Systems theory and improving healthcare

Peter P. Howley[1], Sheuwen W. Chuang[2]

[1]The University of Newcastle, Callaghan, NSW, 2308, AUSTRALIA
Peter.Howley@newcastle.edu.au
[2] Taipei Medical University, Taipei, Taiwan
Sheuwen@tmu.edu.tw

Abstract

The accreditation and quality measurement and reporting systems in health care organisations are believed to influence patient safety and quality of care. In order to gain knowledge about the effects of these two systems, an holistic healthcare systems relationship model was recently constructed and a series of adaptive-control studies developed to explore relationships between segments within the systems relationship model.

This paper describes where we've been, where we are and where we're headed: the studies, the models, the supporting research and the systems theory-based approach encompassing the current direction.

Keywords: clinical indicators, control relationship, quality measurement and reporting, accreditation, systems theory, feedback, Bayesian, posterior predictive

1. Introduction

Clinical indicators (CIs) are essentially measures of performance in a clinical setting. They are intended to be used as screening tools that can identify possible problems or opportunities to improve processes and outcomes in health care organisations (HCOs). Since 1993, Australian HCOs preparing for accreditation, or re-accreditation, with the Australian Council on Healthcare Standards (ACHS) have submitted data on sets of CIs. The ACHS routinely collates this information in 6-month periods and generates CI reports that are provided to the HCOs and accreditation surveyors. In 2009 the ACHS received data from 671 Australian and New Zealand HCOs on 370 CIs across 23 specialties [1].

Individual HCOs who have contributed their CI data to the ACHS receive two kinds of CI reports. The reports are personalised for the HCO and report on the CIs on which they provided data. One of these two reports is a bi-annual 'six-monthly' report which provides aggregated results across all contributing HCOs as well as a comparison with the individual HCO's 'peer' organisations. The second is an annual 'trend' report, which shows comparative information for the period covered, starting from as early as 2001. The six-monthly report provides more simplistic statistical comparisons, is less descriptive and shorter than the trend report.

Additionally, an annual report on the healthcare system's performance is provided which does not identify specific HCOs but instead reports upon performances across the entire healthcare system by clinical area. The report, currently in its 11th edition, is named the "Australasian Clinical Indicator Report 2001-2009: Determining the Potential to improve quality of care: 11th Edition", or DPI report. It is designed for use by governments and medical colleges for directing policy and assisting with resource allocation requirements within clinical areas. The three reports stem from the existing quality and measurement reporting (QMR) system.

Chuang and Inder (2009) [2] identified an holistic healthcare systems relationship model. The model provides the platform for a series of adaptive-control studies into the control and communication relationships between the accreditation system, the QMR system and the HCO-level system. They are referred to as adaptive since the studies can be adapted to any similar accreditation and QMR system despite being conducted in the ACHS setting.

This paper summarises the key developments over the past decade, the current research and the future direction in the improvement of health care via the

QMR and accreditation systems in Australia. The ACHS is the chosen setting.

2. Developments over the past decade

The QMR System

The development of methods for measuring and reporting on the ACHS clinical indicators has been continuing over the past decade. Major improvements during this period have included the introduction of Bayesian hierarchical models, the estimation of potential gains [3] and trend reports.

For a given CI, the i^{th} HCO provides the observed number of patients who incur the 'event of interest' (O_i) and the number of patients at risk of the event (D_i). The CI data can be reported as the observed proportions (O_i/D_i), however, they encompass the between-HCO, or systematic, variation as well as within-HCO, or sampling, variation. Thus, the observed CI proportions for individual HCOs will vary from the 'true underlying proportions' due to sampling variation. In the Bayesian paradigm, a two-stage hierarchical model is used to represent the distributions for the two sources of variation. The first level corresponds to the distribution of the CI proportions across all hospitals, thus representing the systematic variation. The second stage corresponds to the sampling distribution of the O_i.

Bayesian hierarchical models and shrinkage estimators were introduced to account for the effects of sampling variation on the estimated CI proportions For the beta-binomial two-stage hierarchical model, the individual HCO's proportion of admissions having the event of interest, θ_i, is assumed to be drawn from a beta distribution with parameters π and M, where π represents the mean CI proportion and the *spread parameter*, M, indicates the spread of proportions among the hospitals and is inversely related to the variance of the proportions between HCOs, $\sigma^2 = \pi(1-\pi)/(1+M)$. Thus $\theta_i \sim \text{Beta}(\pi, M)$. The O_i, is assumed to follow a binomial distribution, $O_i \sim \text{binomial}(D_i, \theta_i)$ [3].

