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Impact of repeated hospital accreditation surveys on quality and reliability, an 8-year interrupted time series analysis

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ABSTRACT

Objective To evaluate whether hospital re-accreditation improves quality, patient safety and reliability over three accreditation cycles by testing the accreditation life cycle model on quality measures.

Design The validity of the life cycle model was tested by calibrating interrupted time series (ITS) regression equations for 27 quality measures. The change in the variation of quality over the three accreditation cycles was evaluated using the Levene's test.

Setting A 650-bed tertiary academic hospital in Abu Dhabi, UAE.

Participants Each month (over 96 months), a simple random sample of 10% of patient records was selected and audited resulting in a total of 388 800 observations from 14 500 records.

Intervention(s) The impact of hospital accreditation on the 27 quality measures was observed for 96 months, 1-year preaccreditation (2007) and 3 years postaccreditation for each of the three accreditation cycles (2008, 2011 and 2014).

Main outcome measure(s) The life cycle model was evaluated by aggregating the data for 27 quality measures to produce a composite score (Y_c) and to fit an ITS regression equation to the unweighted monthly mean of the series.

Results The results provide some evidence for the validity of the four phases of the life cycle namely, the initiation phase, the presurvey phase, the postaccreditation slump and the stagnation phase. Furthermore, the life cycle model explains 87% of the variation in quality compliance measures (R^2=0.87). The best-fit ITS model contains two significant variables (β_1 and β_3) ($p \leq 0.001$). The Levene's test ($p \leq 0.05$) demonstrated a significant reduction in variation of the quality measures (Y_c) with subsequent accreditation cycles.

Conclusion The study demonstrates that accreditation has the capacity to sustain improvements over the accreditation cycle. The significant reduction in the variation of the quality measures (Y_c) with subsequent accreditation cycles indicates that accreditation supports the goal of high reliability.

Strengths and limitations of this study

- The study uses segmented regression interrupted time series analysis, an alternative to the randomised controlled trial, which is a gold standard by which effectiveness is measured in clinical disciplines.
- This is the second interrupted time series analysis on hospital accreditation.
- This is also the first study on hospital accreditation over three accreditation cycles and validates the life cycle model on hospital accreditation.
- The study is limited to one hospital in the UAE.
- The quality measures were dependent on the accuracy of documentation in the patient record.

INTRODUCTION

Both the frequency and magnitude of medical errors in hospital settings is a matter of public concern globally. Consequently, healthcare leaders are seeking rigorous methods for improving and sustaining quality of healthcare outcomes in hospitals. Hospital accreditation is the strategy most often selected to improve quality and it has become an integral part of healthcare systems in >90 countries.[1]

A key constraint for hospitals is the cost of accreditation, a process that consumes resources that could be used for frontline medical services.[2] There are two key questions: (1) does accreditation make a difference to the quality of care and hospital performance? and (2) to what extent is any positive effect, if evident, sustainable over time? The literature, however, shows inconsistent results over the impact and effectiveness of hospital accreditation.[3–8] Greenfield *et al* investigated the outcomes across 66 studies and inconsistent findings were reported for the relationship between quality measures and accreditation.[5] Furthermore, Devkaran and O'Farrell have argued that rigorous empirical studies that evaluate whether hospitals sustain compliance with quality and patient safety standards over the accreditation cycle are lacking.[7] Most previous research has used

cross-sectional designs and/or comparative static analysis of data at two points in time.[9 10] In order to draw causal inferences on the impact of accreditation on quality and patient safety measures, a *dynamic* analysis is necessary. This was accomplished by pioneering the use of an interrupted time series model to analyse the impact of accreditation on quality compliance measures in a single hospital over a 4-year period.[7 11] We also outlined a new conceptual framework of hospital accreditation—the life cycle model—and presented statistical evidence to support it.[7]

The primary objective of this paper is to evaluate whether hospital reaccreditation results in an improvement in quality and safety standards over three accreditation cycles by testing the effect of accreditation on 27 quality measures by comparing the results of this hospital (hospital B) accreditation time series with our previous study hospital, a 150-bed, multispecialty, acute care hospital (hospital A) in Abu Dhabi, UAE. The secondary objective is to evaluate the extent to which subsequent accreditation cycles impacts on the variation in quality.

Conceptual framework: the life cycle model

Based on the Joint Commission International (JCI) accreditation strategy, most hospitals will pass through various phases during the process of accreditation.[12] Devkaran and O'Farrell hypothesised four distinct phases of the accreditation cycle and derived predictions concerning the time series trend of compliance during each phase.[7] The predictions constitute the building blocks of the life cycle model. The first initiation phase is characterised by a gradual improvement in compliance to standards with a positive change of slope for the quality measures. The second—presurvey phase—occurs within 3–6 months of the accreditation survey. A marked improvement (ramp up) in compliance occurs during this phase, because staff are aware of the proximity of the survey and because the organisation invests resources in preparation. The peak level of compliance performance occurs during this phase. During the third phase—the postaccreditation slump—a drop in *levels* of compliance occurs immediately following the accreditation survey followed by a negative change in *slope* over time.[7] Finally, the stagnation phase follows the postaccreditation slump and there is an undulating plateau of compliance characterised by sporadic changes, but at an overall level substantially above preaccreditation values.[7]

METHODS

Study population

The study was conducted in a publicly funded 650-bed, multispecialty, acute tertiary care hospital in Abu Dhabi, UAE. The annual inpatient census is approximately 18 000. The hospital treats approximately 220 000 ambulatory care patients per year.

Patient involvement

No patients were involved in this study.

Data collection

To test the life cycle model, a total of 27 quality measures were recorded each month at the hospital, over an 8-year period, including three JCI accreditation surveys (table 1). The quality measures were selected by an expert panel to ensure the: (1) interpretability, enabling direct correlation with a specific JCI standard; (2) consistency, with high values indicating better quality and (3) systems-based, measures designed to evaluate a system/domain of quality rather than a single process. The measures represent both important indicators of quality which are primarily reviewed during survey tracers—including patient assessment, surgical procedures, infection control and patient safety—and 9 of the 14 chapters of the JCI Hospital Standards manual.[13]

