Associations Between Lean IT Management and Financial Performance in US Hospitals

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Background and Objectives: To understand the relationship between Lean implementation in information technology (IT) departments and hospital performance, particularly with respect to operational and financial outcomes. **Methods:** Primary data were sourced from 1222 hospitals that responded to the National Survey of Lean (NSL)/Transformational Performance Improvement, which was fielded to 4500 general medical-surgical hospitals across the United States. Secondary sources included hospital performance data from the Agency for Healthcare Research and Quality (AHRQ) and the Centers for Medicare & Medicaid Services (CMS). We performed 2 sets of multivariable regressions using data gathered from US hospitals, linked to AHRQ and CMS performance outcomes. We examined 10 different outcomes measuring financial performance, quality of care, and patient experience, and their associations with Lean adoption within hospital IT departments. We then focused only on those hospitals that adopted Lean in IT to identify specific practices associated with performance. **Results:** Controlling for other factors, adoption of Lean IT management was associated with lower length of stay ($b = –0.098$, $P = .018$) and inpatient expense per discharge ($b = –0.112$, $P = .090$). Specifically, use of visual management tools (eg, A3 storyboards, status sheets) was associated with lower adjusted inpatient expense per discharge ($b = –0.176$, $P = .034$) and higher earnings before interest, taxes, depreciation, and amortization margin ($b = 0.124$, $P = .042$). Such tools were also associated with hospital participation in bundled payment programs (odds ratio = 2.326; $P = .046$; 95% confidence interval, 0.979-5.527) and percentage of net revenue paid on a shared risk basis ($b = 0.188$, $P = .031$). **Conclusions:** Lean IT management was associated with positive financial performance, particularly with hospital participation in value-based payment. More detailed study is needed to understand other influential factors and types of work processes, activities, or mechanisms by which high-functioning IT can contribute to financial outcomes.

Key words: HIT, hospital performance, IT department, Lean management, value-based care

Health information technology, or HIT, is a broad term that encompasses a wide range of technologies that aim to store, share, and/or analyze different forms of health information.[1] For example, HIT involves collecting patient information through electronic health records (EHRs),[2] distributing such information to various providers through health information exchange (HIE) networks,[3] and analyzing data to drive prediction models or clinical decision support systems (CDSSs).[4] HIT is commonly touted as a way to improve the quality of clinical care and cost of providing health care by reducing the length of hospital stays, medical errors, administrative expenses, and other cost measures examined in previous studies.[5-7]

Although the literature is rich with studies focusing on the effects of HIT on quality of care and patient-oriented outcomes,[8-15] the relationship between HIT, including work management processes to support the use of HIT, and financial performance in US hospitals is not well studied. This topic is especially of interest due to the Health Information Technology for Economic and Clinical Health Act passed in 2009, which committed $38.4 billion in incentive payments to both hospitals and individual providers for the adoption and utilization of a certified EHR.[16,17] A financial analysis using longitudinal data from Texas hospitals concluded that HIT implementation was significantly and positively associated with hospital revenue,[18] but related cost studies in this area have yet to be reported across a wider sample of hospitals located across the United States.

HIT aims to improve financial performance largely through improvements to the efficiency of various processes, such as computerized provider order entry (CPOE) systems.[1] Decision support to reduce redundant tests has also been cited as another way that HIT improves efficiency in delivering care.[5,6] Lean is

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an operating and management system focused on process improvement that could serve to support or enhance these effects in IT departments, sharing common goals of improving both efficiency and quality of care. Lean methodology involves a set of principles, practices, and tools to assess and redesign operational processes, as well as systems to monitor the performance of daily work.[19]

Little is known empirically about the use of Lean to improve work processes in information technology (IT) departments of health care organizations. A previous study reported that use of Lean for IT services is positively associated with self-reported hospital performance,[20] but the majority of the literature on the topic remains theoretical,[21-24] limited to providing models of waste identification in HIT. This article aims to contribute to the literature by exploring the relationship between Lean work processes in IT departments and hospital performance, particularly with respect to operational and financial outcomes.

