ significantly by Lean adoption status. Of the 11 outcome measures, 7 showed significant bivariate relationships with Lean adoption at the $p < .05$ level. These unadjusted relationships include lower adjusted inpatient expense per discharge, lower severity-adjusted geometric length of stay, lower 30-day readmission rates, lower death rates in low-mortality diagnosis-related groups, and higher than average national performance on the appropriate use of medical imaging, patient safety, and timeliness of care.

Table 3 shows the results from the first set of regressions in which Lean adoption was the primary independent variable. Controlling for organizational and market variables, these analyses revealed that the adoption of Lean in public hospitals was significantly associated with lower adjusted inpatient expense per discharge and better-than-average national performance on the appropriate use of medical imaging and timeliness of care. In addition, Lean adoption in public hospitals was marginally associated with a higher EBITDA margin and HCAHPS patient experience ratings.

Lean Implementation in Public Hospitals

Table 4 presents regression results for the relationship between the extent of Lean implementation and outcomes previously identified as being associated with better performance among Lean versus non-Lean hospitals (Table 3). Among the public hospitals that reported adopting a Lean approach to performance improvement, Lean education and training for managers, nurses, and physicians was significantly associated with decreases in inpatient expense per discharge. The number of DMS activities that C-suite leaders incorporated into their daily work was significantly associated with the EBITDA margin and HCAHPS scores. The number of DMS activities that managers incorporated into their daily activities was also significantly associated with the EBITDA margin. Finally, leader commitment to Lean was significantly associated with

TABLE 2

Comparison of U.S. Public Hospitals Responding to NSL, by Lean Adoption Status (N = 280)

Variable	Public Lean Hospitals $n = 143$[a]	Public Non-Lean Hospitals $n = 137$[a]	p[b]
Region			.389
Midwest	45 (31.5)	59 (43.1)	
Northeast	6 (4.2)	2 (1.5)	
South	55 (38.5)	43 (31.4)	
West	37 (25.9)	33 (24.1)	
Missing data	0	0	
Core-based statistical area type			<.001
Rural	70 (49.0)	25 (18.2)	
Micropolitan	40 (28.0)	90 (65.7)	
Metropolitan	33 (23.1)	22 (16.1)	
Missing data	0	0	
Bed size			<.001
1–99	74 (51.7)	116 (84.7)	
100–399	41 (28.7)	18 (13.1)	
≥400	28 (19.6)	3 (2.2)	
Missing data	0	0	
Market concentration			.05
Unconcentrated (HHI 100 to <1,500)	39 (27.3)	8 (5.8)	
Moderately concentrated (HHI 1,500 to <2,500)	7 (4.9)	3 (2.2)	
Highly concentrated (HHI ≥2,500)	54 (37.8)	37 (27.0)	
Missing data	0	89	
Percentage Medicaid discharges, *M* (*SD*)	11.22 (10.96)	8.48 (9.36)	.033
Missing data	16	32	
Member of Council of Teaching Hospitals	121 (84.6)	135 (98.5)	<.001
Missing data	0	0	
System member	74 (51.7)	23 (16.8)	<.001
Missing data	0	0	
30-day risk-adjusted mortality index, *M* (*SD*)	12.67 (0.98)	12.74 (0.87)	.631
Missing data	80	120	
Adjusted inpatient expense per discharge ($), *M* (*SD*)	8,549.96 (2,857.12)	12,644.04 (36,051.21)	.014
Missing data	61	95	

TABLE 2

(Continued)

