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Disentangling quality and safety indicator data: a longitudinal, comparative study of hand hygiene compliance and accreditation outcomes in 96 Australian hospitals

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ABSTRACT

Aim: We compared hand hygiene compliance rates with accreditation scores over eight hand hygiene audit points and two accreditation cycles in order to test our hypothesis that hospitals with better accreditation outcomes would achieve higher hand hygiene compliance rates.

Methods: The study comprised a retrospective, longitudinal, multi-site comparative survey of hand hygiene compliance rates and accreditation outcomes in 96 acute public hospitals in New South Wales (NSW), Australia. We matched observational hand hygiene compliance data with accreditation survey results from 2009 to 2013. Hand hygiene compliance rates were assessed against the following explanatory variables: accreditation and infection control scores; timing of the surveys; and hospital size and activity. We used multilevel regression to analyse the data.

Results: Average hand hygiene compliance rates increased from 67.7% to 80.3% during the study period (2010 to 2013), with 46.7% of hospitals achieving target compliance rates of 70% in audit 1, versus 92.3% in audit 8. Average hand hygiene rates at small hospitals were 7.8 percentage points (pp) higher than those at the largest hospitals ($p<0.05$). Hospitals with higher IC accreditation scores in one survey unexpectedly showed hand hygiene compliance rates that were 4.1 pp lower ($p<0.05$) than hospitals with lower IC scores.

Conclusions: Our results indicate that accreditation outcomes and hand hygiene audit data are measuring different parts of the quality and safety spectrum. Our hypothesis appears confounded by an accreditation program that makes it more difficult for smaller hospitals to achieve high IC scores. Understanding what is being measured when selecting indicators is critical as focusing on accreditation results would discount successful hand hygiene implementation by smaller hospitals. Conversely, relying on hand hygiene results would discount the IC related research and leadership investment by larger hospitals.

Strengths and limitations of this study:

- The main strengths of this study lies in the number of participating acute hospitals (96) and length of follow up over eight audit points and two accreditation cycles.
- This study also addresses an important gap in terms of identifying or quantifying the benefits of hospital accreditation.
- The results have important implications for health policy makers internationally in terms of designing health service accreditation programs that can be accurately measured and monitored.
- The main limitation was the lack of a control group in order to assess direct or reverse causal relationships or to prevent omitted variable bias.
- Other limitations include measurement error resulting from using self-reported data, however the data collection methods adhere to World Health Organisation best practice guidelines.

INTRODUCTION

Hospital accreditation programs are designed to set clinical and organisational standards, ensure compliance with those standards and strengthen quality improvement efforts. Accreditation is widely practised with national level accreditation agencies active in at least 27 countries.[1] The problems associated with measuring accreditation benefits are well documented.[2 3] A clear understanding of the inputs, in terms of costs and resource use, and outcomes, in terms of improved patient safety and quality, is essential in ensuring that accreditation programs are achieving their aims of improving patient safety and health care quality.[4 5] Measuring the effects of accreditation on clinical practice and quality of care is important as we need to determine whether the burden of data collection and audit processes are outweighed by the expected improvements in quality and safety outcomes.[5]

In this study we analyse the relationship between hand hygiene compliance rates and accreditation outcomes in order to test the suitability of hand hygiene as an indicator of accreditation outcomes. Our hypothesis is that hospitals with better accreditation outcomes and infection control (IC) scores than others, reflecting organisational processes in support of improvement and a positive culture toward quality and safety,[6] would achieve higher hand hygiene compliance rates.

Hand hygiene assessment is an integral component of the IC standards used to evaluate whether Australian hospitals are compliant with the accreditation standards.[7-9] Hand hygiene compliance rates have been validated as a potential process indicator for accreditation outcomes. Health care associated infections (HAIs) are recognised as a leading cause of increased morbidity and health care costs.[10] A United States (US) study estimated there were 1.7 million HAIs in 2002, comprising 4.5% of admissions, and resulting in nearly 99,000 deaths.[11] A recent meta-analysis estimated the cost of the five most common HAIs at US$9.8 billion per annum.[12] In Australia, the most recent figures available indicate that HAIs resulted in an extra two million bed days in 2005, with estimated additional costs of AU$21 million from post-discharge surgical infections.[13]

There is increasing evidence that improving hand hygiene reduces HAIs and the spread of anti-microbial resistance.[14-18] However, it is difficult to demonstrate a causal link between hand hygiene and HAIs due to a multiplicity of interventions and scarcity of randomised trials.[19-21] Nevertheless, the World Health Organization (WHO) has identified good hand hygiene as a major factor in reducing HAIs based on epidemiological evidence.[18]

Hand hygiene policies in Australian hospitals follow international best practices. They are based on WHO recommendations with a multimodal approach incorporating: access to cleaning agents at the point of care; training and education; monitoring and feedback; reminders in the workplace; and development of an institutional safety climate.[22] Auditors trained by Hand Hygiene Australia (HHA) monitor hand hygiene activity by direct observation of hospital staff and compare hand hygiene activity against the total number of potential "moments" for hand hygiene.[23] The national target for hand hygiene compliance is 70% and audit results are publicly reported three times a year. The Australian Commission on Safety and Quality in Health Care

(ACSQHC) has recommended that hand hygiene programs need to be repeatedly monitored using both process indicators (compliance rates) and outcome indicators (infection rates).[24]

METHODS

Study design, setting and context

The study comprised a retrospective, longitudinal, multi-site comparative survey of hand hygiene compliance rates and accreditation outcomes in acute public hospitals in New South Wales (NSW), Australia. With a population of 7.2 million, NSW comprises 30.5% of the 736 public hospitals and 32.0% of the population in Australia.[25] We employed retrospective data matching techniques over the study period, 2009 to 2013 to analyse the relationship between hand hygiene compliance data and accreditation outcomes.

Data matching and analysis

a) Hand hygiene compliance data

Hand hygiene policies include five "moments" when hand hygiene should be performed: before touching a patient; before a procedure; after a procedure or body fluid exposure risk; after touching a patient; and after touching a patient's surroundings.[23 26] Audits are carried out three times a year by health care workers who have been accredited by HHA. Surveys are conducted using a standardised observation assessment tool which measures hand hygiene activity versus the total number of observed possible "moments". Auditors are trained in selecting the wards or units for the audit, and the minimum number of required "moments" for each audit is determined by hospital size and activity. We obtained the hand hygiene compliance rates data from late 2010 to early 2013 from the NSW Clinical Excellence Commission (CEC), the quality and safety body responsible for implementing the hand hygiene initiative in NSW and collecting hand hygiene audit data.[27]

b) Accreditation program and infection control standards

Data on accreditation outcomes from 2009 to 2013 were provided by the Australian Council on Healthcare Standards (ACHS). The ACHS Evaluation and Quality Improvement Program (EQuIP) was introduced in 1997 and comprises a four year cycle with surveys in years two and four.[28] During these surveys, hospitals are assessed by an external team of surveyors against ACHS developed standards. The EQuIP program has undergone several revisions, none of which materially affected this study. Our study period included EQuIP4 which was introduced in 2007 and used for the surveys in 2009 and 2010, and EQuIP5 which was introduced in 2011. Facilities were scored by surveyors on a five point Likert scale for each standard or criterion assessed in the survey. Scores were designated as Outstanding Achievement (OA), Extensive Achievement (EA), Moderate Achievement (MA), Some Achievement, and Little Achievement. Hospitals needed to achieve MA, EA or OA scores in each mandatory standard or criterion in order to meet accreditation requirements.

IC related criteria were part of a broader standard regarding the safe provision of care and services.[7 8] To meet MA requirements, hospitals needed to ensure that the IC policy: met all regulatory requirements and industry

guidelines; had executive support; incorporated ongoing education activities; and included indicators to show both compliance with policy and effective outcome measurement. Additional activities which counted towards achieving higher (EA and OA) scores included: benchmarking of performance indicators; use of feedback to inform and improve; IC research; and recognised leadership in IC systems.[7 8] Accreditation is often granted to a cluster of facilities within a local health district and therefore reflects conditions at all the facilities within that survey group. These clusters are subject to boundary changes, as seen in the NSW 2011 health system re-organisation, which took place during the study period (2009-2012).[29] We therefore identified the different hospitals within each cluster in order to match the accreditation scores with the hand hygiene data from individual hospitals.

Study Variables

To analyse the matched data we used hand hygiene compliance rates as our outcome of interest, expressed as a continuous outcome variable (*hh).* Data were available at eight different time points from the end of 2010 to early 2013 (see Figure 1). We created dummy variables for the IC standard to designate whether they achieved a high IC score in the first or second survey in each cycle (*hai1* and *hai2* respectively). No hospitals scored less than MA during the study period so we differentiated the outcomes by assigning MA as 0, and the higher scores (EA, and OA) as 1. We created a categorical variable for the number of surveys where each hospital achieved high IC scores (*hait*). There were three possible outcomes: no high scores in either survey (*hait*=0); high scores in one survey (*hait*=1); or high scores in both surveys (*hait* =2). The dummy variable for accreditation (*acct)* was designated 1 for full accreditation, and 0 for partial accreditation. We defined partial accreditation as either accreditation being granted for a reduced time, or resulting in a recommendation for action. No hospitals in the study were refused accreditation during the study period. We assigned a *cycle* variable to identify whether surveys were either carried out in the 2009 and 2011 (cycle =0), or 2010 and 2012 (cycle=1).

Figure 1: Timeline of accreditation surveys and hand hygiene audits

<Insert Figure 1 here>

Acute hospitals were grouped according to the Australian Institute of Health and Welfare activity matrix, based on annual numbers of acute case-mix adjusted separations and geographic location.[30] We used these groups to create a categorical variable (*grp*) with principal referral and specialist hospitals as the reference case (principal=0), with large hospitals scored as 1, medium hospitals as 2, and small hospitals as 3.

Analysis

The nature of the data with irregular audit dates and clustering within hospitals indicated that a multi-level model would be the most appropriate and would allow adjustment for hospital level variance.[31 32] Our model used audit points as Level-1 units and hospitals as Level-2 units. After matching the accreditation and hand hygiene data our sample comprised 96 hospitals each with two accreditation surveys. We tested our main

model (comprising the *hh, hait, acct, grp* and *cycle* variables), and fitted a restrictive model using audits 3 to 8. We looked for timing effects by fitting survey models for each survey and cycle (using *the hh, hai1* or *hai2, cycle*= 0 or 1, and *grp* variables). We tested the model fit versus ordinary least squares by calculating the intra-class correlation to assess the within-hospital effect. We also tested whether to use a random co-efficient or random intercept model. Analysis was conducted using Stata statistical software (version 12SE),[33] applying a two-sided significance level of 5%.

RESULTS

Hand hygiene and accreditation data analysis

We assessed hand hygiene data on 118 hospitals from eight different audit points during 2010 to 2013. Missing data were higher during the first two audits whilst the program was progressively implemented, and for some hospitals we were not able to match the accreditation outcomes because of changes in the accreditation clusters. We did not impute values for missing data as the pattern of missing results indicated these were not missing at random. For example, data some of the smaller hospitals were not included as they did not meet the minimum publication requirements (50 moments of hand hygiene), which we determined was likely to be related to hospital size.

Overall, hand hygiene rates showed an improvement during the study period, with 28 out of 60 hospitals (46.7%) achieving 70% compliance rates in the first audit in 2010 versus 108 out of 117 hospitals (92.3%) in the final audit, in early 2013. Average hand hygiene compliance rates increased from 67.7% in audit 1, to 80.3% in audit 8, and remained above the 70% national target rate from audit 2 onwards. The average audit compliance rates with minimum and maximum values, and standard deviations, are shown in Figure 2**.**

Figure 2: Hand hygiene compliance audits, 2010-2013

<Insert Figure 2 here>

During the study period, 2009-2013, 61 hospitals underwent an accreditation survey in cycle 0, and 44 in cycle 1. The accreditation outcomes showed that 59% of organisations were granted full accreditation in the first survey in each cycle (during 2009-10) versus 77% in the second survey (2011-12). The number of hospitals receiving a high IC scores increased over time, with 13% receiving a high score (EA) in the first survey of each accreditation cycle versus 18% in the second surveys during 2011 and 2012. No hospitals received an OA score for infection control during the study period. We further examined whether there was a difference between meeting, or not meeting, the target compliance rates by comparing the partial data from audit 1 when the program was being rolled out, and the final audit in our study, audit 8 (Table 1). This showed that the large hospitals showed the biggest increase, with 30% meeting the target in audit 1, rising to 100% by audit 8. Principal and large hospitals comprised 51.7% of hospitals in audit 1 versus 39.3% in audit 8, suggesting they were early adopters in the program.

Table 1: Comparison of whether hospitals met national hand hygiene targets in audits 1 and 8

Hospital groups	Audit 1			Audit 8		
	Not met	Met	% Met	Not met	Met	% Met
Principal	13	8	**38.1**	2	28	**93.3**
Large	7	3	**30.0**	0	16	**100.0**
Medium	4	6	**60.0**	3	26	**89.7**
Small	8	11	**57.9**	4	38	**90.5**

The accreditation and IC outcomes improved over time with full accreditation for both surveys being awarded to 30% of hospitals in cycle 0 versus 42% in cycle 1. IC scores showed a similar pattern with 3% of organisations receiving high scores in both surveys in cycle 0 versus 17% in cycle 1. A size effect was noted with 6.9% (n=2) of smaller hospitals receiving a higher infection control score in at least one survey versus 37.0% (n=10) of principal and 42.9% (n=6) of large hospitals.

Multilevel model

After matching the hand hygiene data with hospitals that underwent two accreditation surveys, our main model included data from 661 hand hygiene audits from 96 hospitals, an average of 6.9 audits per hospital. The results (Table 2) show that small and medium sized hospitals experienced significantly higher hand hygiene compliance rates (7.8 percentage points (pp) for small hospitals and 3.8 pp for medium hospitals) compared to principal hospitals. The association between hand hygiene rates and accreditation outcomes, for both overall and IC scores, is less clear. Hospitals achieving high IC scores (EA) in one survey (n=14) showed 4.1 pp lower hand hygiene rates than hospitals achieving an MA score, and this result was significant (p=0.038). Hospitals achieving high IC scores in both surveys (n=8) showed higher rates (2.1 pp) but this was not significant (p=0.39). Achieving full accreditation for both surveys was not significantly associated with hand hygiene rates versus those hospitals which achieved full accreditation in only one survey. The restricted model, using data from audit 3 onwards, also showed a negative relationship between high IC scores and hand hygiene audit results, however, the effect was smaller (2.8 pp) and the results were no longer significant (p=0.15). The size effect in the restricted model was consistent, with small and medium hospitals showing significantly higher hand hygiene rates.

Table 2: Results of our multilevel model

Variables	Main model	Restricted model	Survey models	
	Audits 1-8	Audits 3-8	First Cycle	Second Cycle

	Mean	SE[1]	Mean	SE	Mean	SE	Mean	SE
Higher (OA or EA) score for infection control in one survey	**-0.041***	*0.020*	-0.028	*0.02*				
Higher scores for infection control in both surveys	0.021	*0.025*	0.034	*0.024*				
Higher infection control scores in first survey					-0.043	*0.031*	0.01	*0.028*
Higher infection control scores in second survey					0.045	*0.027*	-.007	*0.022*
Full accreditation on both surveys	0.003	*0.016*	0.007	*0.016*				
Cycle (2009/11= 0)	0.022	*0.014*	0.018	*0.013*				
Hospital group (Principal referral=0)								
Large	0.022	*0.02*	0.024	*0.02*				
Medium	**0.038***	*0.018*	**0.039***	*0.017*				
Small	**0.078***	*0.019*	**0.081***	*0.018*				
Number of observations	661		563		420		282	
Number of hospitals	96		96		60		42	
Average compliance rate	0.74		0.75		0.75		0.75	
Log likelihood	661.85		633.77		401.43		252.52	

[1] Standard error, * Indicates significance at 5% (p<0.05)

Given the greater change in hand hygiene rates during the early audits, we reviewed the data for timing effects by examining the results by survey and cycle. The majority of the first surveys in both cycles were completed before the hand hygiene audits started. The survey models showed that in cycle 0, higher IC scores were associated with lower hand hygiene results (-4.3 pp) in the first survey, versus a positive relationship in the second survey (+4.5 pp), however these were not significant (p=0.17 and 0.102 respectively) and were reversed in the second cycle.