METHODS

Measures and data sources

The National Survey of Lean (NSL)/Transformational Performance Improvement was distributed by the Survey Data Center of the American Hospital Association (AHA) between May and September 2017. The NSL was fielded to 4500 acute general medical and surgical hospitals in the United States to assess both the state of Lean adoption and degree of implementation.[25] This 20-minute survey was developed based on literature review, conversations with Lean experts, and pilot testing with 12 Lean performance improvement specialists. During the pilot test phase, Lean specialists were invited to review, comment on, and suggest revisions to survey questions. The NSL demonstrated high face validity and predictive validity as evidenced in subsequent studies that found NSL scales to be associated with performance outcomes in expected directions.

The NSL was fielded to all AHA general-surgical acute care hospitals in the United States with a request to be completed by the person most knowledgeable of Lean performance improvement activities within the hospital. This was often the chief quality officer, chief transformation officer, chief improvement officer, or other equivalent position within each hospital. The NSL response rate was approximately 27% with 1222 hospitals participating.[26] These 1222 hospitals make up the sample frame used for this current study.

The NSL has been utilized in the literature to explore the relationship between Lean management and a variety of topics, including but not limited to: hospital performance in all general medical/surgical facilities[27]; performance[20] specifically among US public hospitals; and quality improvement care management processes in outpatient settings.[28] It has also been recently used in a benchmarking study to evaluate Lean implementation in the Italian health care system, indicating its potential use as a universal gauge of Lean implementation internationally.[29]

Study variables

Table 1 lists the independent, dependent, and control variables, along with their descriptions and data sources. Hospitals were considered to have adopted Lean if they reported using some form of Lean (either Lean, Lean plus Six Sigma, and/or Robust Process Improvement). Lean adoption in IT departments, a main independent variable of interest for this study, was measured as 1 among a total of 29 hospital units and shared services common to general medical/surgical hospitals, for example, emergency department; intensive care unit; laboratory; finance department; and human resources.

Other Lean-specific independent variables of interest included following 2 that were binary coded: (1) Use of Lean visual management tools (eg, A3s, trend charts, storyboards) in IT departments to conduct work and communicate among team members and (2) inclusion of IT leaders on the hospital's central improvement team. Following 2 additional independent variables assessed general IT roles or functions: (1) Partnership with the hospital and advisement on goal achievement and (2) provision of timely, accurate data to managers for clinical and operational purposes. These measures were scaled 1 (low) to 5 (high) and constructed based on factor analysis with Cronbach αs of .62 and .84, respectively.

Because of the comprehensive nature of the Lean approach to operational excellence, it was important to select a range of performance measures relevant to IT and its potential influence on hospital operations. These measures were broadly categorized into following 3 areas: efficiency/financial viability; quality or appropriateness of care; and self-reported patient experience as shown in Table 1. All measures were sourced from 2018 data provided by the Centers for Medicare & Medicaid Services (CMS), deidentified and linked to the NSL by IBM Watson. Efficiency/financial viability measures included: earnings before interest, taxes, depreciation, and amortization (EBITDA) margin; adjusted inpatient expense per discharge; and 2 indicators of hospital involvement in alternative (ie, not strictly fee-for-service) payment structures, including participation in a bundled payment program and percentage of hospital net patient revenue paid on a shared risk basis. Quality or appropriateness of care was measured by the following: severity adjusted geometric length of stay (LOS); composite indices measuring patient safety; timeliness of care; effectiveness of care; and appropriate use of medical imaging. Finally, patient experience was measured using the overall Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) score, which was corrected to a range of 100 (100% of patients rated the hospital as low performing) to 300 (100% of patients rated the hospital as high performing).

Control variables aimed not only to partially adjust for differences between survey respondents

Table 1. Description of Independent, Dependent, and Control Variables[a]