The outcome measures for the time series analysis incorporated clinical quality measures and were expressed as percentages, proportions or rates, which minimises ceiling effects (table 1). These performance differences were compared across monthly intervals between four time segments, 1-year preaccreditation, 3 years postaccreditation cycle 1, 3 years postaccreditation cycle 2 and 1 year postaccreditation cycle 3 for the selected quality measures. This study had more than the minimum number of eight data points before and after the intervention and thus had sufficient power to estimate the regression coefficients.[14] The larger number of data points (96) permit more stable estimates for forecasting preintervention trends had the intervention not occurred. The principal data source was the electronic medical record. Slovin's formula was used to calculate the sample size per month based on a 95% CI from an average monthly inpatient census of 1400 patients. Each month (during the entire investigation period), a simple random sample of 10% of patient records was selected and audited from the monthly population resulting in a total of 388 800 observations from 14 500 records. The internal data validation process in place within the hospital included: recollecting the data by second person not involved in the original data collection; using a statistically valid sample of records, cases or other data; comparing the original data with the recollected data; calculating the accuracy by dividing the number of data elements found to be same by the total number of data elements and multiplying that total by 100. A 90% accuracy level was considered as an acceptable benchmark. When the data elements differed, the reasons were noted (eg, unclear data definitions) and corrective actions were taken. A new sample was collected after all corrective actions have been implemented to ensure the actions resulted in the desired accuracy level. The sources used for the data validation included, but were not limited to, the electronic medical record and data abstracts; enterprise resource planning software; electronic insurance claims and the adverse event reporting system.

Quality measures that displayed an inverse relationship to percentage measures were transformed. For example, 'percentage of patients with myocardial infarction within

Table 1 Quality measure descriptions for the Sheikh Khalifa Medical City (hospital B) time series analysis

	Measures	Value	Rationale	JCI chapter
Y_1	Percentage of patients with complete medical history and physical examination done within 24 hours of admission	Percentage	To monitor the completion of history and physical examination reports	Assessment of patient
Y_2	Percentage of inpatients who have allergies assessed and documented on admission	Percentage	To provide appropriate treatment to patients with allergies	Assessment of patient, medication management and use
Y_3	Hospital-acquired pressure ulcer incidence (transformed)	Percentage		Care of patient
Y_4	STAT laboratory orders completed within 1 hour	Percentage	STAT orders are laboratory requests requiring a TAT of <60 min usually due to medical emergency. The indicator provides a valuable tool for addressing the medical and logistical necessities underlying STAT ordering practices	Assessment of patient
Y_5	STAT emergency room troponin orders with a turnaround time (TAT) within 1 hour	Percentage	Monitors the efficiency of the total testing cycle, from order entry to availability of results, for STAT troponin orders from all emergency locations	International patient safety goal 2
Y_6	STAT potassium order with TAT within 1 hour	Percentage	Monitors the processing efficiency (from specimen receipt to result verification) for STAT and routine orders from all locations. Potassium is the chemistry indicator	Assessment of patient
Y_7	STAT haemoglobin with TAT within 1 hour	Percentage	Monitors the processing efficiency (from specimen receipt to result verification) for STAT and routine orders from all locations. Haemoglobin is the haematology indicator	Assessment of patient
Y_8	Percentage of patients with myocardial infarction within 72 hours after coronary artery bypass graft surgery *(transformed)*	Percentage	Monitors surgical procedure complications	Care of patient, quality and patient safety
Y_9	Percentage of completed preanaesthesia assessments	Percentage	Monitors anaesthesia compliance with the standards	Anaesthesia and surgical care
Y_{10}	Percentage of patients with completed preinduction assessments	Percentage	Monitors whether patient is fit for anaesthesia	Anaesthesia and surgical care
Y_{11}	Percentage of patients with postdural headache postanaesthesia *(transformed)*	Percentage	Monitors this as a complication within 72 hours of surgery done under epidural or spinal anaesthesia, or after delivery under epidural labour analgesia	Anaesthesia and surgical care
Y_{12}	Percentage of patients with a prolonged postanaesthesia care unit stay (>2 hours) *(transformed)*	Percentage	To measure delays in recovery	Anaesthesia and surgical care, quality and patient safety
Y_{13}	Red blood cell (RBC) unit expiration rate (*transformed)*	Percentage	Monitors the RBC expiration rate. It ensures that RBC wastage is kept to a minimum	Assessment of patients
Y_{14}	Percentage of STAT cross matches done within 1 hour	Percentage	Monitors the efficiency (from specimen receipt in the blood bank to the completion of the crossmatch to antihuman globulin phase with the red cell unit(s) appropriately tagged and ready for release) of STAT crossmatch orders required for immediate transfusion	Assessment of patients

Continued

Table 1 Continued

	Measures	Value	Rationale	JCI chapter
Y_{15}	Percentage of correct documents in the medical record	Percentage	Monitors the accuracy of the documents filed in the medical record	Management of information
Y_{16}	Percentage of 'do not use abbreviations' documented in the medical record *(transformed)*	Percentage	Monitors the usage of unapproved abbreviations in the medical records	Management of information
Y_{17}	Central line-associated bloodstream infection rate in ICU per 1000 device days *(transformed)*	Percentage	Monitors bloodstream infection rate related to central lines in the ICU	Prevention and control of infection
Y_{18}	Indwelling catheter-associated urinary tract infection (UTI) rate in ICU per 1000 device days (*transformed)*	Percentage	Monitors indwelling catheter-associated UTI in the ICU	Prevention and control of infection
Y_{19}	Ventilator-associated pneumonia (VAP) rate in per 1000 device days*(transformed)*	Percentage	Monitors VAP in the ICU	Prevention and control of infection
Y_{20}	Overall healthcare-associated infection rate/1000 patients bed days *(transformed)*	Percentage	Rate of the main healthcare-associated infections that are being monitored in the hospital per 1000 patients days	Prevention and control of infection
Y_{21}	Percentage of supply wastage value in the consumable store *(transformed)*	Percentage	Monitors capital due of expired items in consumable store	Governance leadership and direction
Y_{22}	Pulmonary tuberculosis (TB) cases reported to the health authority within 24 hours of diagnosis	Percentage	Ensures that newly diagnosed TB cases are reported as per the law	Governance leadership and direction
Y_{23}	Percentage of adverse events reported per 1000 patient days	Percentage	Monitors the culture of safety in the organisation	Quality and patient safety
Y_{24}	Readmissions within 48 hours per 1000 discharges *(transformed)*	Percentage	Rate of readmitted patients is an important balancing measure to indicate if changes to patient flow through the system are negatively affecting care	Quality and patient safety
Y_{25}	Unplanned readmission rate within 1 month per 1000 discharges *(transformed)*	Percentage	Monitors unplanned readmission rates to hospital within 1 month following discharge. Readmissions may be indications of quality issues related to shortened length of stay and premature discharge	Quality and patient safety
Y_{26}	Hand hygiene observation rate	Percentage	Compliant hand hygiene patient care practices per 100 patient care practices	International patient safety goal 5
Y_{27}	Inpatient fall rate per 1000 patients days *(transformed)*	Percentage	Patient falls occurring during hospitalisation can result in serious harm	International patient safety goal 6

Source, Devkaran S *et al* 2018.
JCI, Joint Commission International.