For each CI, a measure of the potential gains (or reduction in the number of undesirable events) that could be achieved if the mean proportion was shifted to the 20^{th} centile was introduced. Its calculation is based on the amount of variation in the system (represented by the difference in the mean, π, and 20^{th} centile, p_{20}, of the rates across all HCOs) and the impact upon the system, or volume effect, (represented by the summed D_i across all HCOs providing data for the CI) as shown in expression (1).

$$(\pi - p_{20})\sum_{i=1}^{n} D_i \qquad (1)$$

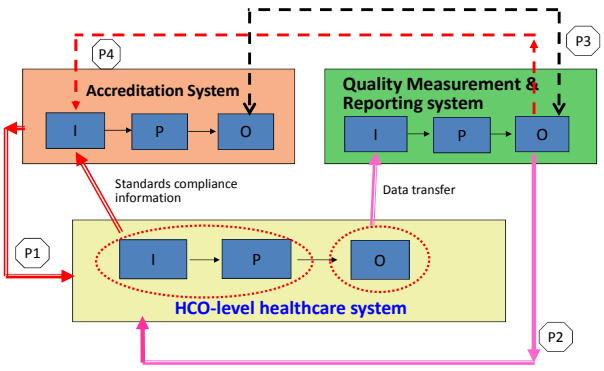
It facilitates and motivates scientific investigation within clinical areas. Smaller variation and smaller potential for system impact (in terms of potential for events occurring, represented by ΣD_i) is reflected in a smaller value for the potential gains. Reported as part of the DPI report, this measure enables comparisons of clinical areas for improvement activity rather than allocating responsibility solely to individual HCOs. Combining with EB shrinkage estimators, it facilitates practicable reports for HCOs.

The annual trend report introduced in the past decade identifies the individual HCO's performance compared with both the entire system of 'peer' organisations, via means, 20^{th} and 80^{th} centile rates, and themselves, based on trend analyses of their 6-monthly rates, after considering both within-HCO and between-HCO variation. It includes both graphical and numerical comparisons, including cumulative excess counts of observations above that expected for the HCO and indicates the HCO's relative performance to itself and the other HCOs contributing information to the CI over time.

Systems theory-based approach to improvement

Chuang and Inder (2009) [2] identified an holistic healthcare systems relationship model and four distinct control and communication relationships, see Figure 1. In summary, P1 is a control relationship that represents hierarchically determined practitioner standards, generated from the accreditation system and given to the HCO-level system. P2 is a communication relationship which represents the communication of outcomes of the QMR system to the HCO-level system for its own internal control response. P3 communicates associations in the outputs of the accreditation and QMR systems. P4 is a control relationship which provides feedback from the QMR's output (CI reports) to the accreditation system's input.

Figure 1. Healthcare systems relationship*



*I – Input, P – Process, O - Output

The three major systems identified in Figure 1 form the health administration system. The safety and

quality characteristics are an emergent property of this system as a whole, not simply its individual system components. The question arises as to the impact of each of these relationships.

Considerable international research into the P1 relationship has revealed varying findings regarding the effectiveness of the accreditation system for providing quality of care [4-7]. Research into the P2 relationship, assessing the effectiveness of the QMR system for improving the quality of care also revealed varying degrees of success. Analysis of the P3 relationship identifies gaps that permit associations between the two outputs to be due to chance. In cases where HCOs achieve accreditation and their QMR approaches are deemed acceptable, partial, inconsistent and conflicting success in improving quality has resulted [8, 9]. For brevity the reader is invited to view Chuang and Inder (2009) for the summary of the results for the P1-P3 relationships.

3. Current

The QMR System

The CI reports involve retrospective analysis and reporting. Such reports, however, could be complemented by tools, such as control charts, that enable HCOs to monitor their performance during the six-month periods of data collection.

A new control chart for monitoring clinical indicator (CI) data based upon the beta-binomial posterior predictive (BBPP) distribution was compared with the more commonly used Bernoulli cumulative sum (Bernoulli CUSUM) chart. Control chart limits were generated and run lengths were simulated for 3894 parameter combinations (π, D_i, θ_i, σ and percentage change in the underlying proportion (required for Bernoulli CUSUM chart)) reflecting the types of CI data collated.