Variable	Description
Independent Variables (2017)[b]	
Lean adoption in IT department	Binary indicator measure for each hospital. Yes (1) = hospital reported adopting Lean, Lean plus Six Sigma, and/or Robust Process Improvement in IT department; No (0) = hospital did not report any adoption of Lean, Lean plus Six Sigma, and/or Robust Process Improvement in IT department
Use of Lean visual management tools	Binary indicator measure for each IT department. Yes (1) = hospital reported using Lean visual management tools (eg, A3s, trend charts, storyboards) to conduct IT work and communicate among team members; No (0) = hospital did not report any use of Lean visual management tools to conduct IT work and communicate among team members
Inclusion of IT leaders on the hospital's central improvement team	Binary indicator measure for each hospital. Yes (1) = hospital reported, including IT leaders on the hospital's central improvement team; No (0) = hospital did not report inclusion of IT leaders on the hospital's central improvement team
IT Collaboration index	Number scale of degree of partnership between IT department and hospital, sourced from following 2 questions: (1) the IT department is an important partner in achieving Lean goals and objectives and (2) the IT department's primary role is to act as advisors to managers (possible range: 1-5)
IT Data Provision index	Number scale of IT department's ability to provide timely, accurate data to managers for clinical and operational purposes, sourced from following 4 questions: (1) the IT department provides managers with the data and analysis they need; (2) the IT department provides access to data that integrate clinical and operational processes; (3) managers receive timely data from our IT department; and (4) managers receive accurate data from our IT department (possible range: 1-4)
Dependent Variables (2018)	
EBITDA margin	Percentage: EBITDA/total operating revenue
Adjusted inpatient expense per discharge[c]	Cost per inpatient discharge adjusted for case mix and area wage indices
Participation in a bundled payment program	0 = No; 1 = Yes
Percentage of hospital's net patient revenue paid on a shared risk basis	Percentage: Hospital's net patient revenue paid on a shared risk basis
Severity adjusted geometric length of stay[c]	Risk-adjusted time of the average length of stay for a patient from entry to discharge
Composite: Patient safety[c]	1 = worse than national average; 2 = same as national average; 3 = better than national average. Hospital Compare Star Rating calculation based on 8 measures
Composite: Timeliness of care[c]	1 = worse than national average; 2 = same as national average; 3 = better than national average. Hospital Compare Star Rating calculation based on 8 measures
Composite: Effectiveness of care[c]	1 = worse than national average; 2 = same as national average; 3 = better than national average. Hospital Compare Star Rating calculation based on 8 measures
Composite: Appropriate use of medical imaging[c]	1 = worse than national average; 2 = same as national average; 3 = better than national average. Hospital Compare Star Rating calculation based on 8 measures
HCAHPS score[c]	Index: Patient responses to the question "How do patients rate the hospital, overall?" (from a standard survey required by CMS) 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 hospitals rate the hospital high)
Control Variables	
Census division[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[c]	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
Percent Medicaid discharges[c]	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)
Years using Lean	Years after first implementation of Lean
Organizational Type	1 = public; 2 = not-for-profit; 3 = investor-owned

Abbreviations: CMS, Centers for Medicare & Medicaid Services; EBITDA, earnings before interest, taxes, depreciation, and amortization; HCAHPS, Hospital Consumer Assessment of Healthcare Providers and Systems; HHI, Hirfindahl-Hirschmann Index; IT, information technology.

[a]Source: 2018 Medicare Cost Report.

[b]Source: 2017 National Survey of Lean/transformational performance improvement in hospitals.

[c]Source: 2018 CMS Hospital Compare (the Composite measures used the methodology for Star Rating groups: https://www.rand.org/content/dam/rand/www/external/health/projects/hospital-performance-report-card/StrRtgDec16PrevQUS_rept_110416.pdf).

[d]Source: 2017 AHA Annual Survey.

compared with nonrespondents but also for potential confounders of hospital performance results. These variables included: census division; area location (eg, rural, urban, suburban); total hospital beds; Hirfindahl-Hirschmann Index of market concentration; percentage of Medicaid discharges; system/network membership; years using Lean; and organizational type (public, not-for-profit, and investor-owned). Many of these characteristics have been shown in the literature to be associated with hospital performance; for example, a hospital's ability to produce financial reserves for performance improvement may be affected by the percentage of patients covered by Medicaid.

Data analysis

We began by conducting bivariate analyses of all study variables by status of Lean adoption, followed by 2 sets of multivariate regression analyses. Continuous dependent variables were analyzed using linear regression models, while logistic regression models were used for binary dependent variables. The first set of regressions measured relationships between Lean adoption in hospital IT departments and performance outcomes as described earlier. The main independent variable was binary, indicating whether or not the hospital had adopted Lean or any of its closely related approaches (ie, Lean plus Six Sigma, Robust Process Improvement). The second, more focused set of regressions, was performed only on hospitals that reported adopting Lean in the IT department. This second set of regressions aimed to identify specific Lean IT practices and/or general IT factors associated with hospital performance to the extent possible with available data. In particular, use of Lean visual management tools in the IT department served a "reference" variable of interest, adjusting for other IT-related factors included with this analysis. Both sets of regressions controlled for the organizational and market factors outlined previously, and the *F* statistic was displayed for continuous variables. All analyses were performed using SPSS Statistics, version 27.