72 hours after coronary artery bypass graft surgery' was transformed to 'percentage of patients without myocardial infarction within 72 hours after coronary artery bypass graft surgery', thus equating higher values to good quality.

Study design

Interrupted time series analysis is the most powerful quasi-experimental design for evaluating the longitudinal effects of an intervention (eg, accreditation) on an outcome of interest where the trend before the accreditation intervention is used as a control period. The advantage of this method over a simple before-and-after study is due to the repeated monthly measures of variables, while controlling for seasonality and secular trends. Shifts in level (intercept) or slope, with $p<0.05$, were defined as statistically significant. Segmented regression models

fit a least squares regression line to each segment of the independent variable, time and thus assume a linear relationship between time and the outcome within each segment.[14–18] The following linear regression equation is specified to estimate the levels and trends in the dependent variable before each of three accreditations, and the changes in levels and trends after each accreditation:

$$Y_t = \beta_0 + \beta_1 \times t_1 + \beta_2 \times I_1 + \beta_3 \times t_2 + \beta_4 \times I_2 + \beta_5 \times t_3 + \beta_6 \times I_3 + \beta_7 \times t_4 + et \quad (1)$$

Where Y_t is the outcome, for example, the inpatient fall rate per 1000 patient days; time t_1, t_2, t_3 and t_4 indicates time in months from the start of each observation period to the end of the period; interventions I_1, I_2 and I_3 are dummy variables taking the value 0 before the intervention and one after the intervention. In this model β_0 is the baseline level of the outcome at the beginning of the series; β_1 the slope prior to accreditation, that is the baseline trend; β_2, β_4 and β_6 are the changes in level immediately after each accreditation and β_3, β_5 and β_7 are the changes in slopes from preaccreditation to post the three accreditations, respectively, and represents the monthly mean of the outcome variable; and et is the random error term.

Data analysis

First, a plot of observations against time was completed in order to reveal key features of the data, including trend, seasonality, outliers, turning points and any discontinuities. Second, segmented regression models were fitted using ordinary least squares regression analysis; and the results reported as level and trend changes. Third, the Durbin-Watson (DW) statistic was used to test for the presence of two types of autocorrelation: (1) the autoregressive process and (2) the moving average process. If the DW was significant, the model was adjusted by estimating the autocorrelation parameter and including it in the segmented regression model. Fourth, the Dickey-Fuller statistic was used to test for stationarity and seasonality. A series displaying seasonality or some other non-stationary pattern was controlled by taking the difference of the series from one period to the next and then analysing this differenced series. Since seasonality induces autoregressive and moving average processes, the detection and inclusion of a seasonal component was implemented in the time series models using the autoregressive moving average (ARMA), ARMA and dynamic regression. A range of model-checking techniques have been used including plotting residuals and partial autocorrelation functions as well as sensitivity analyses. Fifth, there were no significant hospital changes (ie, change in ownership, construction, capacity or scope change >25% of the patient volume, addition of services or mergers) that occurred during the study period based on the JCI accreditation participation requirements 3.[13] Furthermore, the leadership and composition of the quality and safety programme remained the same throughout. Therefore, it may be assumed that the accreditation interventions were the key events to impact the time series. The analysis was conducted using EViews 7.0. In order to verify whether the accreditation process exhibits the life cycle effect, the statistical predictions specified for the 27 measures were tested.

The ultimate confirmatory test of the life cycle model and of the impact of three separate accreditations is to aggregate the data for all 27 quality compliance measures to produce a composite score (Y_C) and to fit an interrupted time series regression equation to an unweighted mean monthly value of the series. The composite measure assumed that all of the 27 indicators have the same weight.

RESULTS

The descriptive statistics of the dependent variables are depicted in table 2 and demonstrate that 88% of measures had a mean and median >90%. The data were symmetrical as the means and medians were similar for all measures. In terms of dispersion, 74% of measures have a SD of 3 or less. The measure Y_{22} has the lowest mean and the highest SD. Table 3 outlines the interrupted time series equations for the 27 quality compliance measures. Several equations display autocorrelation, in which cases the autoregressive (AR) or moving average (MA) variable was included to correct for it. First, 78% of the β_1 coefficients (the slope prior to the first accreditation) are positive, as predicted and half are statistically significant correlating with the presurvey ramp up phase in the life cycle model (table 3). Conversely, 26% of the coefficients are negative, but only three are significant. Second, the β_2 coefficients—the change in level following the first accreditation—are negative and significant in five cases and positive and significant in six. Hence, in 60% of cases the first intervention effect is not significant. The β_3 slope coefficient results are more mixed following the first accreditation: in five cases, coefficients are both negative and significant, and also five are positive and significant. Conversely, for 63% of cases there is no significant effect. Fourth, in the case of the second intervention, β_4, seven coefficients are both negative and significant, whereas only four positive coefficients are significant. For β_5, the second postaccreditation slope, 59% of the coefficients are not significant but 8 of the 11 significant slopes are negative. Similarly, some 85% of the coefficients on (β_6)—the third intervention—are not statistically significant; and, finally, 86% of the postaccreditation slopes (β_7) are not significant (table 3). The mixed results at the level of individual measures provide limited support for the life cycle model with the exception of the presurvey ramp up phase (β_1).

The results of the overall test, using a composite score (Y_C), are summarised in table 4. Diagnostic assumption tests show that there is autocorrelation. Hence, the model was adjusted by estimating the autocorrelation parameter AR (1) and incorporating it in the segmented regression model; inclusion of it eliminates the autocorrelation problem (table 4).