Testing the model

The intra-class correlation co-efficient indicated that 38% of the variance was due to within-hospital effects, indicating sufficient variance for using a random intercept model.[32] We ran a likelihood ratio test using a null model (without the random intercept). This gave a chi-squared test result of 190 (p=0.000), which confirmed our approach versus using ordinary least squares. We also tested the model using IC scores as a random co-

efficient but the results (chi squared= 0.81, p=0.67) indicated that the random intercept model was more appropriate. We noted a ceiling effect in our data with 100% of large hospitals and 92% of all hospitals meeting the target compliance rates by audit 8, with less incentive to reach higher levels. Although hospitals were incrementally enrolled in the hand hygiene program the lack of hand hygiene compliance data in the un-enrolled hospitals meant we were not able to use a stepped wedge design to provide controls or evaluate a before and after effect and our results are subject to omitted variable bias. A fixed effects panel data model might be a more traditional approach to reduce sample variation, but we determined that the random intercept model would be more appropriate due to the policy requirement for all public hospitals to submit hand hygiene data, and the presence of time-invariant variables.[34]

DISCUSSION

Our analysis of 118 NSW hospitals showed that hand hygiene rates increased from 67.7% in audit 1 in late 2010 to 80.3% by audit 8 in early 2013. This compares to rates of 62.2% from a sample of NSW hospitals in February 2007 which were observed following the introduction of the Clean Hand Saves Lives campaign during 2006-2007,[15] and continues the improvement shown nationally in Australia with average hand hygiene rates estimated at 68.3% in 2011.[35] These results can be compared to average hand hygiene rates of 56.6% in 40 US hospitals following the introduction of national hand hygiene guidelines in 2002.[36]

Smaller hospitals in our study had higher hand hygiene compliance rates but the relationship between accreditation outcome and hand hygiene data was less clear. This effect of hospital size on hand hygiene compliance has received confirmation by other research investigating the link between hand hygiene rates and health care associated *Staphylococcus aureas* bacteraemia (SAB).[37 38] We consider the results from small and medium hospitals in our study can be explained by looking at the organisational infrastructure necessary to meet the hand hygiene and accreditation requirements. Both are dependent on a widespread organisational response in terms of education, monitoring, infrastructure and management involvement.[6] Achieving high IC scores requires additional benchmarking, feedback and research capabilities.[7 8] The organisational size effect suggests that small and medium sized hospitals can effectively embrace multimodal quality improvement strategies as seen by the higher compliance rates. However, the requirements for achieving high IC scores within an accreditation survey may be measuring different aspects of quality that are not reflected in the hand hygiene compliance rates. The results indicate that smaller hospitals are able to focus on the practical implementation of a national hand hygiene policy. Having the resources to meet the requirements for higher IC scores, in terms of conducting research or being recognised leaders in infection control, is not practical for these smaller organisations. Although some smaller hospitals will be accredited as part of a larger cluster of hospitals, which includes principal and large hospitals, this is not always the case. Our hypothesis that higher accreditation scores would be reflected in hand hygiene rates appears to be confounded by an accreditation program that makes it more difficult for smaller hospitals to achieve high IC scores.

This study uses one indicator for evaluating accreditation whereas multiple measures may be more effective.[39] For example, outcome indicators are widely used in the US hospital system,[40-42] and include hospital acquired SAB rates and surgical site infection rates. These incorporate a broader mix of the anti-microbial, hand hygiene, and specialist cleaning practice modules of the IC standard. Using outcome indicators would complete Donabedian's triad of performance measures to include structural (accreditation results), process (hand hygiene compliance rates) and outcome (SAB rates) measures.[43 44]

Measurement issues in our study include a possible observer effect since the hospital staff might be aware the audit was taking place. However, although this may increase the compliance rate, the results would still be valid as the standards include requirements for staff education and installation of appropriate infrastructure. Increased rates during an audit imply that the correct infrastructure is in place, in terms of availability of functioning hand washing stations, and that staff are aware of the hand hygiene policies. In addition, any observer effect is likely to be mitigated as all the hospitals used the same methods for collecting data and thus are equally subjected to bias. Other methods to measure hand hygiene activity include measuring consumption rates of hand hygiene products, such as alcohol rubs, [45] and electronic systems for monitoring compliance,[46] but WHO guidelines suggest direct observation is still the gold standard.[40] We also note that although accreditation surveys are assessed on a five point scale, only two scores (MA and EA) were used in the infection control standard during the four surveys in our study. The lack of granularity in the accreditation scores makes it difficult to differentiate accreditation performance. Limitations of the model include reverse causality in that higher compliance rates could lead to higher IC scores at the next survey. This would likely be the case going forward as ACSQHC includes hand hygiene audit results as part of the evidence of implementation of standard 3 under new national standards.[9 47]

Policy Implications

Different indicators will give different perspectives on how an organisation approaches and implements relevant policy. However, the costs of measurement in health care should be balanced against using a range of indicators to capture a broader mix of IC policies, and across the different standards assessed during accreditation surveys. Indicator selection should include both process indicators, recognised as a method of measuring organisational changes,[48] and outcome indicators. Public reporting of indicator data further increases the requirement to accurately identity and measure the parts of the patient safety and quality spectrum that are being addressed. In this study, a focus on the accreditation results would discount the successful implementation of the hand hygiene policy by smaller hospitals. Conversely, just using hand hygiene results would discount the research and leadership investment in infection control by larger hospitals. Disentangling these two outcomes within the same safety and quality initiative is a pre-requisite to understanding how they can be effectively assessed and monitored.

CONCLUSION

Identifying indicators to measure the effectiveness of accreditation is challenging due to the complexity of implementing a wide range of accreditation related processes across multiple hospital activities. These results do not lend support to our study hypothesis that higher IC scores are associated with higher hand hygiene rates. Instead, this study suggests that accreditation outcomes and hand hygiene audit data are complementary. Developing a framework to identify suitable indicators is an important contribution to understanding the impact of hospital accreditation internationally. Policy makers need to appreciate the assumptions behind the choice of indicator and understand exactly what is being measured to ensure that key performance indicators encourage quality improvements in the delivery of hospital services.

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Data sharing: Data available on request from the corresponding author.
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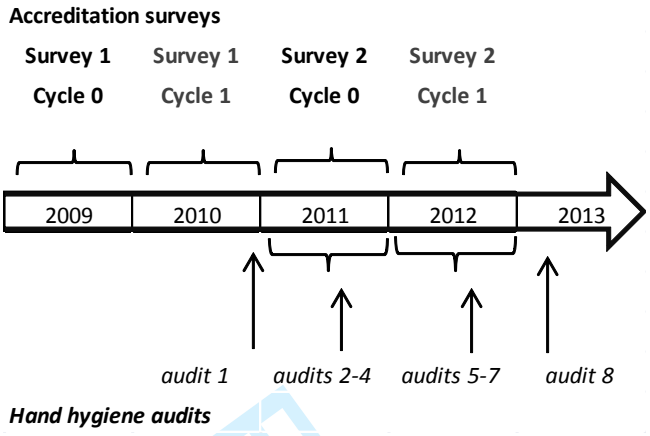

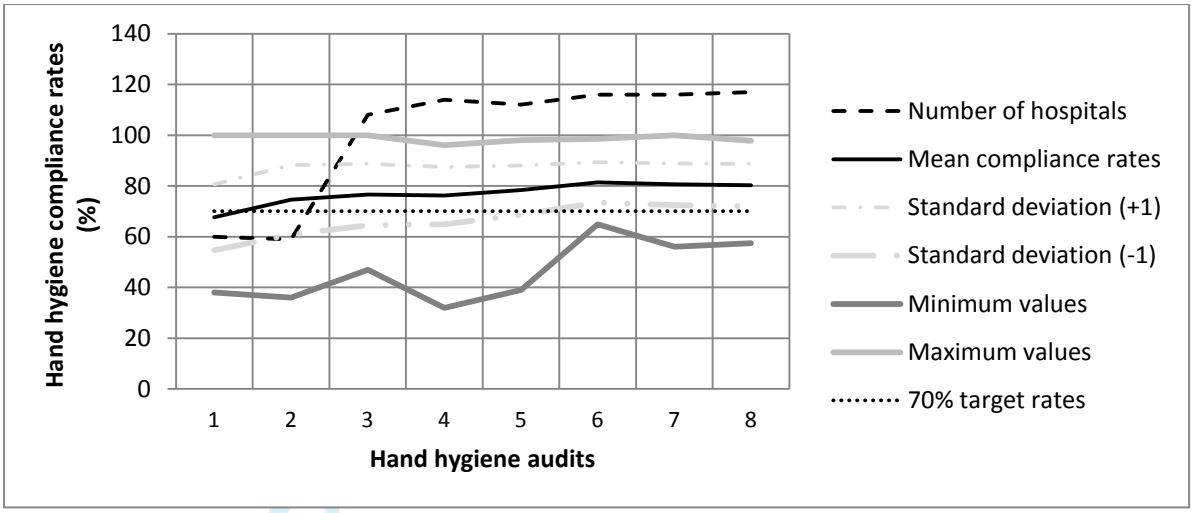

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Disentangling quality and safety indicator data: a longitudinal, comparative study of hand hygiene compliance and accreditation outcomes in 96 Australian hospitals

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Disentangling quality and safety indicator data: a longitudinal, comparative study of hand hygiene compliance and accreditation outcomes in 96 Australian hospitals

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Disentangling quality and safety indicator data: a longitudinal, comparative study of hand hygiene compliance and accreditation outcomes in 96 Australian hospitals

ABSTRACT

Objectives: The study aims are twofold. First, to investigate the suitability of hand hygiene as an indicator of accreditation outcomes and, second, to test the hypothesis that hospitals with better accreditation outcomes achieve higher hand hygiene compliance rates.

Design: A retrospective, longitudinal, multi-site comparative survey.

Setting: Acute public hospitals in New South Wales, Australia.

Participants: 96 acute hospitals with accreditation survey results from two surveys during 2009-2012 and submitted data for more than four hand hygiene audits between 2010 and 2013.

Outcomes: Our primary outcome comprised observational hand hygiene compliance data from eight audits during 2010 to 2013. The explanatory variables in our multilevel regression model included: accreditation outcomes and scores for the infection control standard; timing of the surveys; and hospital size and activity.

Results: Average hand hygiene compliance rates increased from 67.7% to 80.3% during the study period (2010 to 2013), with 46.7% of hospitals achieving target compliance rates of 70% in audit 1, versus 92.3% in audit 8. Average hand hygiene rates at small hospitals were 7.8 percentage points (pp) higher than those at the largest hospitals ($p<0.05$). The association between hand hygiene rates, accreditation outcomes and infection control scores is less clear.

Conclusions: Our results indicate that accreditation outcomes and hand hygiene audit data are measuring different parts of the quality and safety spectrum. Understanding what is being measured when selecting indicators to assess the impact of accreditation is critical as focusing on accreditation results would discount successful hand hygiene implementation by smaller hospitals. Conversely, relying on hand hygiene results would discount the infection control related research and leadership investment by larger hospitals. Our hypothesis appears confounded by an accreditation program that makes it more difficult for smaller hospitals to achieve high infection control scores.

Strengths and limitations of this study:

- The main strengths of this study relates to the use of a comprehensive dataset involving the number of acute hospitals (96) participating in the accreditation process and the length of follow up over eight hand hygiene audit points and two accreditation cycles.
- This study also addresses an important research question in terms of identifying and assessing the components of hospital accreditation and quantifying their inter-related benefits.
- The results have important implications for health policy makers internationally in terms of designing health service accreditation programs that can be accurately measured and monitored.
- The main limitation was the lack of a control group as all hospitals in the survey were accredited. This meant it was not possible to assess direct or reverse causal relationships or to prevent omitted variable bias.
- Other limitations include potential measurement error resulting from the use of self-reported hand hygiene data, however, the data collection methods adhered to World Health Organisation best practice guidelines.

INTRODUCTION

Hospital accreditation programs are designed to set clinical and organisational standards, assess compliance with those standards, and strengthen quality improvement efforts. Accreditation is widely practised with national level accreditation agencies active in at least 27 countries.[1] The problems associated with measuring accreditation benefits are well documented.[2 3] A clear understanding of the inputs, in terms of costs and resource use, and outcomes, in terms of improved patient safety and quality, is essential in ensuring that accreditation programs are achieving their aims of improving patient safety and health care quality.[4 5] Measuring the effects of accreditation on clinical practice and quality of care is important as we need to determine whether the cost burden of data collection and audit processes is outweighed by the expected improvements in quality and safety outcomes.[5]

In this study we analyse the relationship between hand hygiene compliance rates and accreditation outcomes in order to test the suitability of hand hygiene as an indicator of accreditation outcomes. Our hypothesis is that hospitals with better accreditation outcomes and infection control scores than others, reflect organisational processes that support a positive culture toward improving quality and safety,[6] and therefore they would achieve higher hand hygiene compliance rates.

Hand hygiene assessment is an integral component of the infection control standards used to evaluate whether Australian hospitals are compliant with accreditation standards.[7-9] Hand hygiene compliance rates have been validated as a potential process indicator for accreditation outcomes. Moreover, health care associated infections are recognised as a leading cause of increased morbidity and health care costs.[10] A United States (US) study estimated there were 1.7 million healthcare associated infections in 2002, comprising 4.5% of admissions, and resulting in nearly 99,000 deaths.[11] A recent meta-analysis estimated the cost of the five most common healthcare associated infections at US$9.8 billion per annum.[12] In Australia, the most recent figures available indicate that healthcare associated infections resulted in an extra two million bed days in 2005, with estimated additional costs of AU$21 million from post-discharge surgical infections.[13]

There is increasing evidence that improving hand hygiene reduces healthcare associated infections and the spread of anti-microbial resistance.[14-18] However, it is difficult to demonstrate a causal link between hand hygiene and healthcare associated infections due to a multiplicity of interventions and scarcity of randomised trials.[19-21] Nevertheless, the World Health Organisation (WHO) has identified good hand hygiene as a major factor in reducing healthcare associated infections based on epidemiological evidence.[18]

Hand hygiene policies in Australian hospitals follow international best practices. They are based on WHO recommendations with a multimodal approach incorporating: access to cleaning agents at the point of care; training and education; monitoring and feedback; reminders in the workplace; and development of an institutional safety climate.[22] Auditors trained by Hand Hygiene Australia monitor hand hygiene activity by direct observation of hospital staff and compare hand hygiene activity against the total number of potential "moments" for hand hygiene.[23] The national target for hand hygiene compliance is 70% and audit results are

publicly reported three times a year. The Australian Commission on Safety and Quality in Health Care (ACSQHC) has recommended that hand hygiene programs need to be repeatedly monitored using both process indicators (compliance rates) and outcome indicators (infection rates).[24]

METHODS

Study design, setting and context

The study comprised a retrospective, longitudinal, multi-site comparative survey of hand hygiene compliance rates and accreditation outcomes in acute public hospitals in New South Wales (NSW), Australia. With a population of 7.2 million, NSW comprises 30.5% of the 736 public hospitals and 32.0% of the population in Australia.[25] We employed retrospective data matching techniques over the study period, 2009 to 2013, to analyse the relationship between hand hygiene compliance data and accreditation outcomes.