RESULTS

The first set of regressions included all 1222 of hospitals that responded to the NSL/Transformational Performance Improvement. The second set of regressions included only the 407 NSL hospitals that responded affirmatively to use of Lean principles and tools in their IT department. More information about the NSL, including the sample approach, response rates, and summary of results are presented elsewhere.[20,25,27]

Lean adoption in IT departments

Bivariate relationships between Lean adoption in IT departments and hospital performance outcomes, in addition to organizational and market characteristics as control variables, are presented in Table 2. Among the control variables, total hospital beds ($P = .149$) and percentage of Medicaid discharges ($P = .334$) did not significantly differ by Lean adoption status at the $P < .05$ level. Of the dependent measures, participation in a bundled payment program; percentage of hospital net patient revenue paid on a shared risk basis; effectiveness of care; and EBITDA margin demonstrated significant bivariate relationships with Lean adoption ($P < .05$).

Results from the first set of regressions on Lean adoption in IT departments as the independent variable of interest are listed in Table 3. Lean IT adoption was found to be significantly related to lower severity adjusted geometric LOS ($b = –0.098$, $P = .018$) and participation in a bundled payment program (odds ratio [OR] = 2.060; $P = .018$; 95% confidence interval [CI], 1.664-2.690). In addition, although not significant at conventional levels ($P < .05$), Lean IT adoption was associated with a higher HCAHPS score ($b = 0.083$, $P = .051$); adjusted inpatient expense per discharge ($b = –0.112$, $P = .090$); and EBITDA margin ($b = 0.077$, $P = .077$).

Use of visual management tools

Table 4 presents the second set of regression results among hospitals reporting adoption of Lean in the IT department. Of these 407 hospitals, 184 reported use of Lean visual management tools by IT teams. Such tools to support IT work and facilitate communication were positively and significantly associated with participation in a bundled payment program (OR = 2.326; $P = .046$; 95% CI, 0.979-5.527) and percentage of hospital net patient revenue paid on a shared risk basis ($b = 0.188$, $P = .031$). Visual management tools were also associated with lower adjusted inpatient expense per discharge ($b = –0.176$, $P = .034$) and higher EBITDA margin ($b = 0.124$, $P = .042$). Use of visual management by IT was the most significant variable related to these financial indicators, relative to other measures examined such as IT leader representation on the hospital's central improvement team; IT as a partner to achieve hospital goals; and IT provision of data to managers for clinical and operational purposes.

DISCUSSION

Controlling for other factors, adoption of Lean principles and tools in hospital IT departments was associated with several outcomes, including shorter average patient LOS, lower risk-adjusted inpatient cost per discharge, and higher EBIDTA margin. Focusing on this subset of hospitals, we found that use of visual management in IT was associated with specific financial indicators. These included hospital participation in alternative payment arrangements, including bundled payment and increased risk sharing, as well as better financial outcomes, that is, inpatient expense per discharge, EBITDA margin. This subset of findings provided further potential validation of associations between hospital use of Lean management in IT and positive financial performance.

Results from our first set of regressions align with relevant studies in the HIT literature. Previous studies

Table 2. Comparison of Lean Adoption Status in the IT Department (N = 746)