Table 2 Results of descriptive statistical analysis for the 27 quality measures

Variable	Measure description	Mean	SD	Median	Quartile 1	Quartile 3	IQR
Y_C	Composite variable	94.90	3.08	95.60	94.03	97.15	3.12
Y_1	Percentage of patients with complete medical history and physical examination done within 24 hours of admission	93.04	16.78	100.00	96.75	100.00	3.25
Y_2	Percentage of inpatients who have allergies assessed and documented on admission	97.08	4.97	99.32	96.49	100.00	3.51
Y_3	Hospital-acquired pressure ulcer incidence *(transformed)*	99.46	0.36	99.57	99.32	99.69	0.38
Y_4	STAT laboratory orders completed within 1 hour	84.06	3.81	84.84	81.64	87.44	5.79
Y_5	STAT emergency room troponin orders with a turnaround time (TAT) within 1 hour	97.28	2.95	98.17	96.89	98.83	1.93
Y_6	STAT potassium order with TAT within 1 hour	96.44	3.30	97.22	96.24	97.90	1.65
Y_7	STAT haemoglobin with TAT within 1 hour	98.05	1.27	98.29	97.18	99.10	1.92
Y_8	Percentage of patients with myocardial infarction within 72 hours after coronary artery bypass graft surgery *(transformed)*	99.41	2.49	100.00	100.00	100.00	0.00
Y_9	Percentage of completed preanaesthesia assessments	94.92	9.30	99.90	93.65	100.00	6.35
Y_{10}	Percentage of patients with completed preinduction assessments	94.80	9.48	97.75	94.90	100.00	5.10
Y_{11}	Postdural puncture headache *(transformed)*	99.82	1.30	100.00	100.00	100.00	0.00
Y_{12}	Percentage of patients with a prolonged postanaesthesia care unit stay (>2 hours) *(transformed)*	96.10	2.47	96.75	95.64	97.61	1.97
Y_{13}	Red blood cell unit expiration rate *(transformed)*	99.30	1.80	99.76	99.12	100.00	0.88
Y_{14}	Percentage of STAT cross matches done within 1 hour	94.13	3.45	95.08	93.16	96.16	3.00
Y_{15}	Percentage of correct documents in the medical record *(transformed)*	97.06	4.71	99.28	96.79	99.61	2.82
Y_{16}	Percentage of 'do not use abbreviations' documented in the medical record *(transformed)*	91.36	19.78	100.00	95.00	100.00	5.00
Y_{17}	Central line-associated bloodstream infection rate in ICU per 1000 device days *(transformed)*	99.77	0.25	99.80	99.65	100.00	0.35
Y_{18}	Indwelling catheter-associated urinary tract infection rate in ICU per 100 device days *(transformed)*	99.83	0.18	99.85	99.73	100.00	0.27
Y_{19}	Ventilator-associated pneumonia rate per 100 device days *(transformed)*	99.60	0.33	99.69	99.46	99.85	0.39
Y_{20}	Overall healthcare-associated infection rate/1000 patients bed days *(transformed)*	99.93	0.03	99.93	99.91	99.95	0.04
Y_{21}	Percentage of supply wastage value in the consumable store	99.96	0.09	100.00	99.95	100.00	0.05
Y_{22}	Pulmonary tuberculosis cases reported to the health authority within 24 hours of diagnosis	62.67	30.75	66.67	42.56	85.71	43.15
Y_{23}	Percentage of adverse events reported per 1000 patient days *(transformed)*	98.85	0.70	99.12	98.43	99.38	0.95
Y_{24}	Readmission within 48 hours per 100 discharges *(transformed)*	98.61	0.79	98.58	98.13	99.08	0.95
Y_{25}	Unplanned readmission rate within 1 month per 1000 discharges *(transformed)*	92.83	3.14	92.01	90.67	93.82	3.15
Y_{26}	Hand hygiene observation rate	79.36	9.53	82.05	75.38	85.09	9.71
Y_{27}	Inpatient fall rate per 1000 patient days *(transformed)*	99.94	0.03	99.94	99.93	99.95	0.03

The slope prior to the first accreditation (β_1) is positive and highly significant (presurvey ramp up phase), as predicted by the life cycle model of Devkaran and O'Farrell.[7 11] The change in level following the first accreditation survey (β_2) is unexpectedly positive, but is not significant. The postaccreditation slope (β_3), however,

Table 3 Time series analysis for the 27 quality measures

	Model validation and parameter estimation											Diagnostic tests	
	Intercept mean (β_0)	Preaccreditation time (β_1)	Accreditation 1 intervention (β_2)	After accreditation 1 (β_3)	Accreditation 2 intervention (β_4)	After accreditation 2 (β_5)	Accreditation 3 intervention (β_6)	After accreditation 3 (β_7)	AR (1)	MA (1)	F-statistics	R^2	Autocorrelation check Durbin Watson	Test for seasonality/ stationarity: (Dickey Fuller Unit Root Test)
Response variable model	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient P values	Coefficient p values	P values		Result of Durbin Watson	P values Result
(Y_1) **% patients with complete medical history and physical examination within 24** hours Full model	25.59 ≤0.001	4.51 ≤0.001	4.04 0.29	−4.47 ≤0.001	0.52 0.86	0.00 0.99	−0.10 0.98	−0.03 0.96			≤0.001	87.0%	2.74 1.26 No autocorrelation	≤0.001 Series is stationary
(Y_2) % of inpatients who have an allergies documented on admission Full model	86.00 ≤0.001	0.40 0.06	3.94 0.07	−0.29 0.19	−2.18 0.20	−0.03 0.68	−0.18 0.94	−0.13 0.71			≤0.001	53.3%	1.61 2.39 No autocorrelation	≤0.001 Series is stationary
(Y_3) Hospital-acquired pressure ulcer incidence (transformed) Full model	99.20 ≤0.001	−0.01 0.58	−0.18 0.24	0.03 0.05	−0.04 0.75	−0.02 0.00	−0.01 0.95	0.00 0.91			≤0.001	52.3%	1.64 2.36 No autocorrelation	≤0.001 Series is stationary
Y_4) STAT (within 1 hour) order rate (first differencing)	75.20≤0.001	0.32 0.03	Journal of Clinical Epidemiology0.92 0.50	−0.17 0.26	2.45 0.02	−0.26≤0.001	2.51 0.13	−0.24 0.27	0.85≤0.001		≤0.001	78.0%	1.85 2.15 No autocorrelation	≤0.001 Series is stationary after first differencing
(Y_5) STAT ER troponin with turnaround time (TAT) within 1 hour (with MA1)	94.93≤0.001	−0.16 0.27	4.05≤0.001	0.18 0.25	−1.61 0.17	0.09 0.12	−0.41 0.82	−0.17 0.47		0.52≤0.001	≤0.001	45.7%	1.91 2.09 No autocorrelation	≤0.001 Series is stationary
(Y_6) STAT potassium with TAT within 1 hour (with MA1)	82.80≤0.001	1.21≤0.001	−4.18≤0.001	−1.16≤0.001	−2.32 0.01	0.01 0.91	0.91–0.09	−0.03 0.86		0.74≤0.001	≤0.001	79.7%	1.73 2.27 No autocorrelation	≤0.001 Series is stationary
(Y_7) STAT haemoglobin with TAT within 1 hour (with MA1)	96.28≤0.001	0.04 0.45	−0.03 0.95	0.00 0.98	0.95 0.04	−0.07≤0.001	−0.62 0.36	0.18 0.36		0.33≤0.001	≤0.001	44.0%	1.88 2.12 No autocorrelation	≤0.001 Series is stationary
(Y_8) Percentage of patients without myocardial infarction within 72 hours after coronary artery bypass graft surgery	99.94≤0.001	−0.04 0.77	−1.15 0.44	0.09 0.54	−1.41 0.25	0.01 0.89	0.00 1.00	0.00 1.00			0.50	5.35%	0.00 2.19 No autocorrelation	0.50 Series is stationary
(Y_9) Completion of preanaesthesia assessments	59.72≤0.001	3.10≤0.001	−6.68 0.05	−3.38≤0.001	5.80 0.03	0.47≤0.001	−1.41 0.73	−0.42 0.45			≤0.001	65.95%	0.00 1.57 No autocorrelation	≤0.001 Series is stationary
(Y_{10}) Completion of immediate preinduction assessments	55.22≤0.001	3.13≤0.001	−8.60≤0.001	−3.03≤0.001	0.23 0.91	−0.03 0.81	−0.22 0.95	−0.08 0.85			≤0.001	80.11%	0.00 1.83 No autocorrelation	≤0.001 Series is stationary