Data matching and analysis

a) Hand hygiene compliance data

Hand hygiene policies include five "moments" when hand hygiene should be performed: before touching a patient; before a procedure; after a procedure or body fluid exposure risk; after touching a patient; and after touching a patient's surroundings.[23 26] Audits are carried out three times a year by health care workers who have been accredited by Hand Hygiene Australia. Surveys are conducted using a standardised observation assessment tool which measures hand hygiene activity versus the total number of observed possible "moments". Auditors are trained in selecting the wards or units for the audit, and the minimum number of required "moments" for each audit is determined by hospital size and activity. We obtained hand hygiene compliance rates data from late 2010 to early 2013 from the NSW Clinical Excellence Commission, the quality and safety body responsible for implementing the hand hygiene initiative in NSW and collecting hand hygiene audit data.[27]

b) Accreditation program and infection control standards

Data on accreditation outcomes from 2009 to 2013 were provided by the Australian Council on Healthcare Standards (ACHS). The ACHS Evaluation and Quality Improvement Program (EQuIP) was introduced in 1997 and comprises a four year cycle with external surveys in years two and four.[28] During these surveys, hospitals are assessed by an external team of surveyors against ACHS developed standards. The EQuIP program has undergone several revisions, none of which materially affected this study. Our study period included EQuIP4 which was introduced in 2007 and used for the surveys in 2009 and 2010, and EQuIP5 which was introduced in 2011. Accreditation standards were changed significantly following the introduction of national mandatory standards in 2013,[9] but the infection control criteria were the same for both versions of the EQuIP standards assessed during the study period (see supplementary file 1) . Surveyors scored facilities on a five point Likert scale for each standard or criterion assessed in the survey. Scores were designated as Outstanding Achievement (OA), Extensive Achievement (EA), Moderate Achievement (MA), Some Achievement, and (LA

Little Achievement. Hospitals needed to achieve OA, EA or MA, scores in each mandatory standard or criterion in order to meet accreditation requirements.

Infection control related criteria were part of a broader standard regarding the safe provision of care and services.[7 8] To meet accreditation requirements, hospitals needed to ensure that the infection control policy: met all regulatory requirements and industry guidelines; had executive support; incorporated ongoing education activities; and, included indicators to show both compliance with the policy and effective outcome measurements. Additional activities which counted towards achieving higher (EA and OA) scores included: benchmarking of performance indicators; use of feedback to inform and improve; contributing to infection control research; and, recognised leadership in infection control systems.[7 8] Accreditation is often granted to a cluster of facilities within a local health district and therefore reflects conditions at all the facilities within that survey group. These clusters are subject to boundary changes, as seen in the NSW 2011 health system re-organisation, which took place during the study period.[29] We therefore identified the different hospitals within each cluster in order to match the accreditation scores with the hand hygiene data from individual hospitals.

Study Variables

To analyse the matched data we used hand hygiene compliance rates as our outcome of interest, expressed as a continuous outcome variable. Data were available at eight different time points from the end of 2010 to early 2013 (see Figure 1). We characterised the accreditation scores as either full or partial accreditation. Partial accreditation was defined as either accreditation being granted for a reduced time, or resulting in a recommendation for action. No hospitals in the study were refused accreditation during the study period. We included infection control scores in the model by whether hospitals achieved a higher score in one, none (our reference case) or both surveys. To test for a possible timing effect we included a variable to identify whether surveys were either carried out in the 2009 and 2011 accreditation cycle (cycle=0), or the 2010 and 2012 cycle (cycle=1).

Figure 1: Timeline of accreditation surveys and hand hygiene audits

<<<Insert Figure 1 here>>>

Acute hospitals were grouped according to the Australian Institute of Health and Welfare activity matrix, based on annual numbers of acute episodes of care adjusted for patient complexity, and geographic location (see supplementary file 2).[30] We used these groups to create a categorical variable with principal referral and specialist hospitals as the reference case (principal=0), with large hospitals scored as 1, medium hospitals as 2, and small hospitals as 3.

Analysis

The nature of the data, with irregular audit dates and clustering within hospitals, indicated that a multilevel model would be the most appropriate and would allow adjustment for hospital level variance.[31 32] After

matching the accreditation and hand hygiene data our sample comprised 96 hospitals each with two accreditation surveys. For some hospitals we were not able to match the accreditation outcomes because of changes in the accreditation clusters. Missing data were higher during the first two audits whilst the program was progressively implemented. We did not impute values for missing data as the pattern of missing results indicated these were not missing at random. For example, data from some of the smaller hospitals were not included as they did not meet the minimum publication requirements during the study period (50 moments of hand hygiene), which we determined was likely to be related to hospital size.

We tested our main model using hand hygiene data from audits 1 through 8 as the outcome variable, and accreditation outcomes, infection control scores, accreditation cycle, and peer groups as our explanatory variables. We tested the model fit versus ordinary least squares by calculating the intra-class correlation to assess the within-hospital effect. We also tested whether to use a random co-efficient or random intercept model. Analysis was conducted using Stata statistical software (version 12SE),[33] applying a two-sided significance level of 5%. We also fitted a restrictive model using data from audits 3 to 8 to determine whether the different peer group mix in the first two surveys was affecting the results.

RESULTS

Hand hygiene and accreditation data analysis

We assessed hand hygiene data on 118 hospitals from eight different audit points during 2010 to 2013. Overall, hand hygiene rates showed an improvement during the study period, with 28 out of 60 hospitals (46.7%) achieving 70% compliance rates in the first audit in 2010 versus 108 out of 117 hospitals (92.3%) in the final audit, in early 2013. Average hand hygiene compliance rates increased from 67.7% in audit 1, to 80.3% in audit 8, and remained above the 70% national target rate from audit 2 onwards. The average audit compliance rates by audit and hospital peer group are shown in Figure 2.

Figure 2: Mean hand hygiene compliance rates by audit and hospital peer group, 2010-2013<<<Insert Figure 2 here>>>

During the study period, 2009-2013, 61 hospitals underwent an accreditation survey in cycle 0, and 44 in cycle 1. The accreditation outcomes showed that 59% of organisations were granted full accreditation in the first survey in each cycle (during 2009-10) versus 77% in the second survey (2011-12). The number of hospitals receiving higher infection control scores also increased over time, with 13% receiving a higher score (EA) in the first survey of each accreditation cycle versus 18% in the second surveys during 2011 and 2012. No hospitals received an OA score for infection control during the study period. We further examined whether there was a difference between meeting, or not meeting, the target compliance rates by comparing the partial data from audit 1 when the program was being rolled out, and the final audit in our study, audit 8 (see Figure 3). Large hospitals showed the biggest increase, with 30% meeting the target in audit 1, rising to 100% by audit 8.

Figure 3: Percentage of hospitals meeting hand hygiene targets by audit and hospital peer group

<<<Insert Figure 3 here>>>

We also noted that principal and large hospitals comprised 51.7% of hospitals in audit 1 versus 39.3% in audit 8, suggesting they were early adopters in the program. We tested whether this would influence the results using the restricted model (comprising data from audits 3 to 8). The infection control outcomes also improved over time with 3% of organisations receiving high scores in both surveys in cycle 0 versus 17% in cycle 1, however, we note the absolute small numbers involved (n=8). A size effect was noted with 6.5% (n=2) of smaller hospitals receiving a higher infection control score in at least one survey versus 35.7% (n=10) of principal and 46.2% (n=6) of large hospitals (see Table 1).

Table 1: Summary characteristics of accreditation and infection control scores

Table 1: Summary of accreditation and infection control scores, breakdown by peer group and timing of surveys

	Hospital Peer Group			
	Principal	***Large***	***Medium***	***Small***
	N=28	*N=13*	*N=24*	*N=31*
Full accreditation on both surveys	*57.1%*	*61.5%*	*33.3%*	*3.2%*
Full accreditation in cycle 0 (surveys in 2009 and 2011)	*58.8%*	*62.5%*	*21.4%*	*0.0%*
Full accreditation in cycle 1 (surveys in 2010 and 2012)	*54.5%*	*60.0%*	*50.0%*	*10.0%*
Higher IC scores in one survey	*25.0%*	*30.8%*	*8.3%*	*3.2%*
Higher IC scores in both surveys	*10.7%*	*15.4%*	*8.3%*	*3.2%*
Higher IC scores in either survey	*35.7%*	*46.2%*	*16.7%*	*6.5%*
Higher IC scores in cycle 0 (surveys in 2009 and 2011)	*29.4%*	*25.0%*	*7.1%*	*0.0%*
Higher IC scores in second survey of each cycle (2011 or 2012)	*45.5%*	*80.0%*	*30.0%*	*20.0%*
IC=infection control				
Peer group as defined by the Australian Institute of Health and Welfare [30]				

Testing the model

The intra-class correlation co-efficient indicated that 38% of the variance was due to within-hospital effects, indicating sufficient variance for using a random intercept model.[32] We ran a likelihood ratio test using a null model (without the random intercept). This gave a chi-squared test result of 190 (p=0.001), which confirmed our approach versus using ordinary least squares. We also tested the model using infection control scores as a random co-efficient, but the results (chi squared= 0.81, p=0.67) indicated that the random intercept model was more appropriate. We noted a ceiling effect in our data with 100% of large hospitals and 92% of all hospitals meeting the target compliance rates by audit 8, with less incentive to reach higher levels (see Figure 3). Although hospitals were incrementally enrolled in the hand hygiene program, the lack of hand hygiene compliance data in the un-enrolled hospitals meant we were not able to use a stepped wedge design to

provide controls, or evaluate a before and after effect and our results are also subject to omitted variable bias. A fixed effects panel data model might be a more traditional approach to reduce sample variation, but we determined that the random intercept model would be more appropriate due to the policy requirement for all public hospitals to submit hand hygiene data, and the presence of time-invariant variables.[34]

Multilevel model

After matching the hand hygiene data with hospitals that underwent two accreditation surveys, our main model included data from 661 hand hygiene audits from 96 hospitals, an average of 6.9 audits per hospital. The results (Table 2) show that achieving full accreditation for both surveys was not significantly associated with higher hand hygiene rates versus those hospitals achieving full accreditation in only one survey. The association between hand hygiene rates and infection control scores is less clear. Hospitals achieving higher infection control scores (EA) in one survey (n=14) showed 4.2 percentage point (pp) lower hand hygiene rates than hospitals who just met the accreditation standard (MA score), and this result was significant (p=0.033). Hospitals achieving higher infection control scores in both surveys (n=8) showed higher rates (2.1 pp) but this was not significant (p=0.40). Small and medium sized hospitals experienced significantly higher hand hygiene compliance rates (7.8 pp for small hospitals and 3.5 pp for medium hospitals) compared to principal hospitals. The restricted model, using data from audit 3 onwards, also showed a negative relationship between higher infection control scores and hand hygiene audit results. However, the effect was smaller (2.9 pp) and the results were no longer significant (p=0.14). The size effect in the restricted model was consistent with the main model, with small and medium hospitals showing significantly higher hand hygiene rates than principal referral hospitals. These results do not lend support to our study hypothesis that higher infection control scores are associated with higher hand hygiene rates.

Table 2: Multilevel model to show effect of accreditation outcomes on hand hygiene audit rates

Table 2 - Multilevel model showing association of accreditation outcomes on hand hygiene compliance rates						
Variables	**Main Model (audits 1-8)**			**Restricted Model (audits 3-8)**		
	Mean values	**Standard error**	***p values***	**Mean values**	**Standard error**	***p values***
Full accreditation in both surveys	0.004	0.016	*0.809*	0.0077	0.016	*0.620*
Higher infection control scores in one survey	**-0.042**	**0.020**	***0.033***	-0.029	0.020	*0.135*
Higher infection control scores in two surveys	0.021	0.025	*0.404*	0.033	0.024	*0.172*
Later cycle (surveys in 2010/2012	0.024	0.014	*0.073*	0.0205	0.013	*0.123*

Hospital peer group* (principal referral=0)						
Large	0.024	0.020	*0.247*	0.0233	0.023	*0.244*
Medium	**0.035**	**0.017**	***0.046***	**0.0343**	**0.034**	***0.045***
Small	**0.078**	**0.018**	***<0.001***	**0.0807**	**0.081**	***<0.001***
Number of observations	661			563		
Number of hospitals	96			96		
Average compliance rates	0.741			0.744		
Log likelihood	662			634		
***Peer group as defined by the Australian Institute of Health and Welfare [30]**						

DISCUSSION

Our analysis of 118 NSW hospitals showed that hand hygiene rates increased from 67.7% in audit 1 in late 2010 to 80.3% by audit 8 in early 2013. This compares to rates of 62.2% from a sample of NSW hospitals in February 2007 which were observed following the introduction of the Clean Hand Saves Lives campaign during 2006-2007,[15] and continues the improvement shown nationally in Australia with average hand hygiene rates estimated at 68.3% in 2011.[35] It is challenging to compare these results internationally. A US study estimated average hand hygiene rates of 56.6% in 40 hospitals using data collected for one year before and after the introduction of national hand hygiene guidelines in 2002.[36] However, it must be noted that this program was different to that followed by Hand Hygiene Australia and so the results would not be directly comparable.

Smaller hospitals in our study had higher hand hygiene compliance rates but the relationship between accreditation outcomes and hand hygiene data was less clear. This hospital size effect on hand hygiene compliance has been confirmed by other research investigating the link between hand hygiene rates and health care associated *Staphylococcus aureas* bacteraemia.[37 38] We consider the results from small and medium hospitals in our study can be explained by looking at the organisational infrastructure necessary to meet the hand hygiene and accreditation requirements. Both are dependent on a widespread organisational response in terms of education, monitoring, infrastructure and management involvement.[6] Achieving higher infection control scores requires additional benchmarking, feedback and research capabilities.[7 8] The organisational size effect suggests that small and medium sized hospitals can effectively embrace multimodal quality improvement strategies as seen by the higher compliance rates. However, the requirements for achieving high infection control scores within an accreditation survey may be measuring different aspects of quality that are not reflected in the hand hygiene compliance rates. The results indicate that smaller hospitals are able to focus on the practical implementation of a national hand hygiene policy. Having the resources to meet the requirements for higher infection control scores, in terms of conducting research or being recognised leaders in infection control, may not be practical for these smaller organisations. Although some smaller hospitals will be accredited as part of a larger cluster of hospitals, which includes principal and large

hospitals, this is not always the case. Our hypothesis that higher accreditation scores would be reflected in hand hygiene rates appears to be confounded by an accreditation program that makes it more difficult for smaller hospitals to achieve high infection control scores.

This study uses one indicator for evaluating accreditation whereas multiple measures may be more effective.[39] For example, outcome indicators are widely used in the US hospital system,[40-42] and include hospital acquired SAB rates and surgical site infection rates. These incorporate a broader mix of the anti-microbial, hand hygiene, and specialist cleaning practice modules of the infection control standard. Using outcome indicators would complete Donabedian's triad of performance measures to include structural (accreditation results), process (hand hygiene compliance rates) and outcome (*Staphylococcus aureas* infection rates) measures.[43 44]

Measurement issues in our study include a possible observer effect since the hospital staff might be aware the audit was taking place. However, although this may increase the compliance rate, the results would still be valid as the standards include requirements for staff education and installation of appropriate infrastructure. Increased rates during an audit imply that the correct infrastructure is in place, in terms of availability of functioning hand washing stations, and that staff are aware of the hand hygiene policies. In addition, any observer effect is likely to be mitigated as all the hospitals used the same methods for collecting data and thus are equally subjected to this bias. Other methods to measure hand hygiene activity include measuring consumption rates of hand hygiene products, such as alcohol rubs, [45] and electronic systems for monitoring compliance,[46] but WHO guidelines suggest direct observation is still the gold standard.[40] We also note that although accreditation surveys are assessed on a five point scale, only two scores (MA and EA) were used in the infection control standard during the four surveys in our study. The lack of granularity in the accreditation scores makes it difficult to differentiate accreditation performance. Inter-surveyor reliability is recognised as a limitation of audit systems that are based on subjective assessments.[47] To reduce idiosyncratic scoring, ACHS surveyors need to provide evidence to ACHS for their scoring methods, and in the decision to award higher scores, but some variation between surveyors may remain.