Variable	Hospitals that Report Lean Adoption in IT Department (N = 407)[a]	Hospitals that did not Report Lean Adoption in IT Department (N = 339)[a]	*P*[b]
Census division			<.001
Midwest	171 (42.0%)	86 (25.4%)	
Northeast	42 (10.3%)	40 (11.8%)	
South	107 (26.3%)	102 (30.1%)	
West	86 (21.1%)	107 (31.6%)	
Missing	1	4	
Core-based statistical area type			<.001
Rural	252 (61.9%)	254 (74.9%)	
Micro	73 (17.9%)	39 (11.5%)	
Metro	78 (19.2%)	44 (13.0%)	
Missing	4	2	
Bed size			.307
1-99 beds	159 (39.0%)	116 (34.2%)	
100-399 beds	177 (43.5%)	164 (48.4%)	
>400 beds	67 (16.5%)	57 (16.8%)	
Missing	4	2	
Market concentration			.003
Unconcentrated (HHI 100 to <1 500)	124 (30.5%)	141 (41.6%)	
Moderately concentrated (HHI 1 500 to <2 500)	25 (6.1%)	25 (7.4%)	
Highly concentrated (HHI > 2 500)	182 (44.7%)	126 (37.2%)	
Missing	76	47	
Percentage of Medicaid discharges	9.2 (0.5)	8.1 (0.5)	.151
Missing	36	42	
Member of council of teaching hospitals	403 (99.0%)	337 (99.4%)	.332
Missing	4	2	
System member	407 (100%)	339 (100%)	.002
Missing	0	0	
EBITDA margin (%)	10.1 (0.7)	–2.6 (6.5)	.031
Missing	10	13	
Adjusted inpatient expense per discharge	7 930.7 (2562.3)	42 981.1 (9223.4)	.353
Missing	121	83	
Participation in a bundled payment program	343 (84.3%)	282 (83.2%)	.07
Missing	64	57	
Percentage of hospital's net patient revenue paid on a shared risk basis	3.7 (0.6)	2.3 (0.5)	.065
Missing	115	106	
Severity adjusted geometric length of stay	3.2 (0.1)	3.3 (0.1)	.232
Missing	6	5	
HCAHPS score	267.23 (0.5)	265.4 (0.6)	.016
Missing	70	26	

(*continues*)

Table 2. Comparison of Lean Adoption Status in the IT Department (N = 746) (*Continued*)

Variable	Hospitals that Report Lean Adoption in IT Department (N = 407)[a]	Hospitals that did not Report Lean Adoption in IT Department (N = 339)[a]	*P*[b]
Composite—patient safety (based on 8 measures)			.52
Above (better than) national average	131 (32.2%)	116 (34.2%)	
Same as national average	57 (14.0%)	57 (16.9%)	
Below (worse than) national average	102 (25.1%)	78 (23.0%)	
Missing	117	88	
Composite—timeliness of care (based on 5 measures)			
Above (better than) national average	112 (27.5%)	69 (20.4%)	.136
Same as national average	141 (34.6%)	116 (34.2%)	
Below (worse than) national average	105 (25.8%)	97 (28.6%)	
Missing	49	57	
Composite—effectiveness of care (based on 9 measures)			.212
Above (better than) national average	16 (3.9%)	13 (3.8%)	
Same as national average	320 (78.6%)	263 (77.6%)	
Below (worse than) national average	21 (5.2%)	29 (8.6%)	
Missing	50	34	
Composite—appropriate use of medical imaging (based on 5 measures)			.362
Above (better than) national average	61 (15.0%)	41 (12.1%)	
Same as national average	217 (53.3%)	181 (53.4%)	
Below (worse than) national average	61 (15.0%)	26 (7.7%)	
Missing	86	91	

Abbreviations: EBITDA, earnings before interest, taxes, depreciation, and amortization; HCAHPS, Hospital Consumer Assessment of Healthcare Providers and Systems; HHI, Hirfindahl-Hirschmann Index; IT, information technology.

[a]Statistics presented: n (column %); mean (standard deviation [SD]); N missing values.

[b]Statistical tests performed: Chi-square test of independence; *t* test.

indicate that high-functioning IT capabilities can improve hospital operations and lead to reductions in average patient LOS. Hospital information systems, such as EHRs; CPOEs; and CDSSs have been cited as being associated specifically with reduced LOS.[8] Moreover, visual analytical dashboards to expedite diagnosis and electronic discharge planning tools (EDPTs) and postdischarge follow-up systems to automate the discharge process can serve to improve workflows, also contributing to decreased LOS.[8] EDPTs have been reported as improving the management of processes related to discharge, leading to LOS reductions by 1.4 days in 2 separate studies.[30,31]

Findings from our second set of regressions highlight potential relationships between HIT and health care payment policy. There has been a recent shift in the past decade from fee-for-service to value-based reimbursement as health care organizations face greater pressure to deliver higher value care at lower cost. This transition has been largely spurred by the passage of the Affordable Care Act in 2010 and increasing participation in alternative payment models (APMs) that reward value and quality. According to surveys conducted by the Health Care Payment and Learning Action network, health care dollars paid through APMs has risen from approximately 38% in 2015 to 60% in 2018.[32] One common APM is bundled payment, a shared-risk structure that consolidates payments for individual clinical services provided during a single episode of care.[33]