Continued

Table 3 Continued

	Model validation and parameter estimation												Diagnostic tests	
	Intercept mean (β_0)	Preaccreditation time (β_1)	Accreditation 1 intervention (β_2)	After accreditation 1 (β_3)	Accreditation 2 intervention (β_4)	After accreditation 2 (β_5)	Accreditation 3 intervention (β_6)	After accreditation 3 (β_7)	AR (1)	MA (1)	F-statistics	R^2	Autocorrelation check Durbin Watson	Test for seasonality/ stationarity: (Dickey Fuller Unit Root Test)
Response variable model	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient P values	Coefficient p values	P values		Result of Durbin Watson	P values Result
(Y_{11}) Percent of patients without postdural puncture headaches	100.00≤0.001	0.00 1.00	−1.61 0.04	0.06 0.44	−0.59 0.33	−0.06 0.04	0.00 1.00	0.00 1.00			0.02	12.37%	0.00 2.10 No autocorrelation	≤0.001 Series is stationary
(Y_{12}) Prolonged recovery >2 hours (transformed) (first differencing)	96.85≤0.001	0.04≤0.001	−3.53≤0.001	−0.05 0.72	−2.18 0.04	0.04 0.50	0.07 0.96	−0.07 0.74	0.37 ≤0.001		≤0.001	28.20%	0.00 1.83 No autocorrelation	≤0.001 Series is stationary
(Y_{13}) percentage of red blood cell units expired (transformed)	99.74≤0.001	0.02 0.82	−0.17 0.87	−0.03 0.79	−2.62 ≤0.001	−0.09 0.03	−0.40 0.74	−0.12 0.47			0.01	18.96%	0.00 2.07 No autocorrelation	≤0.001 Series is stationary
(Y_{14}) STAT crossmatch within 1 hour	90.11≤0.001	0.05≤0.001	2.05 0.06	0.06 0.44	−0.82≤0.001	−0.03 0.66	0.18 0.93	−0.05 0.85			0.02	47.69%	0.00 1.49 No autocorrelation	≤0.001 Series is stationary
(Y_{15}) percentage of correct documents filed in the record	96.81≤0.001	0.07≤0.001	2.20 0.13	0.70≤0.001	0.72 0.70	−0.13 0.16	−0.14 0.96	0.01 0.97			≤0.001	40.90%	0.00 1.85 No autocorrelation	≤0.001 Series is stationary
(Y_{16}) Percentage of unapproved abbreviations used (transformed)	15.23≤0.001	−0.26≤0.001	2.72 0.62	2.33 0.30	−0.04 0.99	0.53 0.05	0.00 1.00	0.00 1.00			≤0.001	23.82%	0.00 1.69 No autocorrelation	≤0.001 Series is stationary
(Y_{17}) central line-associated bloodstream infections (transformed)	99.51≤0.001	0.04≤0.001	0.21 0.01	0.00 0.10	−2.18 0.04	0.04 0.50	0.07 0.96	−0.07 0.74			≤0.001	28.20%	0.00 1.83 No autocorrelation	≤0.001 Series is stationary
(Y_{18}) Indwelling catheter-associated urinary tract infection rate (transformed)	99.76 ≤0.001	0.00 0.07	0.16 0.01	0.01 0.53	−0.03 0.74	−0.01 ≤0.001	0.24 0.05	−0.03 0.05			≤0.001	23.21%	0.00 1.96 No autocorrelation	≤0.001 Series is stationary
(Y_{19}) Ventilator-associated pneumonia rate (transformed) first differencing	99.51 ≤0.001	0.00 0.03	0.21 0.05	0.09 ≤0.001	0.06 0.58	−0.03 ≤0.001	0.07 0.68	0.00 0.85	0.48 ≤0.001		≤0.001	40.22%	0.00 2.05 No autocorrelation	≤0.001 Series is stationary
(Y_{20}) Overall healthcare-associated infection rate (transformed)	99.92 ≤0.001	0.00 0.09	−0.00 0.91	0.01 0.03	0.02 0.11	−0.00 0.38	−0.02 0.35	0.01 0.26			0.03	15.38%	0.00 1.80 No autocorrelation	≤0.001 Series is stationary
(Y_{21}) Percentage of supply wastage value (transformed) first differencing	99.97 ≤0.001	−0.01 0.01	0.01 0.78	0.02 ≤0.001	−0.03 0.29	−0.01 ≤0.001	0.00 1.00	0.00 1.00	0.60 ≤0.001		≤0.001	55.61%	0.00 2.05 No autocorrelation	≤0.001 Series is stationary