Limitations of the model include reverse causality in that higher compliance rates could lead to higher infection control scores at the next survey where hand hygiene audit rates are used as evidence of implementation during an accreditation survey. This would likely be the case going forward as ACSQHC includes hand hygiene audit results as part of the evidence of implementation of standard 3 under the new national standards.[9 48]

Implications

Different indicators will give different perspectives on how an organisation approaches and implements relevant policy. However, the costs of measurement in health care should be balanced against using a range of indicators to capture a broader mix of infection control policies, and across the different standards assessed during accreditation surveys. Indicator selection should include both process indicators, recognised as a method of measuring organisational changes,[49] and outcome indicators. Public reporting of indicator data

further increases the requirement to accurately identity and measure the parts of the patient safety and quality spectrum that are being addressed. In this study, a focus on the accreditation results would underestimate the successful implementation of the hand hygiene policy by smaller hospitals. Conversely, just using hand hygiene results would underestimate the research and leadership investment in infection control by larger hospitals. Disentangling these two outcomes within the same safety and quality initiative is a pre-requisite to understanding how they can be effectively assessed and monitored. For example, consideration could be given to changing criteria for awarding higher scores for infection control such that achieving higher scores was evidence based and could be feasible for all hospitals.

CONCLUSION

Identifying indicators to measure the effectiveness of accreditation is challenging due to the complexity of implementing a wide range of accreditation related processes across multiple hospital activities. Our results do not support our study hypothesis that higher infection control scores are associated with higher hand hygiene rates. Instead, this study suggests that accreditation outcomes and hand hygiene audit data measure different parts of the quality and safety spectrum. Developing a framework to identify suitable indicators is an important contribution to understanding the impact of hospital accreditation internationally. Policy makers need to appreciate the assumptions behind the choice of indicator and understand exactly what is being measured to ensure that key performance indicators encourage quality improvements in the delivery of hospital services.

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Ethics: Human Research Ethics Committee approval for this study was granted by UNSW (approval number HREC 10274).

Figure Legends

Figure 1: Timeline of accreditation surveys and hand hygiene audits

Figure 2: Mean hand hygiene compliance rates by audit and hospital peer group, 2010-2013

Figure 3: Percentage of hospitals meeting hand hygiene targets by audit and hospital peer group

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Disentangling quality and safety indicator data: a longitudinal, comparative study of hand hygiene compliance and accreditation outcomes in 96 Australian hospitals

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Ethics: The University of New South Wales Human Research Ethics Committee has approved this project (approval number HREC 10274).

Disentangling quality and safety indicator data: a longitudinal, comparative study of hand hygiene compliance and accreditation outcomes in 96 Australian hospitals

ABSTRACT

~~**Aim:** We compared hand hygiene compliance rates with accreditation scores over eight hand hygiene audit points and two accreditation cycles in order to test our hypothesis that hospitals with better accreditation outcomes would achieve higher hand hygiene compliance rates.~~

~~**Methods:** The study comprised a retrospective, longitudinal, multi-site comparative survey of hand hygiene compliance rates and accreditation outcomes in 96 acute public hospitals in New South Wales (NSW), Australia. We matched observational hand hygiene compliance data with accreditation survey results from 2009 to 2013. Hand hygiene compliance rates were assessed against the following explanatory variables: accreditation and infection control scores; timing of the surveys; and hospital size and activity. We used multilevel regression to analyse the data.~~

~~**Results:** Average hand hygiene compliance rates increased from 67.7% to 80.3% during the study period (2010 to 2013), with 46.7% of hospitals achieving target compliance rates of 70% in audit 1, versus 92.3% in audit 8. Average hand hygiene rates at small hospitals were 7.8 percentage points (pp) higher than those at the largest hospitals ($p<0.05$). Hospitals with higher accreditation scores in one survey unexpectedly showed hand hygiene compliance rates that were 4.1 pp lower ($p<0.05$) than hospitals with lower IC scores~~The association between hand hygiene rates, accreditation outcomes and infection control scores is less clear~~.~~

~~**Conclusions:** Our results indicate that accreditation outcomes and hand hygiene audit data are measuring different parts of the quality and safety spectrum. Our hypothesis appears confounded by an accreditation program that makes it more difficult for smaller hospitals to achieve high IC scores. Understanding what is being measured when selecting indicators to assess the impact of accreditation~~asse is critical as focusing on ~~accreditation results would discount successful hand hygiene implementation by smaller hospitals. Conversely, relying on hand hygiene results would discount the IC related research and leadership investment by larger hospitals.~~

Objectives: The study aims are twofold. First, to investigate the suitability of hand hygiene as an indicator of accreditation outcomes and, second, to test the hypothesis that hospitals with better accreditation outcomes achieve higher hand hygiene compliance rates.

Design: A retrospective, longitudinal, multi-site comparative survey.

Setting: Acute public hospitals in New South Wales, Australia.

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Participants: 96 acute hospitals with accreditation survey results from two surveys during 2009-2012 and submitted data for more than four hand hygiene audits between 2010 and 2013.

Outcomes: Our primary outcome comprised observational hand hygiene compliance data from eight audits during 2010 to 2013. The explanatory variables in our multilevel regression model included: accreditation outcomes and scores for the infection control standard; timing of the surveys; and hospital size and activity.

Results: Average hand hygiene compliance rates increased from 67.7% to 80.3% during the study period (2010 to 2013), with 46.7% of hospitals achieving target compliance rates of 70% in audit 1, versus 92.3% in audit 8. Average hand hygiene rates at small hospitals were 7.8 percentage points (pp) higher than those at the largest hospitals ($p<0.05$). The association between hand hygiene rates, accreditation outcomes and infection control scores is less clear.

Conclusions: Our results indicate that accreditation outcomes and hand hygiene audit data are measuring different parts of the quality and safety spectrum. Understanding what is being measured when selecting indicators to assess the impact of accreditation is critical as focusing on accreditation results would discount successful hand hygiene implementation by smaller hospitals. Conversely, relying on hand hygiene results would discount the infection control related research and leadership investment by larger hospitals. Our hypothesis appears confounded by an accreditation program that makes it more difficult for smaller hospitals to achieve high infection control scores.

Strengths and limitations of this study:

- The main strengths of this study relates to the use of a comprehensive dataset involving ~~lies in~~ the number of ~~participating~~ acute hospitals (96) participating in the accreditation process and the length of follow up over eight hand hygiene audit points and two accreditation cycles.
- This study also addresses an important ~~gap~~ research question in terms of identifying and assessing the components of hospital accreditation and ~~or~~ quantifying their inter-related benefits.
- ~~benefits of hospital accreditation.~~
- The results have important implications for health policy makers internationally in terms of designing health service accreditation programs that can be accurately measured and monitored.
- The main limitation was the lack of a control group as all hospitals in the survey were accredited. This meant it was not possible ~~in order~~ to assess direct or reverse causal relationships or to prevent omitted variable bias.
- Other limitations include potential measurement error resulting from ~~using~~ the use of self-reported hand hygiene data, however, the data collection methods adhered to World Health Organisation best practice guidelines.

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INTRODUCTION

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Hospital accreditation programs are designed to set clinical and organisational standards, ~~ensure~~ assess compliance with those standards, and strengthen quality improvement efforts. Accreditation is widely practised with national level accreditation agencies active in at least 27 countries.[1] The problems associated with measuring accreditation benefits are well documented.[2 3] A clear understanding of the inputs, in terms of costs and resource use, and outcomes, in terms of improved patient safety and quality, is essential in ensuring that accreditation programs are achieving their aims of improving patient safety and health care quality.[4 5] Measuring the effects of accreditation on clinical practice and quality of care is important as we need to determine whether the cost burden of data collection and audit processes ~~are~~ is outweighed by the expected improvements in quality and safety outcomes.[5]

In this study we analyse the relationship between hand hygiene compliance rates and accreditation outcomes in order to test the suitability of hand hygiene as an indicator of accreditation outcomes. Our hypothesis is that hospitals with better accreditation outcomes and infection control ~~(IC)~~ scores than others, reflect~~ing~~ organisational processes that ~~in~~ support ~~of improvement and~~ a positive culture toward improving quality and safety,[6] and therefore they would achieve higher hand hygiene compliance rates.

Hand hygiene assessment is an integral component of the infection control ~~IC~~ standards used to evaluate whether Australian hospitals are compliant with ~~the~~ accreditation standards.[7-9] Hand hygiene compliance rates have been validated as a potential process indicator for accreditation outcomes. Moreover, ~~H~~health care associated infections ~~(HAIs)~~ are recognised as a leading cause of increased morbidity and health care costs.[10] A United States (US) study estimated there were 1.7 million ~~HAIs~~ healthcare associated infections in 2002, comprising 4.5% of admissions, and resulting in nearly 99,000 deaths.[11] A recent meta-analysis estimated the cost of the five most common ~~HAIs~~ healthcare associated infections at US$9.8 billion per annum.[12] In Australia, the most recent figures available indicate that ~~HAIs~~ healthcare associated infections resulted in an extra two million bed days in 2005, with estimated additional costs of AU$21 million from post-discharge surgical infections.[13]

There is increasing evidence that improving hand hygiene reduces ~~HAIs~~ healthcare associated infections and the spread of anti-microbial resistance.[14-18] However, it is difficult to demonstrate a causal link between hand hygiene and ~~HAIs~~ healthcare associated infections due to a multiplicity of interventions and scarcity of randomised trials.[19-21] Nevertheless, the World Health ~~Organization~~ Organisation (WHO) has identified good hand hygiene as a major factor in reducing ~~HAIs~~ healthcare associated infections based on epidemiological evidence.[18]

Hand hygiene policies in Australian hospitals follow international best practices. They are based on WHO recommendations with a multimodal approach incorporating: access to cleaning agents at the point of care; training and education; monitoring and feedback; reminders in the workplace; and development of an institutional safety climate.[22] Auditors trained by Hand Hygiene Australia ~~(HHA)~~ monitor hand hygiene activity

by direct observation of hospital staff and compare hand hygiene activity against the total number of potential "moments" for hand hygiene.[23] The national target for hand hygiene compliance is 70% and audit results are publicly reported three times a year. The Australian Commission on Safety and Quality in Health Care (ACSQHC) has recommended that hand hygiene programs need to be repeatedly monitored using both process indicators (compliance rates) and outcome indicators (infection rates).[24]

METHODS

Study design, setting and context

The study comprised a retrospective, longitudinal, multi-site comparative survey of hand hygiene compliance rates and accreditation outcomes in acute public hospitals in New South Wales (NSW), Australia. With a population of 7.2 million, NSW comprises 30.5% of the 736 public hospitals and 32.0% of the population in Australia.[25] We employed retrospective data matching techniques over the study period, 2009 to 2013, to analyse the relationship between hand hygiene compliance data and accreditation outcomes.

Data matching and analysis

a) Hand hygiene compliance data

Hand hygiene policies include five "moments" when hand hygiene should be performed: before touching a patient; before a procedure; after a procedure or body fluid exposure risk; after touching a patient; and after touching a patient's surroundings.[23 26] Audits are carried out three times a year by health care workers who have been accredited by ~~HHA~~Hand Hygiene Australia. Surveys are conducted using a standardised observation assessment tool which measures hand hygiene activity versus the total number of observed possible "moments". Auditors are trained in selecting the wards or units for the audit, and the minimum number of required "moments" for each audit is determined by hospital size and activity. We obtained ~~the~~ hand hygiene compliance rates data from late 2010 to early 2013 from the NSW Clinical Excellence Commission ~~(CEC)~~, the quality and safety body responsible for implementing the hand hygiene initiative in NSW and collecting hand hygiene audit data.[27]

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b) Accreditation program and infection control standards

Data on accreditation outcomes from 2009 to 2013 were provided by the Australian Council on Healthcare Standards (ACHS). The ACHS Evaluation and Quality Improvement Program (EQuIP) was introduced in 1997 and comprises a four year cycle with external surveys in years two and four.[28] During these surveys, hospitals are assessed by an external team of surveyors against ACHS developed standards. ~~-~~The EQuIP program has undergone several revisions, none of which materially affected this study. Our study period included EQuIP4 which was introduced in 2007 and used for the surveys in 2009 and 2010, and EQuIP5 which was introduced in 2011. Accreditation standards were changed significantly following the introduction of national mandatory standards in 2013,[9] but the infection control criteria were the same for both versions of the EQuIP standards assessed during the study period (see supplementary file 1) . ~~s~~S~~Facilities were scored by s~~urveyors scored

facilities on a five point Likert scale for each standard or criterion assessed in the survey. Scores were designated as Outstanding Achievement (OA), Extensive Achievement (EA), Moderate Achievement (MA), Some Achievement, and (LA Little Achievement. Hospitals needed to achieve OA, EA or MA, ~~EA or OA~~ scores in each mandatory standard or criterion in order to meet accreditation requirements.

~~IC~~ Infection control related criteria were part of a broader standard regarding the safe provision of care and services.[7 8] To meet ~~MA~~accreditation ~~-~~requirements, hospitals needed to ensure that the ~~IC~~ infection control policy: met all regulatory requirements and industry guidelines; had executive support; incorporated ongoing education activities; and, included indicators to show both compliance with the policy and effective outcome measurements. Additional activities which counted towards achieving higher (EA and OA) scores included: benchmarking of performance indicators; use of feedback to inform and improve; ~~IC~~ contributing to infection control research; and, ~~,~~ recognised leadership in ~~IC~~ infection control systems.[7 8] Accreditation is often granted to a cluster of facilities within a local health district and therefore reflects conditions at all the facilities within that survey group. These clusters are subject to boundary changes, as seen in the NSW 2011 health system re-organisation, which took place during the study period ~~(2009-2012)~~.[29] We therefore identified the different hospitals within each cluster in order to match the accreditation scores with the hand hygiene data from individual hospitals.

Study Variables

To analyse the matched data we used hand hygiene compliance rates as our outcome of interest, expressed as a continuous outcome variable ~~*(hh)*~~. Data were available at eight different time points from the end of 2010 to early 2013 (see Figure 1). We characterised the accreditation scores as either full or partial accreditation. ~~,~~ ~~with p~~Partial accreditation was defined as either accreditation being granted for a reduced time, or resulting in a recommendation for action. No hospitals in the study were refused accreditation during the study period. We included infection control scores in the model by whether hospitals achieved a higher score in one, none (our reference case) or both surveys. To test for a possible timing effect we included a variable to identify whether surveys were either carried out in the 2009 and 2011 accreditation cycle (cycle=0), or the 2010 and 2012 cycle (cycle=1).

Figure 1: Timeline of accreditation surveys and hand hygiene audits

<<<Insert Figure 1 here>>>

~~We created dummy variables for the IC standard to designate whether they achieved a high IC score in the first or second survey in each cycle (*hai1* and *hai2* respectively). No hospitals scored less than MA during the study period so we differentiated the outcomes by assigning MA as 0, and the higher scores (EA, and OA) as 1. We created a categorical variable for the number of surveys where each hospital achieved high IC scores (*hait*). There were three possible outcomes: no high scores in either survey (*hait*=0); high scores in one survey (*hait*=1); or high scores in both surveys (*hait* =2). The dummy variable for accreditation (*acct)* was designated 1 for full accreditation, and 0 for partial accreditation. We defined partial accreditation as either accreditation~~

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being granted for a reduced time, or resulting in a recommendation for action. No hospitals in the study were refused accreditation during the study period. We assigned a *cycle* variable to identify whether surveys were either carried out in the 2009 and 2011 (cycle =0), or 2010 and 2012 (cycle=1).

Figure 1: Timeline of accreditation surveys and hand hygiene audits

<Insert Figure 1 here>

Acute hospitals were grouped according to the Australian Institute of Health and Welfare activity matrix, based on annual numbers of acute case-mix adjusted separationsepisodes of care adjusted for patient complexity, and geographic location (see supplementary file 2).[30] We used these groups to create a categorical variable (*grp*) with principal referral and specialist hospitals as the reference case (principal=0), with large hospitals scored as 1, medium hospitals as 2, and small hospitals as 3.