Variable	Public Lean Hospitals $n = 143$[a]	Public Non-Lean Hospitals $n = 137$[a]	p[b]
EBITDA margin (%), *M* (*SD*)	8.39 (18.72)	4.10 (18.25)	.472
Missing data	5	2	
Severity-adjusted geometric length of stay, *M* (*SD*)	3.43 (1.45)	2.89 (1.33)	.032
Missing data	3	2	
HCAHPS score, *M* (*SD*)	267.51 (12.26)	267.57 (13.594)	.343
Missing data	13	40	
30-day readmission rates (%), *M* (*SD*)	15.27 (0.66)	15.23 (0.48)	.024
Missing data	9	11	
Patient left ED without being seen (%), *M* (*SD*)	1.92 (1.77)	1.81 (1.94)	.840
Missing data	33	43	
Death rate in low-mortality DRGs, *M* (*SD*)	0.00044 (0.0015)	0.0024 (0.012)	.002
Missing data	9	15	
Composite: appropriate use of medical imaging (based on five measures)			<.001
Above (better than) national average	20 (14.0)	10 (7.3)	
Same as national average	58 (40.6)	62 (45.3)	
Below (worse than) national average	17 (11.9)	21 (15.3)	
Missing data	48	44	
Composite: patient safety (based on eight measures)			<.001
Above (better than) national average	28 (19.6)	27 (19.7)	
Same as national average	15 (10.5)	13 (9.5)	
Below (worse than) national average	39 (27.3)	36 (26.3)	
Missing data	61	61	
Composite: timeliness of care (based on five measures)			<.001
Above (better than) national average	42 (29.4)	30 (21.9)	
Same as national average	51 (35.7)	37 (27.0)	
Below (worse than) national average	27 (18.9)	41 (29.9)	
Missing data	23	29	

Note. DRG = diagnosis-related group; EBITDA = earnings before interest, taxes, depreciation, and amortization; ED = emergency department; HCAHPS = Hospital Consumer Assessment of Healthcare Providers and Systems; HHI = Herfindahl–Hirschman Index; NSL = National Survey of Lean/Transformational Performance Improvement.

[a]Data are *n* (%) unless otherwise specified.

[b]Statistical tests performed: χ^2 test of independence, *t* test.

TABLE 3

Summary of Regression Estimates of the Relationship Between Lean Adoption and Hospital Performance Measures, Controlling for Organizational and Market Variables[a] (N = 280)

Dependent Variable	*b* for Lean Adoption (*p*)	*t*-Test Statistic	Adjusted R^2	*F*-Test Statistic (*p*)
30-day risk-adjusted mortality index	0.062 (.324)	0.989	0.110	2.426 (.132)
Adjusted inpatient expense per discharge	–0.203 (.045)	–1.887	0.002	1.088 (.002)
EBITDA margin	0.114 (.055)	1.928	0.009	3.716 (.055)
Severity-adjusted geometric length of stay	0.006 (.928)	0.091	0.209	11.735 (<.001)
HCAHPS score	0.116 (.072)	1.807	0.109	5.996 (<.001)
30-day readmission rates	–0.053 (.427)	–0.796	0.057	3.442 (.001)
Patients left without being seen	0.024 (.668)	0.430	0.213	10.714 (<.001)
Death rate in low-mortality DRGs	–0.064 (.360)	–0.918	0.003	1.105 (.261)
Composite: appropriate use of medical imaging	0.168 (.006)	2.745	0.188	10.421 (<.001)
Composite: patient safety	0.074 (.133)	1.508	0.472	37.256 (<.001)
Composite: timeliness of care	0.097 (.007)	2.811	0.127	6.095 (<.001)

Note. DRG = diagnosis-related group; EBITDA = earnings before interest, taxes, depreciation, and amortization; HCAHPS = Hospital Consumer Assessment of Healthcare Providers and Systems.

[a]Organizational and market variables include region, area type, bed size, market concentration, percentage Medicaid discharges, hospital system, and network membership.

better-than-average national scores for appropriate use of medical imaging and timeliness of care. The study findings showed no significant associations between the extent of Lean implementation and the other dependent variables.

DISCUSSION

Our results show that more than half of the public hospitals that responded to the NSL survey had adopted some form of Lean management for performance improvement. Comparing Lean versus non-Lean hospitals, we identified five measures that were associated with better performance among public hospitals that reported adopting Lean. These measures centered on financial performance, operational quality or efficiency of care, and patient-reported experience, partially supporting our first hypothesis.