Continued

Table 3 Continued

	Model validation and parameter estimation												Diagnostic tests	
	Intercept mean (β_0)	Preaccreditation time (β_1)	Accreditation 1 intervention (β_2)	After accreditation 1 (β_3)	Accreditation 2 intervention (β_4)	After accreditation 2 (β_5)	Accreditation 3 intervention (β_6)	After accreditation 3 (β_7)	AR (1)	MA (1)	F-statistics	R^2	Autocorrelation check Durbin Watson	Test for seasonality/ stationarity: (Dickey Fuller Unit Root Test)
Response variable model	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient p values	Coefficient P values	Coefficient p values	P values		Result of Durbin Watson	P values Result
(Y_{22}) Pulmonary tuberculosis cases reported to health authority within 24 hours of diagnosis first differencing	29.05 0.01	0.25 0.21	25.26 0.08	−0.93 0.58	−24.29 0.06	−0.24 0.71	−26.04 0.19	4.44 0.09	0.26 ≤0.001		≤0.001	27.39%	0.00 2.05 No autocorrelation	0.02 Series is stationary
(Y_{23}) Adverse event reports per 1000 patient days (transformed) first differencing	99.76 ≤0.001	−0.02 ≤0.001	0.32 0.24	−0.03 0.32	0.72 ≤0.001	0.01 0.61	−0.06 0.85	−0.01 0.87	0.68 ≤0.001		≤0.001	75.67%	0.00 2.07 No autocorrelation	≤0.001 Series is stationary
(Y_{24}) Readmission within 48 hours per 1000 discharges (transformed) first differencing	98.43 ≤0.001	0.05 0.22	−0.37 0.35	−0.05 0.22	−0.70 0.03	0.02 0.14	−2.25 ≤0.001	0.37 ≤0.001	0.70 ≤0.001		≤0.001	48.36%	0.00 1.91 No autocorrelation	≤0.001 Series is stationary
(Y_{25}) Unplanned readmission rate within 1 month per 1000 discharges (transformed) first differencing	91.76 ≤0.001	0.13 0.43	−0.51 0.73	−0.15 0.36	−3.36 ≤0.001	0.22 ≤0.001	−9.58 ≤0.001	1.20 ≤0.001	0.74 ≤0.001		≤0.001	45.10%	0.00 1.79 No autocorrelation	0.04 Series is stationary
(Y_{26}) Hand hygiene observation rate first differencing	67.05 ≤0.001	−0.02 0.96	8.19 0.09	0.36 0.50	−5.23 0.17	−0.33 0.08	4.36 0.45	−0.61 0.44	0.69 ≤0.001		≤0.001	59.03%	0.00 1.93 No autocorrelation	0.01 Series is stationary
(Y_{27}) Inpatient fall rate (transformed) first differencing	99.9 ≤0.001	0.0 0.1	0.0 ≤0.001	0.00 0.10	0.02 0.11	0.00 0.79	−0.01 0.51	0.00 0.73	0.26 ≤0.001		≤0.001	20.01%	0.00 1.76 No autocorrelation	0.02 Series is stationary

AR, autoregressive variable; MA, moving average variable.

Table 4 Interrupted time series composite model for the 27 quality measures

Response variable	Model	Diagnostic tests																Test for seasonality/ stationarity (Dickey Fuller Unit Root Test)
		Intercept (mean) (β_0)		Preaccreditation time (β_1)		Accreditation 1 intervention (β_2)		After accreditation 1 (β_3)		Accreditation 2 intervention (β_4)		After accreditation 2 (β_5)		Accreditation 3 intervention (β_6)		After accreditation 3 (β_7)		AR (1)		F-statistics	R^2	Autocorrelation check Durbin Watson Statistic	
		Coefficient	p values	Coefficient	p values	Coefficient	p values	Coefficient	p values	Coefficient	p values	Coefficient	p values	Coefficient	p values	Coefficient	p values	Coefficient	p values	P values		Result of Durbin Watson	P values Result
Y_C composite model*	Full model	87.20	≤0.001	0.49	≤0.001	0.79	0.17	−0.45	≤0.001	−0.03	0.94	−0.01	0.71	−0.44	0.53	−0.01	0.95			≤0.001	86.60%	1.46 2.54 Positive autocorrelation	≤0.001 Series is stationary
	Full model with AR (1)	86.89	≤0.001	0.52	≤0.001	0.60	0.25	−0.48	≤0.001	−0.07	0.95	−0.01	0.87	−0.40	0.91	−0.01	0.99	0.25	≤0.001	≤0.001	87.37%	1.91 2.09 No autocorrelation	≤0.001 Series is stationary

*Composite quality measure (Y_C) is the mean of the 27 quality measures.
AR, autoregressive variable.

is negative and statistically significant (postaccreditation slump), as postulated by the model. The changes in level following the second and third accreditation surveys are both negative, but are not significant (table 4). Similarly, the postaccreditation slopes following these two later surveys are both negative, as hypothesised, but are not significant. The R^2 value for the composite model with the AR (1) function indicates that over 87% of the variation in quality compliance outcomes is explained (table 4). There is, however, a problem with multicollinearity. Inspection of the three postaccreditation slopes in figure 1 shows a long gently undulating plateau of compliance which is consistent with the non-significance of the second and third accreditations; and is substantiated by the evidence that the mean compliance level before the first accreditation was 89.2% and, following the three accreditations, the mean levels were 95.2%, 96.3% and 97.4%, respectively. The evidence for the life cycle model is stronger in the case of the first hospital accreditation survey than in the subsequent accreditations. Given that our model has a high R^2 value of 0.87, it is a useful predictive tool, although it results in somewhat unstable parameter an estimate which makes it more difficult to assess the effect of individual independent variables.

Clearly, we cannot forecast precisely what would have occurred if the one accreditation in 2008 had not been followed by subsequent survey visits in 2011 and 2014, that is, the counterfactual position. However, if compliance had been allowed to slip following the first survey, it would be expected that improvements in quality would occur both before the second and third surveys in 2011 and 2014; and that there would also be falls in levels of compliance immediately following these surveys. None of these outcomes occurred. This implies that once a high level of compliance has been achieved after the initial accreditation survey, it is highly likely to be maintained (figure 1).