Analysis

The nature of the data, with irregular audit dates and clustering within hospitals, indicated that a multi-level model would be the most appropriate and would allow adjustment for hospital level variance.[31 32] Our model used audit points as Level-1 units and hospitals as Level-2 units. ?? is this sentence necessary as non-mathematical readers are likely to wonder what level 1 and level 2 mean – I guess it depends how much specific detail is needed about the model After matching the accreditation and hand hygiene data our sample comprised 96 hospitals each with two accreditation surveys. For some hospitals we were not able to match the accreditation outcomes because of changes in the accreditation clusters. Missing data were higher during the first two audits whilst the program was progressively implemented., and for some hospitals we were not able to match the accreditation outcomes because of changes in the accreditation clusters We did not impute values for missing data as the pattern of missing results indicated these were not missing at random. For example, data from some of the smaller hospitals were not included as they did not meet the minimum publication requirements during the study period (50 moments of hand hygiene), which we determined was likely to be related to hospital size.

We tested our main model using hand hygiene data from audits 1 through 8 as the outcome variable, and accreditation outcomes, infection control scores, accreditation cycle, and peer groups as our explanatory variables. (comprising the *hh, hait, acct, grp* and *cycle* variables), and fitted a restrictive model using data from audits 3 to 8. We looked for timing effects by fitting survey models for each survey and cycle (using *the hh, hai1* or *hai2, cycle*= 0 or 1, and *grp* variables). We tested the model fit versus ordinary least squares by calculating the intra-class correlation to assess the within-hospital effect. We also tested whether to use a random co-efficient or random intercept model. Analysis was conducted using Stata statistical software (version 12SE),[33] applying a two-sided significance level of 5%. We also fitted a restrictive model using data from audits 3 to 8 to determine whether the different peer group mix in the first two surveys was affecting the results.

RESULTS

Hand hygiene and accreditation data analysis

We assessed hand hygiene data on 118 hospitals from eight different audit points during 2010 to 2013. ~~Missing data were higher during the first two audits whilst the program was progressively implemented, and for some hospitals we were not able to match the accreditation outcomes because of changes in the accreditation clusters. We did not impute values for missing data as the pattern of missing results indicated these were not missing at random. For example, data some of the smaller hospitals were not included as they did not meet the minimum publication requirements (50 moments of hand hygiene), which we determined was likely to be related to hospital size.~~

Overall, hand hygiene rates showed an improvement during the study period, with 28 out of 60 hospitals (46.7%) achieving 70% compliance rates in the first audit in 2010 versus 108 out of 117 hospitals (92.3%) in the final audit, in early 2013. Average hand hygiene compliance rates increased from 67.7% in audit 1, to 80.3% in audit 8, and remained above the 70% national target rate from audit 2 onwards. The average audit compliance rates ~~with minimum and maximum values, and standard deviations, are shown in~~by audit and hospital peer group are shown in Figure 2.

Figure 2: Mean hand hygiene compliance rates by audit and hospital peer group, 2010-2013

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~~**Figure 2: Hand hygiene compliance audits, 2010-2013**~~

~~<Insert Figure 2 here>~~

During the study period, 2009-2013, 61 hospitals underwent an accreditation survey in cycle 0, and 44 in cycle 1. The accreditation outcomes showed that 59% of organisations were granted full accreditation in the first survey in each cycle (during 2009-10) versus 77% in the second survey (2011-12). The number of hospitals receiving ~~a~~ higher infection control ~~IC~~ scores also increased over time, with 13% receiving a higher score (EA) in the first survey of each accreditation cycle versus 18% in the second surveys during 2011 and 2012. No hospitals received an OA score for infection control during the study period. We further examined whether there was a difference between meeting, or not meeting, the target compliance rates by comparing the partial data from audit 1 when the program was being rolled out, and the final audit in our study, audit 8 (~~Table 1~~see Figure 3). ~~This showed that the l~~Large hospitals showed the biggest increase, with 30% meeting the target in audit 1, rising to 100% by audit 8.

~~Principal and large hospitals comprised 51.7% of hospitals in audit 1 versus 39.3% in audit 8, suggesting they were early adopters in the program.~~

~~Table 1~~**Figure 3: Percentage of hospitals meeting hand hygiene targets by audit and hospital peer group**

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~~Comparison of whether hospitals met national hand hygiene targets in audits 1 and 8~~

~~Hospital groups~~	~~Audit 1~~			~~Audit 8~~		
	~~Not met~~	~~Met~~	~~% Met~~	~~Not met~~	~~Met~~	~~% Met~~
~~Principal~~	~~13~~	~~8~~	~~38.1~~	~~2~~	~~28~~	~~93.3~~
~~Large~~	~~7~~	~~3~~	~~30.0~~	~~0~~	~~16~~	~~100.0~~
~~Medium~~	4	~~6~~	~~60.0~~	~~3~~	~~26~~	~~89.7~~
~~Small~~	~~8~~	~~11~~	~~57.9~~	4	~~38~~	~~90.5~~

<<<Insert Figure 3 here>>>

We also noted that ~~the~~ principal and large hospitals comprised 51.7% of hospitals in audit 1 versus 39.3% in audit 8, suggesting they were early adopters in the program. ~~, and w~~We tested whether this would influence the results using the restricted model (comprising data from audits 3 to 8).

The ~~accreditation and IC~~ infection control outcomes also improved over time ~~with full accreditation for both surveys being awarded to 30% of hospitals in cycle 0 versus 42% in cycle 1. IC scores showed a similar pattern~~ with 3% of organisations receiving high scores in both surveys in cycle 0 versus 17% in cycle 1, however, we note the absolute small numbers involved (n=8). A size effect was noted with 6.~~9~~5% (n=2) of smaller hospitals receiving a higher infection control score in at least one survey versus ~~37.0~~35.7% (n=10) of principal and ~~42.9~~46.2% (n=6) of large hospitals (~~.~~see Table 1).

Table 1: Summary characteristics of accreditation and infection control scores

Table 1: Summary of accreditation and infection control scores, breakdown by peer group and timing of surveys

	Hospital Peer Group			
	Principal	***Large***	***Medium***	***Small***
	N=28	***N=13***	***N=24***	***N=31***
Full accreditation on both surveys	***57.1%***	***61.5%***	***33.3%***	***3.2%***
Full accreditation in cycle 0 (surveys in 2009 and 2011)	***58.8%***	***62.5%***	***21.4%***	***0.0%***
Full accreditation in cycle 1 (surveys in 2010 and 2012)	***54.5%***	***60.0%***	***50.0%***	***10.0%***
Higher IC scores in one survey	***25.0%***	***30.8%***	***8.3%***	***3.2%***
Higher IC scores in both surveys	***10.7%***	***15.4%***	***8.3%***	***3.2%***
Higher IC scores in either survey	***35.7%***	***46.2%***	***16.7%***	***6.5%***
Higher IC scores in cycle 0 (surveys in 2009 and 2011)	***29.4%***	***25.0%***	***7.1%***	***0.0%***
Higher IC scores in second survey of each cycle (2011 or 2012)	***45.5%***	***80.0%***	***30.0%***	***20.0%***

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IC=infection control				
Peer group as defined by the Australian Institute of Health and Welfare [30]				

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[30 34]**Testing the model**

The intra-class correlation co-efficient indicated that 38% of the variance was due to within-hospital effects, indicating sufficient variance for using a random intercept model.[32] We ran a likelihood ratio test using a null model (without the random intercept). This gave a chi-squared test result of 190 (p=0.001), which confirmed our approach versus using ordinary least squares. We also tested the model using infection control scores as a random co-efficient, but the results (chi squared= 0.81, p=0.67) indicated that the random intercept model was more appropriate. We noted a ceiling effect in our data with 100% of large hospitals and 92% of all hospitals meeting the target compliance rates by audit 8, with less incentive to reach higher levels (see Figure 3). Although hospitals were incrementally enrolled in the hand hygiene program, the lack of hand hygiene compliance data in the un-enrolled hospitals meant we were not able to use a stepped wedge design to provide controls, or evaluate a before and after effect and our results are also subject to omitted variable bias. A fixed effects panel data model might be a more traditional approach to reduce sample variation, but we determined that the random intercept model would be more appropriate due to the policy requirement for all public hospitals to submit hand hygiene data, and the presence of time-invariant variables.[34]

Multilevel model

After matching the hand hygiene data with hospitals that underwent two accreditation surveys, our main model included data from 661 hand hygiene audits from 96 hospitals, an average of 6.9 audits per hospital. The results (Table 2) show that achieving full accreditation for both surveys was not significantly associated with higher hand hygiene rates versus those hospitals achieving full accreditation in only one survey. The association between hand hygiene rates and infection control scores is less clear. Hospitals achieving higher infection control scores (EA) in one survey (n=14) showed 4.2 percentage point (pp) lower hand hygiene rates than hospitals who just met the accreditation standard (MA score), and this result was significant (p=0.033). Hospitals achieving higher infection control scores in both surveys (n=8) showed higher rates (2.1 pp) but this was not significant (p=0.40). S~~that s~~mall and medium sized hospitals experienced significantly higher hand hygiene compliance rates (7.8 ~~percentage points (~~pp~~)~~ for small hospitals and 3.~~8~~ 5 pp for medium hospitals) compared to principal hospitals. ~~The association between hand hygiene rates and accreditation outcomes, for both overall and IC scores, is less clear. Hospitals achieving high IC scores (EA) in one survey (n=14) showed 4.1 pp lower hand hygiene rates than hospitals achieving an MA score, and this result was significant (p=0.038). Hospitals achieving high IC scores in both surveys (n=8) showed higher rates (2.1 pp) but this was not significant (p=0.39). Achieving full accreditation for both surveys was not significantly associated with hand hygiene rates versus those hospitals which achieved full accreditation in only one survey.~~ The restricted

model, using data from audit 3 onwards, also showed a negative relationship between higher infection control ~~IC~~ scores and hand hygiene audit results. ~~,~~ ~~h~~However, the effect was smaller (2.~~8~~ 9 pp) and the results were no longer significant (p=0.~~15~~14). The size effect in the restricted model was consistent with the main model, with small and medium hospitals showing significantly higher hand hygiene rates than principal referral hospitals. These results do not lend support to our study hypothesis that higher infection control scores are associated with higher hand hygiene rates.

~~These results do not lend support to our study hypothesis that higher infection control scores are associated with higher hand hygiene rates.~~

~~I have just cut and pasted the above sentence from the conclusion – I think it is more appropriate here as a summary of the results and how they relate to the original hypothesis – perhaps it can be reworded for the conclusion.~~

Table 2: ~~Results of our m~~Multilevel model to show effect of accreditation outcomes on hand hygiene audit rates

Table 2 - Multilevel model showing association of accreditation outcomes on hand hygiene compliance rates						
Variables	Main Model (audits 1-8)			Restricted Model (audits 3-8)		
	Mean values	Standard error	*p values*	Mean values	Standard error	*p values*
Full accreditation in both surveys	0.004	0.016	*0.809*	0.0077	0.016	*0.620*
Higher infection control scores in one survey	-0.042	0.020	*0.033*	-0.029	0.020	*0.135*
Higher infection control scores in two surveys	0.021	0.025	*0.404*	0.033	0.024	*0.172*
Later cycle (surveys in 2010/2012	0.024	0.014	*0.073*	0.0205	0.013	*0.123*
Hospital peer group* (principal referral=0)						
Large	0.024	0.020	*0.247*	0.0233	0.023	*0.244*
Medium	0.035	0.017	*0.046*	0.0343	0.034	*0.045*
Small	0.078	0.018	*<0.001*	0.0807	0.081	*<0.001*
Number of observations	661			563		

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Number of hospitals	96	.	.	96	.	.
Average compliance rates	0.741	.	.	0.744	.	.
Log likelihood	662	.	.	634	.	.

*Peer group as defined by the Australian Institute of Health and Welfare [30]

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~~30~~

~~Variables~~	~~Main model~~		~~Restricted model~~		~~Survey models~~			
	~~Audits 1-8~~		~~Audits 3-8~~		~~First Cycle~~		~~Second Cycle~~	
	~~Mean~~	~~SE~~[1]	~~Mean~~	~~SE~~	~~Mean~~	~~SE~~	~~Mean~~	~~SE~~
~~Higher (OA or EA) score for infection control in one survey~~	~~**0.041***~~	~~*0.020*~~	~~0.028~~	~~*0.02*~~				
~~Higher scores for infection control in both surveys~~	~~0.021~~	~~*0.025*~~	~~0.034~~	~~*0.024*~~				
~~Higher infection control scores in first survey~~					~~-0.043~~	~~*0.031*~~	~~0.01~~	~~*0.028*~~
~~Higher infection control scores in second survey~~					~~0.045~~	~~*0.027*~~	~~-.007~~	~~*0.022*~~
~~Full accreditation on both surveys~~	~~0.003~~	~~*0.016*~~	~~0.007~~	~~*0.016*~~				
~~Cycle (2009/11= 0)~~	~~0.022~~	~~*0.014*~~	~~0.018~~	~~*0.013*~~				
~~Hospital group (Principal referral=0)~~								
~~Large~~	~~0.022~~	~~*0.02*~~	~~0.024~~	~~*0.02*~~				
~~Medium~~	~~**0.038***~~	~~*0.018*~~	~~**0.039***~~	~~*0.017*~~				
~~Small~~	~~**0.078***~~	~~*0.019*~~	~~**0.081***~~	~~*0.018*~~				
~~Number of observations~~	~~661~~		~~563~~		~~420~~		~~282~~	
~~Number of hospitals~~	~~96~~		~~96~~		~~60~~		~~42~~	
~~Average compliance rate~~	~~0.74~~		~~0.75~~		~~0.75~~		~~0.75~~	-
~~Log likelihood~~	~~661.85~~		~~633.77~~		~~401.43~~		~~252.52~~	-

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~~[1]Standard error, * Indicates significance at 5% (p<0.05)~~

~~Given the greater change in hand hygiene rates during the early audits, we reviewed the data for timing effects by examining the results by survey and cycle. The majority of the first surveys in both cycles were~~

completed before the hand hygiene audits started. The survey models showed that in cycle 0, higher IC scores were associated with lower hand hygiene results (-4.3 pp) in the first survey, versus a positive relationship in the second survey (+4.5 pp), however these were not significant (p=0.17 and 0.102 respectively) and were reversed in the second cycle.

Testing the model

The intra-class correlation co-efficient indicated that 38% of the variance was due to within-hospital effects, indicating sufficient variance for using a random intercept model.[32] We ran a likelihood ratio test using a null model (without the random intercept). This gave a chi-squared test result of 190 (p=0.000), which confirmed our approach versus using ordinary least squares. We also tested the model using IC scores as a random co-efficient but the results (chi squared= 0.81, p=0.67) indicated that the random intercept model was more appropriate. We noted a ceiling effect in our data with 100% of large hospitals and 92% of all hospitals meeting the target compliance rates by audit 8, with less incentive to reach higher levels. Although hospitals were incrementally enrolled in the hand hygiene program the lack of hand hygiene compliance data in the un-enrolled hospitals meant we were not able to use a stepped wedge design to provide controls or evaluate a before and after effect and our results are subject to omitted variable bias. A fixed effects panel data model might be a more traditional approach to reduce sample variation, but we determined that the random intercept model would be more appropriate due to the policy requirement for all public hospitals to submit hand hygiene data, and the presence of time-invariant variables.[34]

DISCUSSION

Our analysis of 118 NSW hospitals showed that hand hygiene rates increased from 67.7% in audit 1 in late 2010 to 80.3% by audit 8 in early 2013. This compares to rates of 62.2% from a sample of NSW hospitals in February 2007 which were observed following the introduction of the Clean Hand Saves Lives campaign during 2006-2007,[15] and continues the improvement shown nationally in Australia with average hand hygiene rates estimated at 68.3% in 2011.[35] It is challenging to compare these results internationally. A US study estimated These results can be compared to average hand hygiene rates of 56.6% in 40 US hospitals using data collected for one year before and after the following the introduction of national hand hygiene guidelines in 2002.[36] However, it must be noted that this program me was different to that followed by Hand Hygiene Australia and so the results would not be directly comparable.