Although our research findings indicate that Lean management was associated with improvements in these areas, there were no significant

TABLE 4

Summary of Regression Estimates of the Relationship Between Extent of Lean Implementation and High Performance Among Lean Public Hospitals, Controlling for Number of Years Using Lean and Organizational and Market Variables (N = 143)

Dependent Variable	*b* for No. of Years (*p*)	*b* for No. of Lean Units (*p*)	*b* for Education and Training Index (*p*)	*b* for Leadership Commitment (*p*)	*b* for Daily Management System: C-Suite (*p*)	*b* for Daily Management System: Managers (*p*)	Adjusted R^2	*F*-Test Statistic (*p*)
Adjusted inpatient expense	0.001 (.994)	−0.145 (.396)	−0.165 (.025)	−0.080 (.568)	0.131 (.429)	−0.100 (.586)	0.141	1.780 (.058)
HCAHPS score	0.084 (.385)	0.303 (.002)	−0.129 (.183)	0.054 (.594)	0.237 (.022)	0.076 (.532)	0.209	4.121 (<.001)
EBITDA margin	0.168 (.867)	0.243 (.049)	0.120 (.304)	0.038 (.750)	0.286 (.042)	0.260 (.050)	−0.005	0.947 (.155)
Composite: appropriate use of medical imaging	0.249 (.011)	−0.097 (.433)	0.058 (.588)	0.243 (.031)	−0.095 (.477)	0.038 (.780)	0.085	2.104 (.021)
Composite: timeliness of care	0.214 (.041)	−0.090 (.452)	−0.105 (.307)	0.251 (.021)	−0.198 (.124)	−0.043 (.742)	0.099	2.306 (.011)

Note. EBITDA = earnings before interest, taxes, depreciation, and amortization; HCAHPS = Hospital Consumer Assessment of Healthcare Providers and Systems.

associations with clinical quality. This observation corroborates previous findings indicating that merely adopting Lean does not automatically lead to desired outcomes in healthcare (Menachemi et al., 2020; Rundall et al., 2021). Our results showed that the extent of Lean implementation varied widely throughout hospital units. Many hospitals had not implemented Lean across the organization but rather incorporated it only in select departments. The potential impact of one Lean department on certain hospitalwide outcomes (e.g., risk-adjusted mortality) is limited, which may explain the lack of significant findings for certain outcomes.

Consistent with previous studies (Po et al., 2019; Shortell et al., 2021), our results suggest that Lean adoption is associated more universally with improvements in financial performance and operational efficiency. We identified specific areas in which improvement occurred in public hospitals, including inpatient expense per patient discharge, timeliness in delivering patient care, and appropriate use of medical imaging. Such findings may be particularly meaningful for hospitals in the public sector, where resources are constrained and performance incentives may be less prevalent. The marginally significant association with patient-reported experience, as measured by a composite HCAHPS score, is also noteworthy and consistent with Lean's focus on the "voice of the customer" (Griffith, 2017; Nelson-Peterson & Leppa, 2007), while the marginally significant association with the EBITDA margin reinforces the notion of Lean's profitability potential (Po et al., 2019; Soliman et al., 2018). In this study, Lean adoption accounted for nearly 11% of the variability in HCAHPS scores, suggesting important benefits for patients receiving care in public hospitals.

Our second hypothesis was also partially supported. Specifically, more extensive Lean training and education for hospital managers, physicians, and nurses was associated with lower hospital spending per patient discharge. In addition, more frequent use of DMS practices by managers was associated with higher EBITDA margins. Similarly, greater use of Lean DMS by C-suite leaders was associated with higher EBITDA margins and higher HCAHPS scores. These findings support the notion that Lean education and training, as well as senior executive and manager engagement with Lean systems, can lead to positive results in public hospitals (Curry et al., 2011). Moreover, the study findings showed that hospitals with greater leader commitment to Lean had a better-than-average performance on national measures reflecting high-value care, specifically appropriate use of imaging and timeliness of care.

Importance of Implementation

Our research findings reinforce those of prior studies, including the status of Lean adoption in public hospitals (Po et al., 2019; Rundall et al., 2021). While the reasons for relatively low adoption need to be further explored, our findings add to the literature by highlighting measures that reflect the extent of Lean implementation in hospitals. To this end, we identified that Lean teaching and education, the use of Lean practices by C-suite leaders and managers, and

commitment to Lean from upper management were significantly associated with better performance in public hospitals.