Finally, we compare the results of the composite model (Y_C) for the 27 measures (hospital B) with that of the 23 quality measures for the 150-bed hospital A (figure 2).[7 11] A number of interesting patterns are apparent. First, the slopes prior to accreditation (β_2) are both positive and highly significant, as hypothesised. Second, the change in level following the first accreditation survey (β_3) signals a significant decline in compliance, as predicted, in the case of hospital A; while for the current study, hospital B, the effect is not significant. Third, as postulated, the postaccreditation slope (β_3) is both negative and statistically significant for each hospital. Fourth, there is a striking similarity in the shape of the two graphs with a marked improvement in compliance during the first presurvey phase; a drop in the level of compliance following the accreditation survey at hospital A, while similar falls in level were recorded after two of the three accreditations at hospital B, followed in both hospitals by undulating plateaus of compliance, at a level substantially greater than those recorded prior to the first accreditation survey. Fifth, a notable feature of the results is that, although

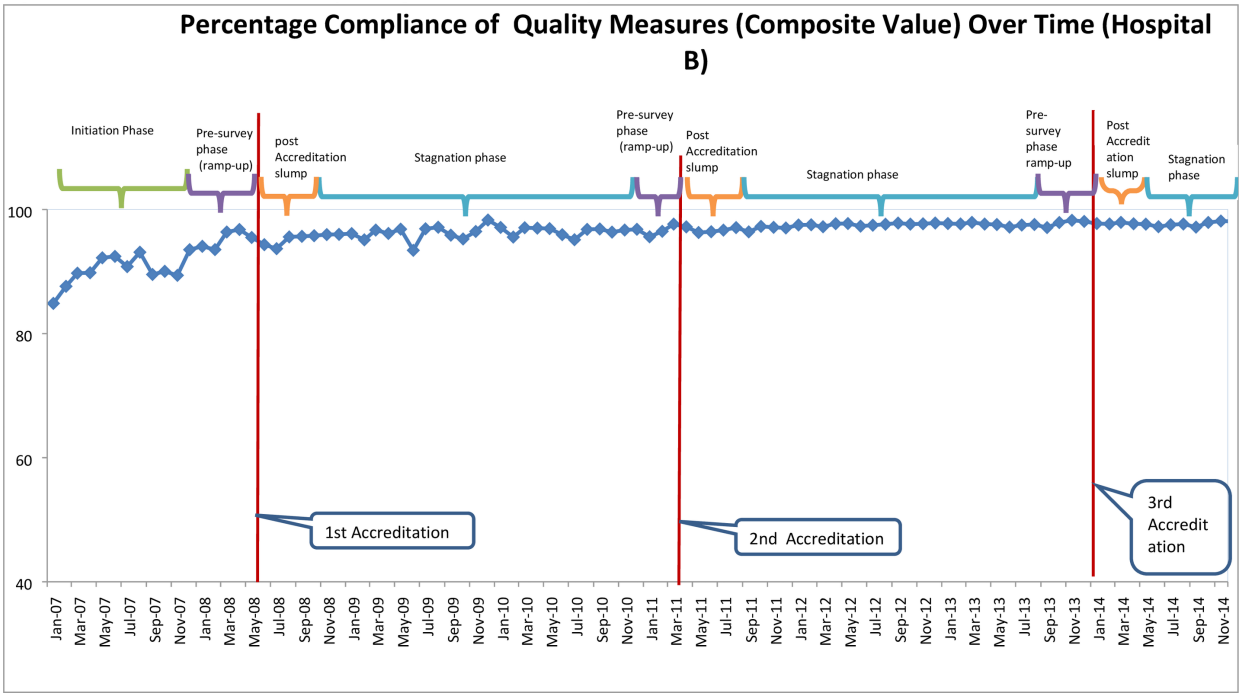

Figure 1 Phases of the accreditation life cycle: empirical evidence over 8 years.

the pattern of compliance change is very similar, the level of compliance at hospital B is slightly higher: for the presurvey phase the average level of compliance at hospital B is 87.40% compared with 79.5% at hospital A; while for the postaccreditation period, the hospital B compliance average of 96% also exceeds that of hospital A (93%). It is important to note that both hospitals adopted the same approach to accreditation and survey preparation by following the JCI roadmap to accreditation.[12 13]

Finally, having demonstrated that there is a significant difference between group means of the composite measure (Y_C), we tested the null hypothesis that there is no significant difference between the group variances. The results of Levene's test show that the hypothesis of homogeneity of variances is rejected at $p<0.05$ (table 5). Therefore, there is a significant difference between the four group variances and figure 3 shows that the variances decrease after each successive accreditation. Hence, with the exception of the means for groups C and D, successive accreditations lead to an increase in the mean and decrease in the variance of the composite compliance measure (Y_C). The results of the confirmatory test of the

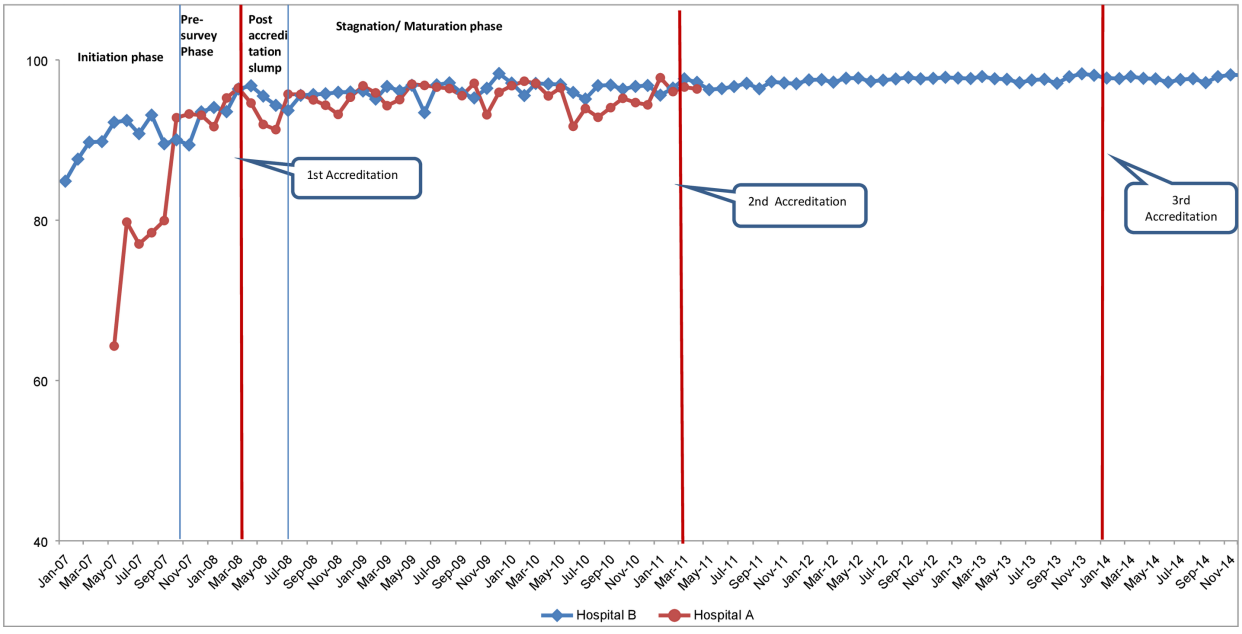

Figure 2 Life cycle model comparison between hospital A (previous study) and hospital B (current study).