For the case where the underlying proportion of cases with an event of interest had to be estimated, the BBPP chart was shown to have the desired smaller out-of-control average run length in 71% of the simulations.

Whilst these results are promising the charts are yet to be included in the reports and provided to the HCOs.

The Control Relationship (P4)

The P4 control relationship, not previously explored in detail, is crucial towards creating a positive correlation, or *communication*, between the QMR and accreditation systems and achieving continuous quality improvement in the system's outcomes. Accreditation surveyors were identified as a key system component in activating the relationship; if the QMR's CI reports had been both utilised by HCOs to guide quality improvement as well as referenced by surveyors as a tool to assess quality improvement in HCOs, then surveyors could produce valuable feedback to HCOs via the accreditation process.

The authors' study of ACHS accreditation surveyors has revealed half used the CI reports most or all of the time and half also found solely positive responses from the HCOs when discussing the reports, with 20% solely negative (reflecting ignorance of relevance and use). 75% to 89% of surveyors perceived the reports to be useful for the quality and safety objectives for each of senior executive officials, clinicians, safety and quality managers, and accreditation surveyors. Changes to processes to ensure CI reports are not omitted from pre-survey packages along with improved education of surveyors and HCOs on how to better utilise the reports for the purposes of improvement in the safety and quality of healthcare were revealed as significant factors that would increase their usage.

4. Future research

In order to create a well-designed closed feedback loop among the accreditation, QMR systems and HCO-level systems, a series of adaptive studies related to the P1-P4 relationships need to be pursued. The P4 relationship has begun to be explored with the surveyor-based adaptive study reported upon in Section 3. These results identify the relative use of the CI reports by accreditation surveyors and HCOs and the perceived appropriateness of the reports. Implementation of the conclusions augurs well for surveyors ultimately being able to produce valuable feedback to HCOs via the accreditation process. However, that result is still far from a *fait accompli*. A study investigating the current decision process of surveyors undertaking accreditation investigations and how CI reports may need to be modified to support the decision process is a next required step towards achieving the desired results.

Association studies between the accreditation and QMR systems are required to support the P3 relationship. These studies will involve assessing the amount of association between the accreditation results and the CI reports and the potential for mapping the CIs to the accreditation standards.

The P2 relationship relates to the communication of outcomes of the QMR system to the HCO-level system. Whilst the study results reported in Section 3 identify more positive than negative responses from HCOs when surveyors discuss the CI reports with them, it also identifies scope for improvement. Studies to assess the needs of the HCO regarding the interpretation, understanding, value, timeliness and

perceived usefulness of the existing CI reports for the HCO's own internal control response will help establish the desired P2 relationship.

Studies to assess the value, and potential development, of risk mapping style CI reports that reduce the amount of interpretation and better describe the information at hand will be required.

Finally, the required P2 relationship can only be achieved by the ongoing development of statistical tools to complement existing methods and reports. To this end, continued testing and ultimate introduction of control charts, development of the models underpinning the analyses as well as the introduction of pro-forma for HCOs on how to collect their CI data and appropriate sampling methods for the HCOs to reduce their efforts in collecting their CI data, is continuing.

5. Conclusion

The ACHS CI data is the largest source of data that attempts to measure the quality of care in Australia and New Zealand. The QMR system generating the CI reports has continued to be developed and improved over the past decade.

Given the Bayesian paradigm within which the CI data have been analysed and reported, it is encouraging that there appears to be a parameter space in which the Bayesian-based BBPP control chart detects changes in the underlying proportion more quickly than the CUSUM alternative. It is feasible to consider using a particular chart for a given CI; continued investigation is warranted.

The results of the accreditation surveyor study identified factors affecting the use of the CI reports and their perceived usefulness. The combination of the recommendations and the relatively positive reported use and perceived usefulness of the reports indicates that implementing the control relationship between the QMR and accreditation systems is a promising expectation. There are, however, other key system components, such as the survey method and accreditation standards, which play critical roles in the feedback loops and building the control relationship, warranting further studies.

The future studies into the P1-P4 relationships in the healthcare system model will occur within the setting of the ACHS and provide guidance on policy and improve the health care system and its outcomes. However, the findings in this setting extend to both the *international* health care setting and the international non-health care setting. Industry, government, education, business each has performance measurement and reporting systems and accreditation (both internal and external) processes. The systems theory-based relationships and the conclusions reached in the health care setting can apply and provide guidance, and a platform for future research, in these non-health care settings.

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