We found that use of Lean visual management in hospital IT departments corresponded with increased participation in bundled payment programs, as well as percentage of hospital net patient revenue paid on a shared risk basis. Bundled payment programs necessitate greater communication and coordination between providers, which may be facilitated by HIT. Hospitals in bundled payment programs are shown to be more likely to send and receive information through HIE, exchange different types of health information, and

Table 3. Summary of Regression Estimates of the Relationship Between Lean Adoption in IT and Hospital Performance Measures, Controlling for Organizational and Market Variables[a] (N = 746)

Dependent Variable	*b* (OR Where Noted) for Lean Adoption (*P*), (95% CI)	*t* Statistic (Chi-square)	Adjusted R^2	*F* Test Statistic (*P*)
HCAHPS score	0.083 (0.051)	1.957	0.166	7.896 (<.001)
Adjusted inpatient expense per discharge	–0.112 (0.090)	–1.313	0.101	4.680 (<.001)
EBITDA margin	0.077 (0.077)	1.773	0.001	1.053 (.399)
Severity adjusted geometric length of stay	–0.098 (0.009)	–2.626	0.328	18.413 (<.001)
Percentage of hospital's net patient revenue paid on a shared risk basis	0.008 (0.881)	0.529	0.052	2.498 (.002)
Participation in a bundled payment program	OR = 2.060 (.018), (1.664-2.690)	3.290 (0.07)	N/A	N/A
Composite: Effectiveness of care	0.055 (0.237)	1.184	0.015	1.549 (.090)
Composite: appropriate use of medical imaging	–0.013 (0.786)	–0.272	0.025	1.823 (.033)
Composite: patient safety	–0.056 (0.256)	–1.136	0.013	1.417 (.141)
Composite: timeliness of care	–0.0211 (0.548)	0.008	0.333	18.752 (<.001)

Abbreviations: CI, confidence interval; EBITDA, earnings before interest, taxes, depreciation, and amortization; HCAHPS, Hospital Consumer Assessment of Healthcare Providers and Systems; IT, information technology; OR, odds ratio.

[a]Organizational and market variables include region, area type, bed size, market concentration, percentage of Medicaid discharges, system or network membership, years using Lean, and organizational type.

to use HIE more often.[34] In addition, physicians using HIT report better experiences receiving necessary information on patient history and reason for referral from other providers.[35] This association between bundled payment programs and increased coordination via HIT is part of a broader trend seen with APMs in general. Lin et al.[36] report that full-year APM participation is associated with greater HIE diversity (data types), breadth (partner types), and depth (odds of using a push and pull approach) compared with nonparticipating hospitals.

Lean IT studies to date have largely focused on identifying waste in the IT context.[21-24] A preliminary review conducted by Kalong and Yusof[23] describe models of waste identification in IT, and concluded that Ohno's model[37] is suitable for both the health care and IT domains. Other models have been proposed, such as one by Kundu et al.,[24] which builds on Ohno's work and formulates additional categories specific to the IT environment. Examples of these categories include resource inefficiency, ineffective communication, processive inefficiency, recurring incidents, and lack of a discipline system. Many of these categories may be improved through the use of Lean visual management tools. For example, value stream mapping identifies unnecessary, wasteful process steps and is used to reduce inefficiencies. Visual tracking charts represent actual versus expected performance of a targeted work process, which could be used to compare rates of recurring incidences. These Lean visual management tools can improve the overall functioning of IT departments, which may also lead to increased communication and coordination between providers. Hospitals can leverage Lean tools to better manage financial incentives associated with the shift toward value-based care.

In our study, use of Lean IT management was associated with improved financial metrics in the form of lower inpatient expense per discharge and higher EBITDA margin. Relevant studies show that HIT can improve hospital financial performance in a number of ways. Lowered medical liability costs, decreased back-office administration office expense, and higher productivity through rapid availability of patient charts are several drivers of improved hospital financial well-being fueled by HIT.[38] Hospitals with HIT laboratory tracking systems have been shown to report better financial performance in terms of operating margin, total margin, return on assets, current ratio, and debt ratio.[39] Increased investment in HIT has also been associated with greater profit, with a one-tenth of a percentage increase in IT expenditures associated with approximately $100 000 in increased profit as estimated by Thouin et al.[40]