Smaller hospitals in our study had higher hand hygiene compliance rates but the relationship between accreditation outcomes and hand hygiene data was less clear. This effect of hospital size effect on hand hygiene compliance has received confirmationbeen confirmed by other research investigating the link between hand hygiene rates and health care associated *Staphylococcus aureas* bacteraemia (SAB).[37 38] We consider the results from small and medium hospitals in our study can be explained by looking at the organisational infrastructure necessary to meet the hand hygiene and accreditation requirements. Both are dependent on a widespread organisational response in terms of education, monitoring, infrastructure and

management involvement.[6] Achieving higher ~~IC~~ infection control scores requires additional benchmarking, feedback and research capabilities.[7 8] The organisational size effect suggests that small and medium sized hospitals can effectively embrace multimodal quality improvement strategies as seen by the higher compliance rates. However, the requirements for achieving high ~~IC~~ infection control scores within an accreditation survey may be measuring different aspects of quality that are not reflected in the hand hygiene compliance rates. The results indicate that smaller hospitals are able to focus on the practical implementation of a national hand hygiene policy. Having the resources to meet the requirements for higher ~~IC~~ infection control scores, in terms of conducting research or being recognised leaders in infection control, ~~is~~ may not be practical for these smaller organisations. Although some smaller hospitals will be accredited as part of a larger cluster of hospitals, which includes principal and large hospitals, this is not always the case. Our hypothesis that higher accreditation scores would be reflected in hand hygiene rates appears to be confounded by an accreditation program that makes it more difficult for smaller hospitals to achieve high ~~IC~~ infection control scores.

This study uses one indicator for evaluating accreditation whereas multiple measures may be more effective.[39] For example, outcome indicators are widely used in the US hospital system,[40-42] and include hospital acquired SAB rates and surgical site infection rates. These incorporate a broader mix of the anti-microbial, hand hygiene, and specialist cleaning practice modules of the ~~IC~~ infection control standard. Using outcome indicators would complete Donabedian's triad of performance measures to include structural (accreditation results), process (hand hygiene compliance rates) and outcome (*Staphylococcus aureas* infection rates ~~AB rates~~) measures.[43 44]

Measurement issues in our study include a possible observer effect since the hospital staff might be aware the audit was taking place. However, although this may increase the compliance rate, the results would still be valid as the standards include requirements for staff education and installation of appropriate infrastructure. Increased rates during an audit imply that the correct infrastructure is in place, in terms of availability of functioning hand washing stations, and that staff are aware of the hand hygiene policies. In addition, any observer effect is likely to be mitigated as all the hospitals used the same methods for collecting data and thus are equally subjected to this bias. Other methods to measure hand hygiene activity include measuring consumption rates of hand hygiene products, such as alcohol rubs, [45] and electronic systems for monitoring compliance,[46] but WHO guidelines suggest direct observation is still the gold standard.[40] We also note that although accreditation surveys are assessed on a five point scale, only two scores (MA and EA) were used in the infection control standard during the four surveys in our study. The lack of granularity in the accreditation scores makes it difficult to differentiate accreditation performance. Inter-surveyor reliability is recognised as a limitation of audit systems that are based on subjective assessments.[47] To reduce idiosyncratic scoring, ACHS surveyors need to provide evidence to ACHS for their scoring methods, and in the decision to award higher scores, but some variation between surveyors may remain.

-Limitations of the model include reverse causality in that higher compliance rates could lead to higher ~~IC~~ infection control scores at the next survey where hand hygiene audit rates are used as evidence of implementation during an accreditation survey. This would likely be the case going forward as ACSQHC includes hand hygiene audit results as part of the evidence of implementation of standard 3 under the new national standards.[9 48]

~~Policy~~ Implications

Different indicators will give different perspectives on how an organisation approaches and implements relevant policy. However, the costs of measurement in health care should be balanced against using a range of indicators to capture a broader mix of ~~IC~~ infection control policies, and across the different standards assessed during accreditation surveys. Indicator selection should include both process indicators, recognised as a method of measuring organisational changes,[49] and outcome indicators. Public reporting of indicator data further increases the requirement to accurately identity and measure the parts of the patient safety and quality spectrum that are being addressed. In this study, a focus on the accreditation results would ~~discount~~ underestimate~~??~~ the successful implementation of the hand hygiene policy by smaller hospitals. Conversely, just using hand hygiene results would ~~discount~~ underestimate~~?~~ the research and leadership investment in infection control by larger hospitals. Disentangling these two outcomes within the same safety and quality initiative is a pre-requisite to understanding how they can be effectively assessed and monitored. For example, consideration could be given to changing criteria for awarding higher ~~marks~~scores for infection control such that achieving higher scores was evidence based and could be feasible for all hospitals.

CONCLUSION

Identifying indicators to measure the effectiveness of accreditation is challenging due to the complexity of implementing a wide range of accreditation related processes across multiple hospital activities. ~~These~~ Our results do not ~~lend~~ support ~~to~~ our study hypothesis that higher ~~IC~~ infection control scores are associated with higher hand hygiene rates. Instead, this study suggests that accreditation outcomes and hand hygiene audit data ~~data are complementary~~measure different parts of the quality and safety spectrum. Developing a framework to identify suitable indicators is an important contribution to understanding the impact of hospital accreditation internationally. Policy makers need to appreciate the assumptions behind the choice of indicator and understand exactly what is being measured to ensure that key performance indicators encourage quality improvements in the delivery of hospital services.

ACKNOWLEDGMENTS, COMPETING INTERESTS, and FUNDING

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health safety and quality from the United Kingdom, Spain and Sweden. The collaboration includes two leading health safety and quality bodies (ACSQHC and the NSW Clinical Excellence Commission~~CEC~~) plus three of the major Australian health services accreditation agencies: ACHS, Australian General Practice Accreditation Limited ~~(AGPAL)~~, and the Australian Aged Care Quality Agency ~~(AACQA)~~. The authors would like to thank ACHS and the NSW ~~CEC~~ Clinical Excellence Commission for providing data for the study. The authors would also like to acknowledge the help and encouragement received from the PhD group at the Centre for Health Economics Research and Evaluation at the University of Technology Sydney, in particular: Prof. Marion Haas; Dr. Rebecca Reeve; and Ms. Bonny Parkinson.

Competing interests: None declared

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Ethics: Human Research Ethics Committee approval for this study was granted by UNSW (approval number HREC 10274).

Figure Legends

Figure 1: Timeline of accreditation surveys and hand hygiene audits

Figure 2: Mean hand hygiene compliance rates by audit and hospital peer group, 2010-2013

Figure 3: Percentage of hospitals meeting hand hygiene targets by audit and hospital peer group

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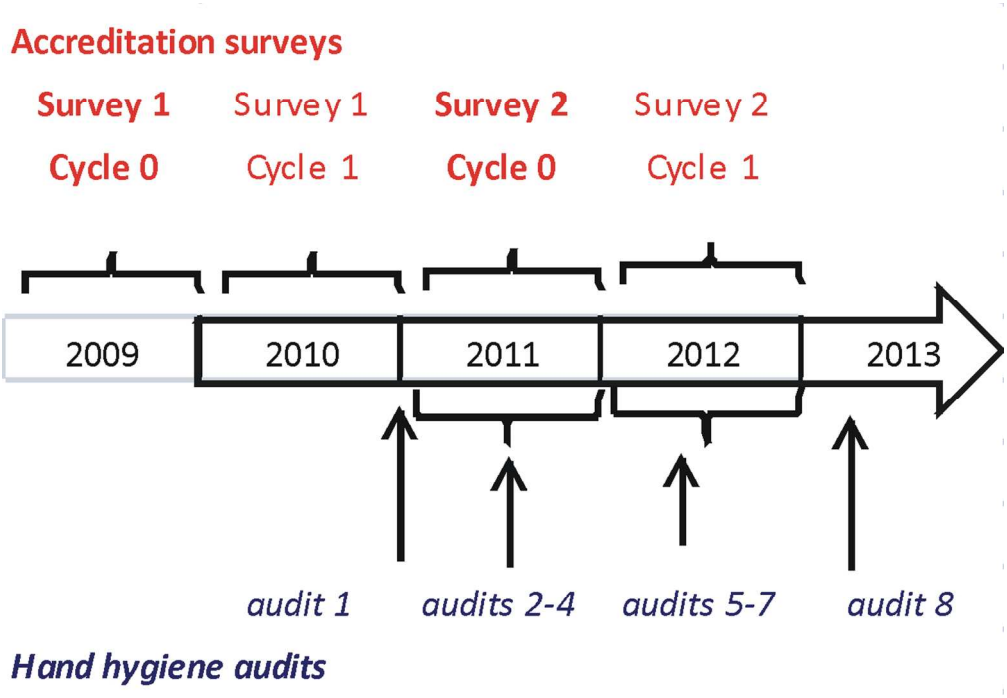

Figure 1: Timeline of accreditation surveys and hand hygiene audits

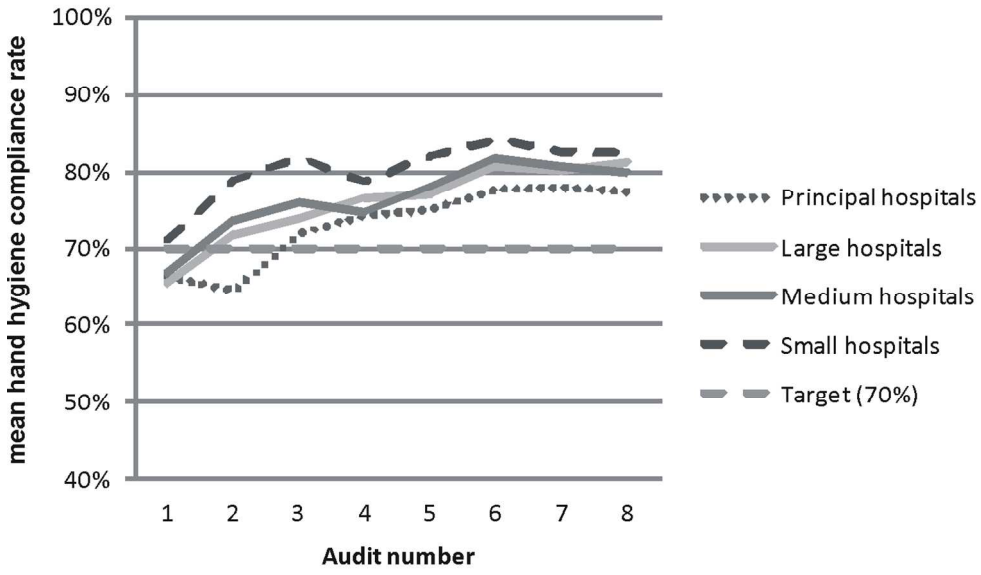

Figure 2: Mean hand hygiene compliance rates by audit and hospital peer group, 2010-2013

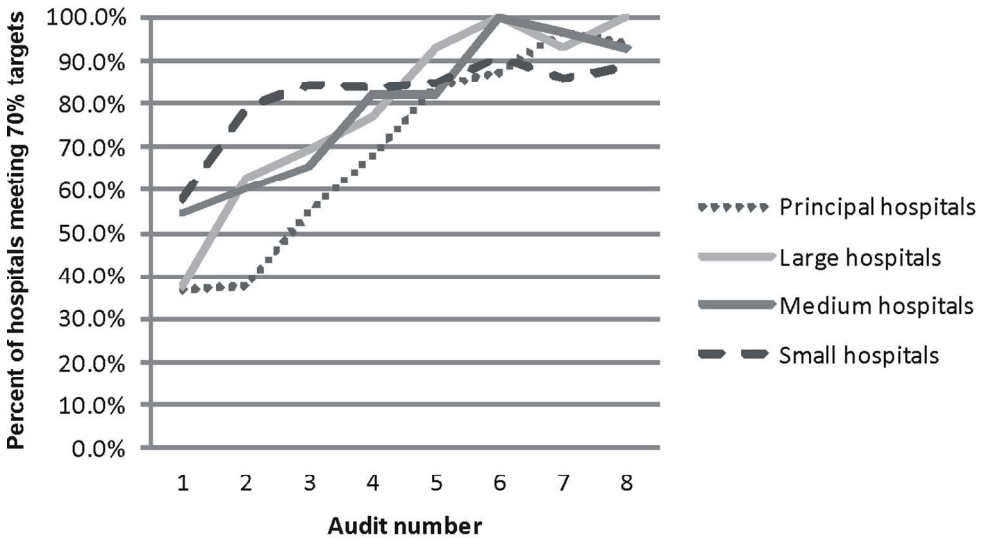

Figure 3: Percentage of hospitals meeting hand hygiene targets by audit and hospital peer group

Mandatory criteria assessed during EQuIP 4 & 5 surveys
Care is planned and delivered in collaboration with the consumer/patient and when relevant, the carer, to achieve the best possible outcomes
Consumers/patients are informed of the consent process, and they understand and provide consent for their care
Outcomes of clinical care are evaluated by healthcare providers, and where appropriate, are communicated to the consumer/patient
Processs for clinical handover, transfer of care and discharge, address the needs of the consumer/patient for ongoing care
The health record ensures comprehensive and accurate information is collaboratively gathered, recorded, and used in care delivery
Medications are managed to ensure safe and effective consumer/patient outcomes
The infection control system supports safe practive and ensures a safe environment for consumers/patients and healthcare workers
The organisation's continuous quality improvement system demonstrates its commitment to improving the outcomes of care and service delivery
The integrated organisation-wide risk management framework ensures that corporate and clinical risks are identified, minimised, and managed
Healthcare incidents are managed to ensure improvements to the systems of care
Processes for credentialling and defining the scope of clinical practice support safe, quality clinical care
Documented corporate and clinical policies and procedures assist the organisation to provide safe, quality health care
Safety management systems ensure safety and wellbeing of consumers/patients, staff, visitors and contractors
Emergency and disaster management supports safe practice and a safe environment
Standards for EQuIP 4 and 5 [7 8]

Hospital Peer Groups		AIHW Definition	Study Definition
Principal referral and specialist women's and children's	A1	Major city hospitals with > 20,000 acute case-mix adjusted separations and Regional hospitals with >16,000 acute case-mix adjusted separations per annum	Principal
	A2	Specialised acute women's and children's hospitals with >10,000 acute case-mix adjusted separations per annum	
Large hospitals	B1	Major city acute hospitals treating > 10,000 acute case-mix adjusted separations per annum	Large
	B2	Regional acute hospitals treating > 8,000 acute case-mix adjusted separations per annum, and remote hospitals with > 5,000 case-mix adjusted separations per annum	
Medium hospitals	C1	Medium acute hospitals in Regional and Major city areas treating between 5,000 and 10,000 acute case-mix adjusted separations per annum	Medium
	C2	Medium acute hospitals in Regional and Major city areas treating between 2,000 and 5,000 acute case-mix adjusted separations per annum, and acute hospitals treating <2000 acute case-mix adjusted separations per annum but > 2,000 separations per annum	
Small acute hospitals	D1	Small Regional acute hospitals treating < 2000 acute case-mix adjusted separations per annum	Small
	D3	Small remote hospitals (< 5,000 acute case-mix adjusted separations per annum), most are < 2,000 separations	

Australian Institute of Health and Welfare peer groups [30]

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Disentangling quality and safety indicator data: a longitudinal, comparative study of hand hygiene compliance and accreditation outcomes in 96 Australian hospitals

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Disentangling quality and safety indicator data: a longitudinal, comparative study of hand hygiene compliance and accreditation outcomes in 96 Australian hospitals

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Disentangling quality and safety indicator data: a longitudinal, comparative study of hand hygiene compliance and accreditation outcomes in 96 Australian hospitals

ABSTRACT

Objectives: The study aims are twofold. First, to investigate the suitability of hand hygiene as an indicator of accreditation outcomes and, second, to test the hypothesis that hospitals with better accreditation outcomes achieve higher hand hygiene compliance rates.