Our findings also have implications for making breakthrough improvements in public hospitals (Ahn et al., 2021). Various initiatives have shown some correlation between improved hospital performance and Lean adoption and implementation (Menachemi et al., 2020; Rundall et al., 2021; Shortell et al., 2018). To achieve these improvements, upper management and other leaders in the hospital must be educated as well as committed to a comprehensive Lean enterprise transformation-driving strategy. Indeed, research has shown that stakeholder engagement is one of the main drivers of successful Lean transformation in healthcare organizations (Fournier et al., 2021; Hung et al., 2015, Leite et al., 2020). Greater attention to promoting hospitalwide education and training for C-suite leaders, champions, and other stakeholders in hospital management is needed. Such an approach would also strengthen management's capacity to support providers in engaging with methods of daily continuous improvement. Research suggests that this can foster better problem-solving behaviors, which are important for delivering high-quality care (Gemmel et al., 2019).

Study Limitations

The study conclusions should be interpreted with certain limitations in mind. Because of the nature of the study, none of the findings imply causality. Rather, the significant findings suggest only positive associations within each hospital at the time of the survey. The cross-sectional nature of our analysis limits the ability to connect Lean with each hospital's performance because of other possible initiatives that may have been in place in conjunction with or before Lean adoption. The adjusted R^2 suggests that Lean adoption was not consistently predictive of the variability seen in outcomes. Future studies could leverage two approaches to address this dilemma. First, longitudinal data on Lean implementation and related changes in performance could reduce barriers to causality implications, while also informing additional research on the amount of time needed to achieve lean maturity and its observable effects. Second, case study research involving direct observation can provide supplemental information regarding Lean adoption, implementation, and related challenges based on primary real-time perspectives.

Additionally, the survey was completed by the chief transformation officer, chief performance improvement officer, chief quality officer, or an individual with an equivalent title in each hospital. Their responses may have differed from those of other staff members in the same hospital because of bias and differences in the interpretation of survey questions. Moreover, although we controlled for certain organizational and market variables that were linked from the IBM Watson Health database, not all information was available for each hospital, and this could have affected our study results. More data collection and research involving missing variables would lend additional support to our hypotheses if similar associations were found.

Additional research should be conducted regarding the quality of Lean implementation in public hospitals. Throughout our study, multiple measures of implementation were used; however, none specifically assessed quality as indicated by, for example, fidelity or adherence to Lean standard work. Future studies could investigate this phenomenon by using a combination of direct observation and qualitative and survey research to assess manager and frontline adherence to Lean practices. Lean applications in hospitals are not monolithic and can follow different patterns based on environmental and organizational factors (Dorval & Jobin, 2022). A study observing different levels and types of Lean practices, as well as sustained use of Lean practices, could provide more data to validate hypothesized effects on overall hospital performance. Such research would lead to a better understanding of not only the degree but also the quality, of implementation from multiple data sources.

CONCLUSIONS

Previous research suggests the importance of Lean methodology for improving hospital performance (Shortell et al., 2018), yet few studies have highlighted specific aspects of implementation and their associations with performance in public hospitals. Our study findings confirm that in addition to Lean implementation across hospital units, the level of commitment among hospital leaders plays a major role in Lean improvement. For example, having committed C-suite executives who incorporate Lean practices and lead by example can be powerful motivators.

The potential impact of Lean in public hospitals may be contingent on hospital leaders' ability to ensure its effective implementation. Further research is needed to understand successful Lean adoption and implementation, and how they can best be evaluated. Fundamentally, Lean aims to provide hospitals with a continuous improvement culture that empowers employees from top to bottom to solve problems and provide high-value care for patients. If widely and consistently practiced by hospital leaders and embedded within the organizational culture, Lean can benefit U.S. public hospitals, particularly in areas of financial performance, operational quality and efficiency, and patient experience of care.

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