Table 5 Anova and Levene's test for variances between accreditation cycles

Summary				
Groups	*Count*	*Sum*	*Average*	*Variance*
Presurvey phase	16	40.28	2.52	3.00
Postsurvey phase after accreditation 1	36	28.62	0.80	0.41
Postsurvey phase after accreditation 2	34	12.37	0.36	0.08
Postsurvey phase after accreditation 3	10	2.53	0.25	0.04

proposed life cycle model, using a composite score (Y_C) of the 27 quality measures, provide proof of the life cycle model.

DISCUSSION

Empirical evidence to support the effectiveness of accreditation is still lacking, which creates a legitimacy problem for healthcare policymakers and hospital management.[4] Is achieving and, above all, maintaining accreditation worth the time and money if there is uncertainty about whether it results in measurable improvements in healthcare delivery and outcomes?[2–6 19] While accreditation enhances quality performance, its major benefit lies in organisations integrating standards into their routine workflows. Integration ensures that the ramp up to surveys is avoided and that organisations reliably apply the evidence-based practices for each patient during each encounter.

Unannounced surveys

Announced triennial surveys have been criticised for permitting healthcare organisations to perform for the 'test'; and, when the accreditation survey is completed, facilities may return to their presurvey reality. Therefore, unannounced surveys have been proposed to mitigate this effect and to encourage a continuous improvement culture. However, there are only two published (Australian and Danish) studies comparing announced and unannounced surveys. Both studies show no evidence of increased citations of non-compliance in unannounced surveys compared with announced surveys.[20 21]

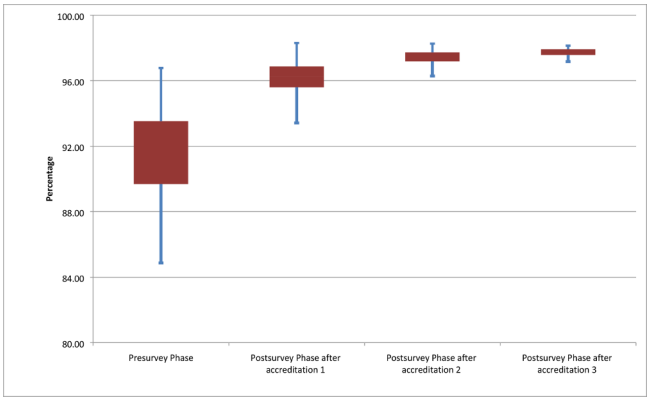

Figure 3 Box plot comparing variation in performance between the accreditation cycles.

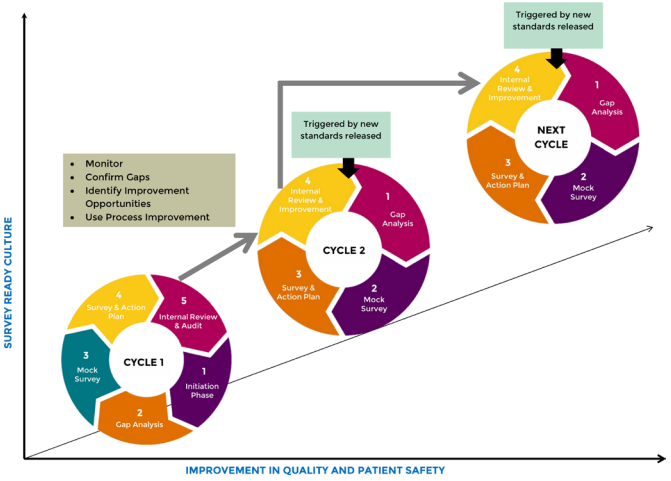

Figure 4 Wheel of continual survey readiness. Adapted from Devkaran and O'Farrell.[7,11]

Continual survey readiness

Rather than assign the accountability to accreditation bodies for the associated life cycle, organisations need to review their own continual survey readiness strategies. The components of an effective continual survey readiness programmes remain unexplored. Therefore, the authors propose a survey readiness cycle that is grounded on the four phases of the accreditation life cycle model, supported by the literature and influenced by the Institute for Healthcare Improvement Model for Improvement.[20–23] The proposed survey readiness cycle consists for four components: (1) a gap analysis; (2) a mock survey; (3) postsurvey action plans that occur after the actual survey and (4) intracycle internal reviews and improvement (figure 4). For the cycle to be effective, a leadership oversight body needs to be created with the objective of conducting regular reviews of compliance using associated metrics to ensure that the process is sustained. If an accredited organisation has integrated the standards into routine practice with a foundation that is built on fundamental patient safety principles, they are likely to minimise errors. Furthermore, when hospitals consistently perform according to standard, they attain the status of a high reliability organisation.[23]

CONCLUSION

We pioneered the first study of hospital accreditation to conduct a dynamic analysis of the impact of accreditation on quality compliance measures using interrupted time series analysis.[7 11] This paper has advanced the research in several important ways: (1) by studying another hospital over an extended 8-year period; (2) by conducting an

interrupted time series analysis of 27 quality compliance measures over a period incorporating three separate accreditation evaluations and (3) by demonstrating that subsequent accreditation surveys significantly reduces variation in quality performance which correlates with higher reliability.

The evidence from both hospital studies suggests that the tangible impact of accreditation has the capacity to sustain improvements over the accreditation cycle. Our results suggest that once a high level of quality compliance has been achieved—following the first accreditation visit—it is highly likely to be sustained. In addition, repeated surveys reduce variations in quality performance therefore supporting the organisation's journey to high reliability.

The following limitations should be acknowledged. First, the accuracy of measures is dependent on the quality of documentation in the patient record. For instance, if the documentation was deficient then this was reflected in the measure. Second, the choice of quality measures is defined by the availability of evidence in patient records. Third, this study is set in the UAE and may not be generalisable to hospitals in other settings. Fourth, both study hospitals provide acute tertiary care and have limited generalisability to specialty hospitals or primary/secondary care healthcare facilities. Fifth, interrupted time series analysis is limited by time-varying confounding improvement initiatives that may have occurred at the department level however, since this methodology evaluates changes in rates of an outcome at a system-level, confounding by individual level variables will not introduce serious bias unless it occurs simultaneously with the intervention. Sixth, although ceiling effects were minimised, it is acknowledged that if a measure is close to 100% then any subsequent improvement will only be small. However, our analysis has shown conclusively that each successive accreditation lead to an increase in means and also to a decrease in the variances of the composite measure. Finally, more studies are required to evaluate methodologies for achieving continuous survey readiness.

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