Design: A retrospective, longitudinal, multi-site comparative survey.

Setting: Acute public hospitals in New South Wales, Australia.

Participants: 96 acute hospitals with accreditation survey results from two surveys during 2009-2012 and submitted data for more than four hand hygiene audits between 2010 and 2013.

Outcomes: Our primary outcome comprised observational hand hygiene compliance data from eight audits during 2010 to 2013. The explanatory variables in our multilevel regression model included: accreditation outcomes and scores for the infection control standard; timing of the surveys; and hospital size and activity.

Results: Average hand hygiene compliance rates increased from 67.7% to 80.3% during the study period (2010 to 2013), with 46.7% of hospitals achieving target compliance rates of 70% in audit 1, versus 92.3% in audit 8. Average hand hygiene rates at small hospitals were 7.8 percentage points (pp) higher than those at the largest hospitals ($p<0.05$). The association between hand hygiene rates, accreditation outcomes and infection control scores is less clear.

Conclusions: Our results indicate that accreditation outcomes and hand hygiene audit data are measuring different parts of the quality and safety spectrum. Understanding what is being measured when selecting indicators to assess the impact of accreditation is critical as focusing on accreditation results would discount successful hand hygiene implementation by smaller hospitals. Conversely, relying on hand hygiene results would discount the infection control related research and leadership investment by larger hospitals. Our hypothesis appears confounded by an accreditation program that makes it more difficult for smaller hospitals to achieve high infection control scores.

Strengths and limitations of this study:

- The main strengths of this study relates to the use of a comprehensive dataset involving the number of acute hospitals (96) participating in the accreditation process and the length of follow up over eight hand hygiene audit points and two accreditation cycles.
- This study also addresses an important research question in terms of identifying and assessing the components of hospital accreditation and quantifying their inter-related benefits.
- The results have important implications for health policy makers internationally in terms of designing health service accreditation programs that accurately monitor a wide range of hospital size and type.
- The main limitation was the lack of a control group as all hospitals in the survey were accredited. This meant it was not possible to assess direct or reverse causal relationships or to prevent omitted variable bias.
- Other limitations include potential measurement error resulting from the use of self-reported hand hygiene data, however, the data collection methods adhered to World Health Organisation best practice guidelines.

INTRODUCTION

Hospital accreditation programs are designed to set clinical and organisational standards, assess compliance with those standards, and strengthen quality improvement efforts. Accreditation is widely practised with national level accreditation agencies active in at least 27 countries.[1] The problems associated with measuring accreditation benefits are well documented.[2 3] A clear understanding of the inputs, in terms of costs and resource use, and outcomes, in terms of improved patient safety and quality, is essential in ensuring that accreditation programs are achieving their aims of improving patient safety and health care quality.[4 5] Measuring the effects of accreditation on clinical practice and quality of care is important as we need to determine whether the cost burden of data collection and audit processes is outweighed by the expected improvements in quality and safety outcomes.[5]

In this study we analyse the relationship between hand hygiene compliance rates and accreditation outcomes in order to test the suitability of hand hygiene as an indicator of accreditation outcomes. Our hypothesis is that hospitals with better accreditation outcomes and infection control scores than others, reflect organisational processes that support a positive culture toward improving quality and safety,[6] and therefore they would achieve higher hand hygiene compliance rates.

Hand hygiene assessment is an integral component of the infection control standards used to evaluate whether Australian hospitals are compliant with accreditation standards.[7-9] Hand hygiene compliance rates have been validated as a potential process indicator for accreditation outcomes. Moreover, health care associated infections are recognised as a leading cause of increased morbidity and health care costs.[10] A United States (US) study estimated there were 1.7 million healthcare associated infections in 2002, comprising 4.5% of admissions, and resulting in nearly 99,000 deaths.[11] A recent meta-analysis estimated the cost of the five most common healthcare associated infections at US$9.8 billion per annum.[12] In Australia, the most recent figures available indicate that healthcare associated infections resulted in an extra two million bed days in 2005, with estimated additional costs of AU$21 million from post-discharge surgical infections.[13]

There is increasing evidence that improving hand hygiene reduces healthcare associated infections and the spread of anti-microbial resistance.[14-18] However, it is difficult to demonstrate a causal link between hand hygiene and healthcare associated infections due to a multiplicity of interventions and scarcity of randomised trials.[19-21] Nevertheless, the World Health Organisation (WHO) has identified good hand hygiene as a major factor in reducing healthcare associated infections based on epidemiological evidence.[18]

Hand hygiene policies in Australian hospitals follow international best practices. They are based on WHO recommendations with a multimodal approach incorporating: access to cleaning agents at the point of care; training and education; monitoring and feedback; reminders in the workplace; and development of an institutional safety climate.[22] Auditors trained by Hand Hygiene Australia monitor hand hygiene activity by direct observation of hospital staff and compare hand hygiene activity against the total number of potential "moments" for hand hygiene.[23] The national target for hand hygiene compliance is 70% and audit results are

publicly reported three times a year. The Australian Commission on Safety and Quality in Health Care (ACSQHC) has recommended that hand hygiene programs need to be repeatedly monitored using both process indicators (compliance rates) and outcome indicators (infection rates).[24]

METHODS

Study design, setting and context

The study comprised a retrospective, longitudinal, multi-site comparative survey of hand hygiene compliance rates and accreditation outcomes in acute public hospitals in New South Wales (NSW), Australia. With a population of 7.2 million, NSW comprises 30.5% of the 736 public hospitals and 32.0% of the population in Australia.[25] We employed retrospective data matching techniques over the study period, 2009 to 2013, to analyse the relationship between hand hygiene compliance data and accreditation outcomes.

Data matching and analysis

a) Hand hygiene compliance data

Hand hygiene policies include five "moments" when hand hygiene should be performed: before touching a patient; before a procedure; after a procedure or body fluid exposure risk; after touching a patient; and after touching a patient's surroundings.[23 26] Audits are carried out three times a year by health care workers who have been accredited by Hand Hygiene Australia. Surveys are conducted using a standardised observation assessment tool which measures hand hygiene activity versus the total number of observed possible "moments". Auditors are trained in selecting the wards or units for the audit, and the minimum number of required "moments" for each audit is determined by hospital size and activity. We obtained hand hygiene compliance rates data from late 2010 to early 2013 from the NSW Clinical Excellence Commission, the quality and safety body responsible for implementing the hand hygiene initiative in NSW and collecting hand hygiene audit data.[27]

b) Accreditation program and infection control standards

Data on accreditation outcomes from 2009 to 2013 were provided by the Australian Council on Healthcare Standards (ACHS). The ACHS Evaluation and Quality Improvement Program (EQuIP) was introduced in 1997 and comprises a four year cycle with external surveys in years two and four.[28] During these surveys, hospitals are assessed by an external team of surveyors against ACHS developed standards. The EQuIP program has undergone several revisions, none of which materially affected this study. Our study period included EQuIP4 which was introduced in 2007 and used for the surveys in 2009 and 2010, and EQuIP5 which was introduced in 2011. Accreditation standards were changed significantly following the introduction of national mandatory standards in 2013,[9] but the infection control criteria were the same for both versions of the EQuIP standards assessed during the study period (see supplementary file 1) . Surveyors scored facilities on a five point Likert scale for each standard or criterion assessed in the survey. Scores were designated as Outstanding Achievement (OA), Extensive Achievement (EA), Moderate Achievement (MA), Some Achievement, and (LA

Little Achievement. Hospitals needed to achieve OA, EA or MA, scores in each mandatory standard or criterion in order to meet accreditation requirements.

Infection control related criteria were part of a broader standard regarding the safe provision of care and services.[7 8] To meet accreditation requirements, hospitals needed to ensure that the infection control policy: met all regulatory requirements and industry guidelines; had executive support; incorporated ongoing education activities; and, included indicators to show both compliance with the policy and effective outcome measurements. Additional activities which counted towards achieving higher (EA and OA) scores included: benchmarking of performance indicators; use of feedback to inform and improve; contributing to infection control research; and, recognised leadership in infection control systems.[7 8] Accreditation is often granted to a cluster of facilities within a local health district and therefore reflects conditions at all the facilities within that survey group. These clusters are subject to boundary changes, as seen in the NSW 2011 health system re-organisation, which took place during the study period.[29] We therefore identified the different hospitals within each cluster in order to match the accreditation scores with the hand hygiene data from individual hospitals.

Study Variables

To analyse the matched data we used hand hygiene compliance rates as our outcome of interest, expressed as a continuous outcome variable. Data were available at eight different time points from the end of 2010 to early 2013 (see Figure 1). We characterised the accreditation scores as either full or partial accreditation. Partial accreditation was defined as either accreditation being granted for a reduced time, or resulting in a recommendation for action. No hospitals in the study were refused accreditation during the study period. We included infection control scores in the model by whether hospitals achieved a higher score in one, none (our reference case) or both surveys. To test for a possible timing effect we included a variable to identify whether surveys were either carried out in the 2009 and 2011 accreditation cycle (cycle=0), or the 2010 and 2012 cycle (cycle=1).

Figure 1: Timeline of accreditation surveys and hand hygiene audits

<<<Insert Figure 1 here>>>

Acute hospitals were grouped according to the Australian Institute of Health and Welfare activity matrix, based on annual numbers of acute episodes of care adjusted for patient complexity, and geographic location (see supplementary file 2).[30] We used these groups to create a categorical variable with principal referral and specialist hospitals as the reference case (principal=0), with large hospitals scored as 1, medium hospitals as 2, and small hospitals as 3.

Analysis

The nature of the data, with irregular audit dates and clustering within hospitals, indicated that a multilevel model would be the most appropriate and would allow adjustment for hospital level variance.[31 32] After

matching the accreditation and hand hygiene data our sample comprised 96 hospitals each with two accreditation surveys. For some hospitals we were not able to match the accreditation outcomes because of changes in the accreditation clusters. Missing data were higher during the first two audits whilst the program was progressively implemented. We did not impute values for missing data as the pattern of missing results indicated these were not missing at random. For example, data from some of the smaller hospitals were not included as they did not meet the minimum publication requirements during the study period (50 moments of hand hygiene), which we determined was likely to be related to hospital size.

We tested our main model using hand hygiene data from audits 1 through 8 as the outcome variable, and accreditation outcomes, infection control scores, accreditation cycle, and peer groups as our explanatory variables. We tested the model fit versus ordinary least squares by calculating the intra-class correlation to assess the within-hospital effect. We also tested whether to use a random co-efficient or random intercept model. Analysis was conducted using Stata statistical software (version 12SE),[33] applying a two-sided significance level of 5%. We also fitted a restrictive model using data from audits 3 to 8 to determine whether the different peer group mix in the first two surveys was affecting the results.

RESULTS

Hand hygiene and accreditation data analysis

We assessed hand hygiene data on 118 hospitals from eight different audit points during 2010 to 2013. Overall, hand hygiene rates showed an improvement during the study period, with 28 out of 60 hospitals (46.7%) achieving 70% compliance rates in the first audit in 2010 versus 108 out of 117 hospitals (92.3%) in the final audit, in early 2013. Average hand hygiene compliance rates increased from 67.7% in audit 1, to 80.3% in audit 8, and remained above the 70% national target rate from audit 2 onwards. The average audit compliance rates by audit and hospital peer group are shown in Figure 2.

Figure 2: Mean hand hygiene compliance rates by audit and hospital peer group, 2010-2013<<<Insert Figure 2 here>>>

During the study period, 2009-2013, 61 hospitals underwent an accreditation survey in cycle 0, and 44 in cycle 1. The accreditation outcomes showed that 59% of organisations were granted full accreditation in the first survey in each cycle (during 2009-10) versus 77% in the second survey (2011-12). The number of hospitals receiving higher infection control scores also increased over time, with 13% receiving a high score (EA) in the first survey of each accreditation cycle versus 18% in the second surveys during 2011 and 2012. No hospitals received an OA score for infection control during the study period. We further examined whether there was a difference between meeting, or not meeting, the target compliance rates by comparing the partial data from audit 1 when the program was being rolled out, and the final audit in our study, audit 8 (see Figure 3). Large hospitals showed the biggest increase, with 30% meeting the target in audit 1, rising to 100% by audit 8.

Figure 3: Percentage of hospitals meeting hand hygiene targets by audit and hospital peer group

<<<Insert Figure 3 here>>>

We also noted that principal and large hospitals comprised 51.7% of hospitals in audit 1 versus 39.3% in audit 8, suggesting they were early adopters in the program. We tested whether this would influence the results using the restricted model (comprising data from audits 3 to 8). The infection control outcomes also improved over time with 3% of organisations receiving high scores in both surveys in cycle 0 versus 17% in cycle 1, however, we note the absolute small numbers involved (n=8). A size effect was noted with 6.5% (n=2) of smaller hospitals receiving a higher infection control score in one or both surveys versus 35.7% (n=10) of principal and 46.2% (n=6) of large hospitals (see Table 1).

Table 1: Summary characteristics of accreditation and infection control scores

Table 1: Summary of accreditation and infection control scores, breakdown by peer group and timing of surveys				
	Hospital Peer Group			
	Principal	***Large***	***Medium***	***Small***
	N=28	*N=13*	*N=24*	*N=31*
Full accreditation on both surveys	*57.1%*	*61.5%*	*33.3%*	*3.2%*
Full accreditation in cycle 0 (surveys in 2009 and 2011)	*58.8%*	*62.5%*	*21.4%*	*0.0%*
Full accreditation in cycle 1 (surveys in 2010 and 2012)	*54.5%*	*60.0%*	*50.0%*	*10.0%*
High IC scores in one survey	*25.0%*	*30.8%*	*8.3%*	*3.2%*
High IC scores in both surveys	*10.7%*	*15.4%*	*8.3%*	*3.2%*
High IC scores in cycle 0 (surveys in 2009 and 2011)	*29.4%*	*25.0%*	*7.1%*	*0.0%*
High IC scores in second survey of each cycle (2011 or 2012)	*45.5%*	*80.0%*	*30.0%*	*20.0%*
IC=infection control				
Peer group as defined by the Australian Institute of Health and Welfare [30]				

Testing the model

The intra-class correlation co-efficient indicated that 38% of the variance was due to within-hospital effects, indicating sufficient variance for using a random intercept model.[32] We ran a likelihood ratio test using a null model (without the random intercept). This gave a chi-squared test result of 190 (p=0.001), which confirmed our approach versus using ordinary least squares. We also tested the model using infection control scores as a random co-efficient, but the results (chi squared= 0.81, p=0.67) indicated that the random intercept model was more appropriate. We noted a ceiling effect in our data with 100% of large hospitals and 92% of all hospitals meeting the target compliance rates by audit 8, with less incentive to reach higher levels (see Figure 3). Although hospitals were incrementally enrolled in the hand hygiene program, the lack of hand hygiene compliance data in the un-enrolled hospitals meant we were not able to use a stepped wedge design to

provide controls, or evaluate a before and after effect and our results are also subject to omitted variable bias. A fixed effects panel data model might be a more traditional approach to reduce sample variation, but we determined that the random intercept model would be more appropriate due to the policy requirement for all public hospitals to submit hand hygiene data, and the presence of time-invariant variables.[34]

Multilevel model

After matching the hand hygiene data with hospitals that underwent two accreditation surveys, our main model included data from 661 hand hygiene audits from 96 hospitals, an average of 6.9 audits per hospital. The results (Table 2) show that achieving full accreditation for both surveys was not significantly associated with higher hand hygiene rates versus those hospitals achieving full accreditation in only one survey. The association between hand hygiene rates and infection control scores is less clear. Hospitals achieving high infection control scores (EA) in one survey (n=14) showed 4.2 percentage point (pp) lower hand hygiene rates than hospitals who just met the accreditation standard (MA score), and this result was significant (p=0.033). Hospitals achieving high infection control scores in both surveys (n=8) showed higher rates (2.1 pp) but this was not significant (p=0.40). Small and medium sized hospitals experienced significantly higher hand hygiene compliance rates (7.8 pp for small hospitals and 3.5 pp for medium hospitals) compared to principal hospitals. The restricted model, using data from audit 3 onwards, also showed a negative relationship between higher infection control scores and hand hygiene audit results. However, the effect was smaller (2.9 pp) and the results were no longer significant (p=0.14). The size effect in the restricted model was consistent with the main model, with small and medium hospitals showing significantly higher hand hygiene rates than principal referral hospitals. These results do not lend support to our study hypothesis that high infection control scores are associated with higher hand hygiene rates.