Our study findings should be considered within the context of several limitations. The first is that several associations between Lean adoption in IT departments and our selected performance measures, particularly those regarding patient satisfaction and clinical outcomes, may be subject to confounding variables not accounted for by our analysis. The survey used to source our data did not cover factors, such as HIT investment; use of IT in decision-making; or integration of HIT within an organization, which may be a focus for future studies. Second, given the cross-sectional nature of the source data, our findings do not imply causality but rather associations that warrant further study using longitudinal or randomized

Table 4. Summary of Regression Estimates of the Relationship Between Adoption of Lean Visual Management Tools and Hospital Performance Measures, Controlling for Organizational and Market Variables[a] (N = 407)

Dependent Variable	*b* (OR Where Noted) for Lean Visual Management Tools (*P*), (95% CI)	*b* (OR Where Noted) for Inclusion of Lean Leaders on Central Improvement Teams (*P*)	*b* (OR Where Noted) for IT Collaboration (*P*)	*b* (OR Where Noted) for IT Data Provision (*P*)	*t* Statistic (Chi-Squared)	Adjusted R^2	*F* Test Statistic (*P*)
HCAHPS score	0.054 (0.429)	–0.014 (0.828)	–0.089 (0.227)	–0.048 (0.529)	1.329	0.253	5.087 (<.001)
Adjusted inpatient expense per discharge	–0.176 (0.034)	–0.001 (0.985)	0.051 (0.557)	0.01 (0.988)	–2.141	0.106	2.324 (.001)
EBITDA margin	0.124 (0.042)	0.030 (0.656)	–0.210 (0.006)	–0.109 (0.158)	1.806	0.229	4.589 (<.001)
Severity adjusted geometric length of stay	–0.055 (0.367)	0.054 (0.362)	0.000 (0.999)	0.045 (0.510)	–0.904	0.382	8.521 (<.001)
Percentage of hospital's net patient revenue paid on a shared risk basis	0.188 (0.031)	0.089 (0.293)	–0.155 (0.100)	0.111 (0.254)	2.171	0.084	1.872 (.022)
Participation in a bundled payment program	OR = 2.326 (.046), (0.979-5.527)	OR = 1.246 (.641), (0.494-3.147)	OR = 1.477 (.186), (0.829-2.631)	OR = 0.623 (.118), (0.344-1.127)	50.295	N/A	N/A
Composite: Effectiveness of care	–0.079 (0.317)	0.094 (0.217)	–0.074 (0.388)	0.095 (0.286)	–1.004	0.013	1.164 (.297)
Composite: Appropriate use of medical imaging	–0.092 (0.271)	–0.068 (0.407)	–0.029 (0.740)	–0.119 (0.183)	–1.104	–0.021	0.769 (.727)
Composite: Patient safety	0.079 (0.335)	0.001 (0.993)	0.035 (0.693)	–0.113 (0.210)	0.967	0.011	1.133 (.326)
Composite: Timeliness of care	0.053 (0.426)	–0.80 (0.219)	0.029 (0.680)	0.018 (0.804)	1.208	0.294	6.058 (<.001)

Abbreviations: CI, confidence interval; EBITDA, earnings before interest, taxes, depreciation, and amortization; HCAHPS, Hospital Consumer Assessment of Healthcare Providers and Systems; IT, information technology; OR, odds ratio.
[a]Organizational and market variables include region, area type, bed size, market concentration, percent Medicaid discharges, system or network membership.

controlled trial data. In addition, the NSL was completed by the person most knowledgeable of Lean performance improvement activities throughout the hospital. This was often the chief transformation officer, chief performance improvement officer, chief quality officer, or equivalent position in each hospital, which may introduce bias or present limited perspectives on the survey questions. Finally, while we were able to leverage available NSL data, more in-depth questions about HIT or improvement activities in IT departments could lend further understanding of the processes or mechanisms by which IT leads to improved outcomes. Ongoing data collection and future research on such topics is warranted to support our current study findings.

CONCLUSION

HIT is increasingly used in US hospitals as health care organizations face greater pressure to provide better care at lower cost. We found that adoption of the Lean management system in IT departments was associated with hospital operational and financial efficiencies, including lower LOS and inpatient expense per discharge. Furthermore, use of Lean visual management tools was associated with lower adjusted inpatient expense per discharge and higher EBITDA margin. Such tools were also associated with participation in a bundled payment program and percentage of hospital net patient revenue paid on a shared risk basis. Our study findings suggest that Lean management applied to IT processes has the potential to assist hospitals in the transition toward value-based care.

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