Table 2: Multilevel model to show effect of accreditation outcomes on hand hygiene audit rates

Table 2 - Multilevel model showing association of accreditation outcomes on hand hygiene compliance rates						
Variables	**Main Model (audits 1-8)**			**Restricted Model (audits 3-8)**		
	Mean values	**Standard error**	***p values***	**Mean values**	**Standard error**	***p values***
Full accreditation in both surveys	0.004	0.016	*0.809*	0.0077	0.016	*0.620*
High infection control scores in one survey	**-0.042**	**0.020**	***0.033***	-0.029	0.020	*0.135*
High infection control scores in two surveys	0.021	0.025	*0.404*	0.033	0.024	*0.172*
Later cycle (surveys in 2010/2012	0.024	0.014	*0.073*	0.0205	0.013	*0.123*

Hospital peer group* (principal referral=0)						
Large	0.024	0.020	*0.247*	0.0233	0.023	*0.244*
Medium	**0.035**	**0.017**	***0.046***	**0.0343**	**0.034**	***0.045***
Small	**0.078**	**0.018**	***<0.001***	**0.0807**	**0.081**	***<0.001***
Number of observations	661			563		
Number of hospitals	96			96		
Average compliance rates	0.741			0.744		
Log likelihood	662			634		
***Peer group as defined by the Australian Institute of Health and Welfare [30]**						

DISCUSSION

Our analysis of 118 NSW hospitals showed that hand hygiene rates increased from 67.7% in audit 1 in late 2010 to 80.3% by audit 8 in early 2013. This compares to rates of 62.2% from a sample of NSW hospitals in February 2007 which were observed following the introduction of the Clean Hand Saves Lives campaign during 2006-2007,[15] and continues the improvement shown nationally in Australia with average hand hygiene rates estimated at 68.3% in 2011.[35] It is challenging to compare these results internationally. A US study estimated average hand hygiene rates of 56.6% in 40 hospitals using data collected for one year before and after the introduction of national hand hygiene guidelines in 2002.[36] However, it must be noted that this program was different to that followed by Hand Hygiene Australia and so the results would not be directly comparable.

Smaller hospitals in our study had higher hand hygiene compliance rates but the relationship between accreditation outcomes and hand hygiene data was less clear. This hospital size effect on hand hygiene compliance has been confirmed by other research investigating the link between hand hygiene rates and health care associated *Staphylococcus aureas* bacteraemia.[37 38] We consider the results from small and medium hospitals in our study can be explained by looking at the organisational infrastructure necessary to meet the hand hygiene and accreditation requirements. Both are dependent on a widespread organisational response in terms of education, monitoring, infrastructure and management involvement.[6] Achieving higher infection control scores requires additional benchmarking, feedback and research capabilities.[7 8] The organisational size effect suggests that small and medium sized hospitals can effectively embrace multimodal quality improvement strategies as seen by the higher compliance rates. However, the requirements for achieving high infection control scores within an accreditation survey may be measuring different aspects of quality that are not reflected in the hand hygiene compliance rates. The results indicate that smaller hospitals are able to focus on the practical implementation of a national hand hygiene policy. Having the resources to meet the requirements for higher infection control scores, in terms of conducting research or being recognised leaders in infection control, may not be practical for these smaller organisations. Although some smaller hospitals will be accredited as part of a larger cluster of hospitals, which includes principal and large

hospitals, this is not always the case. Our hypothesis that higher accreditation scores would be reflected in hand hygiene rates appears to be confounded by an accreditation program that makes it more difficult for smaller hospitals to achieve high infection control scores.

This study uses one indicator for evaluating accreditation whereas multiple measures may be more effective.[39] For example, outcome indicators are widely used in the US hospital system,[40-42] and include hospital acquired SAB rates and surgical site infection rates. These incorporate a broader mix of the anti-microbial, hand hygiene, and specialist cleaning practice modules of the infection control standard. Using outcome indicators would complete Donabedian's triad of performance measures to include structural (accreditation results), process (hand hygiene compliance rates) and outcome (*Staphylococcus aureas* infection rates) measures.[43 44]

Measurement issues in our study include a possible observer effect since the hospital staff might be aware the audit was taking place. However, although this may increase the compliance rate, the results would still be valid as the standards include requirements for staff education and installation of appropriate infrastructure. Increased rates during an audit imply that the correct infrastructure is in place, in terms of availability of functioning hand washing stations, and that staff are aware of the hand hygiene policies. In addition, any observer effect is likely to be mitigated as all the hospitals used the same methods for collecting data and thus are equally subjected to this bias. Other methods to measure hand hygiene activity include measuring consumption rates of hand hygiene products, such as alcohol rubs, [45] and electronic systems for monitoring compliance,[46] but WHO guidelines suggest direct observation is still the gold standard.[40] We also note that although accreditation surveys are assessed on a five point scale, only two scores (MA and EA) were used in the infection control standard during the four surveys in our study. The lack of granularity in the accreditation scores makes it difficult to differentiate accreditation performance. Inter-surveyor reliability is recognised as a limitation of audit systems that are based on subjective assessments.[47] To reduce idiosyncratic scoring, ACHS surveyors need to provide evidence to ACHS for their scoring methods, and in the decision to award higher scores, but some variation between surveyors may remain.

Limitations of the model include reverse causality in that higher compliance rates could lead to higher infection control scores at the next survey where hand hygiene audit rates are used as evidence of implementation during an accreditation survey. This would likely be the case going forward as ACSQHC includes hand hygiene audit results as part of the evidence of implementation of standard 3 under the new national standards.[9 48]

Implications

Different indicators will give different perspectives on how an organisation approaches and implements relevant policy. However, the costs of measurement in health care should be balanced against using a range of indicators to capture a broader mix of infection control policies, and across the different standards assessed during accreditation surveys. Indicator selection should include both process indicators, recognised as a method of measuring organisational changes,[49] and outcome indicators. Public reporting of indicator data

further increases the requirement to accurately identity and measure the parts of the patient safety and quality spectrum that are being addressed. In this study, a focus on the accreditation results would underestimate the successful implementation of the hand hygiene policy by smaller hospitals. Conversely, just using hand hygiene results would underestimate the research and leadership investment in infection control by larger hospitals. Disentangling these two outcomes within the same safety and quality initiative is a pre-requisite to understanding how they can be effectively assessed and monitored. For example, consideration could be given to changing criteria for awarding higher scores for infection control such that achieving higher scores was evidence based and could be feasible for all hospitals. Although we focus on Australian hospitals in our study, international accreditation programs will also need to ensure that indicators accurately capture outcomes and reflect performance across a range of hospital size and type.

CONCLUSION

Identifying indicators to measure the effectiveness of accreditation is challenging due to the complexity of implementing a wide range of accreditation related processes across multiple hospital activities. Our results do not support our study hypothesis that high infection control scores are associated with higher hand hygiene rates. Instead, this study suggests that accreditation outcomes and hand hygiene audit data measure different parts of the quality and safety spectrum. Developing a framework to identify suitable indicators is an important contribution to understanding the impact of hospital accreditation internationally. Policy makers need to appreciate the assumptions behind the choice of indicator and understand exactly what is being measured to ensure that key performance indicators encourage quality improvements in the delivery of hospital services.

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Ethics: Human Research Ethics Committee approval for this study was granted by UNSW (approval number HREC 10274).

Contributorship Statement:

Contribution: JB, DG, JW and VM contributed to the concept and design of the study. VM, JB and DG contributed to the acquisition of the data, EG contributed to the model specification and model analysis, KF and AH contributed to the data collection and analysis.

Drafting: VM wrote the first draft of the manuscript, JB and DG provided a critical revision of the first draft, EG contributed to drafting the results sections, KF and AH contributed to drafting the methods section, JW contributed to drafting the discussion section.

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Figure Legends

Figure 1: Timeline of accreditation surveys and hand hygiene audits

Figure 2: Mean hand hygiene compliance rates by audit and hospital peer group, 2010-2013

Figure 3: Percentage of hospitals meeting hand hygiene targets by audit and hospital peer group

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Disentangling quality and safety indicator data: a longitudinal, comparative study of hand hygiene compliance and accreditation outcomes in 96 Australian hospitals

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Disentangling quality and safety indicator data: a longitudinal, comparative study of hand hygiene compliance and accreditation outcomes in 96 Australian hospitals

ABSTRACT

Objectives: The study aims are twofold. First, to investigate the suitability of hand hygiene as an indicator of accreditation outcomes and, second, to test the hypothesis that hospitals with better accreditation outcomes achieve higher hand hygiene compliance rates.

Design: A retrospective, longitudinal, multi-site comparative survey.

Setting: Acute public hospitals in New South Wales, Australia.

Participants: 96 acute hospitals with accreditation survey results from two surveys during 2009-2012 and submitted data for more than four hand hygiene audits between 2010 and 2013.

Outcomes: Our primary outcome comprised observational hand hygiene compliance data from eight audits during 2010 to 2013. The explanatory variables in our multilevel regression model included: accreditation outcomes and scores for the infection control standard; timing of the surveys; and hospital size and activity.

Results: Average hand hygiene compliance rates increased from 67.7% to 80.3% during the study period (2010 to 2013), with 46.7% of hospitals achieving target compliance rates of 70% in audit 1, versus 92.3% in audit 8. Average hand hygiene rates at small hospitals were 7.8 percentage points (pp) higher than those at the largest hospitals ($p<0.05$). The association between hand hygiene rates, accreditation outcomes and infection control scores is less clear.

Conclusions: Our results indicate that accreditation outcomes and hand hygiene audit data are measuring different parts of the quality and safety spectrum. Understanding what is being measured when selecting indicators to assess the impact of accreditation is critical as focusing on accreditation results would discount successful hand hygiene implementation by smaller hospitals. Conversely, relying on hand hygiene results would discount the infection control related research and leadership investment by larger hospitals. Our hypothesis appears confounded by an accreditation program that makes it more difficult for smaller hospitals to achieve high infection control scores.

Strengths and limitations of this study:

- The main strengths of this study relates to the use of a comprehensive dataset involving the number of acute hospitals (96) participating in the accreditation process and the length of follow up over eight hand hygiene audit points and two accreditation cycles.
- This study also addresses an important research question in terms of identifying and assessing the components of hospital accreditation and quantifying their inter-related benefits.
- The results have important implications for health policy makers internationally in terms of designing health service accreditation programs that accurately monitor a wide range of hospital size and type~~that can be accurately measured and monitored~~.
- The main limitation was the lack of a control group as all hospitals in the survey were accredited. This meant it was not possible to assess direct or reverse causal relationships or to prevent omitted variable bias.
- Other limitations include potential measurement error resulting from the use of self-reported hand hygiene data, however, the data collection methods adhered to World Health Organisation best practice guidelines.

INTRODUCTION

Hospital accreditation programs are designed to set clinical and organisational standards, assess compliance with those standards, and strengthen quality improvement efforts. Accreditation is widely practised with national level accreditation agencies active in at least 27 countries.[1] The problems associated with measuring accreditation benefits are well documented.[2 3] A clear understanding of the inputs, in terms of costs and resource use, and outcomes, in terms of improved patient safety and quality, is essential in ensuring that accreditation programs are achieving their aims of improving patient safety and health care quality.[4 5] Measuring the effects of accreditation on clinical practice and quality of care is important as we need to determine whether the cost burden of data collection and audit processes is outweighed by the expected improvements in quality and safety outcomes.[5]

In this study we analyse the relationship between hand hygiene compliance rates and accreditation outcomes in order to test the suitability of hand hygiene as an indicator of accreditation outcomes. Our hypothesis is that hospitals with better accreditation outcomes and infection control scores than others, reflect organisational processes that support a positive culture toward improving quality and safety,[6] and therefore they would achieve higher hand hygiene compliance rates.

Hand hygiene assessment is an integral component of the infection control standards used to evaluate whether Australian hospitals are compliant with accreditation standards.[7-9] Hand hygiene compliance rates have been validated as a potential process indicator for accreditation outcomes. Moreover, health care associated infections are recognised as a leading cause of increased morbidity and health care costs.[10] A United States (US) study estimated there were 1.7 million healthcare associated infections in 2002, comprising 4.5% of admissions, and resulting in nearly 99,000 deaths.[11] A recent meta-analysis estimated the cost of the five most common healthcare associated infections at US$9.8 billion per annum.[12] In Australia, the most recent figures available indicate that healthcare associated infections resulted in an extra two million bed days in 2005, with estimated additional costs of AU$21 million from post-discharge surgical infections.[13]

There is increasing evidence that improving hand hygiene reduces healthcare associated infections and the spread of anti-microbial resistance.[14-18] However, it is difficult to demonstrate a causal link between hand hygiene and healthcare associated infections due to a multiplicity of interventions and scarcity of randomised trials.[19-21] Nevertheless, the World Health Organisation (WHO) has identified good hand hygiene as a major factor in reducing healthcare associated infections based on epidemiological evidence.[18]

Hand hygiene policies in Australian hospitals follow international best practices. They are based on WHO recommendations with a multimodal approach incorporating: access to cleaning agents at the point of care; training and education; monitoring and feedback; reminders in the workplace; and development of an institutional safety climate.[22] Auditors trained by Hand Hygiene Australia monitor hand hygiene activity by direct observation of hospital staff and compare hand hygiene activity against the total number of potential "moments" for hand hygiene.[23] The national target for hand hygiene compliance is 70% and audit results are

publicly reported three times a year. The Australian Commission on Safety and Quality in Health Care (ACSQHC) has recommended that hand hygiene programs need to be repeatedly monitored using both process indicators (compliance rates) and outcome indicators (infection rates).[24]

METHODS

Study design, setting and context

The study comprised a retrospective, longitudinal, multi-site comparative survey of hand hygiene compliance rates and accreditation outcomes in acute public hospitals in New South Wales (NSW), Australia. With a population of 7.2 million, NSW comprises 30.5% of the 736 public hospitals and 32.0% of the population in Australia.[25] We employed retrospective data matching techniques over the study period, 2009 to 2013, to analyse the relationship between hand hygiene compliance data and accreditation outcomes.

Data matching and analysis

a) Hand hygiene compliance data

Hand hygiene policies include five "moments" when hand hygiene should be performed: before touching a patient; before a procedure; after a procedure or body fluid exposure risk; after touching a patient; and after touching a patient's surroundings.[23 26] Audits are carried out three times a year by health care workers who have been accredited by Hand Hygiene Australia. Surveys are conducted using a standardised observation assessment tool which measures hand hygiene activity versus the total number of observed possible "moments". Auditors are trained in selecting the wards or units for the audit, and the minimum number of required "moments" for each audit is determined by hospital size and activity. We obtained hand hygiene compliance rates data from late 2010 to early 2013 from the NSW Clinical Excellence Commission, the quality and safety body responsible for implementing the hand hygiene initiative in NSW and collecting hand hygiene audit data.[27]

b) Accreditation program and infection control standards

Data on accreditation outcomes from 2009 to 2013 were provided by the Australian Council on Healthcare Standards (ACHS). The ACHS Evaluation and Quality Improvement Program (EQuIP) was introduced in 1997 and comprises a four year cycle with external surveys in years two and four.[28] During these surveys, hospitals are assessed by an external team of surveyors against ACHS developed standards. The EQuIP program has undergone several revisions, none of which materially affected this study. Our study period included EQuIP4 which was introduced in 2007 and used for the surveys in 2009 and 2010, and EQuIP5 which was introduced in 2011. Accreditation standards were changed significantly following the introduction of national mandatory standards in 2013,[9] but the infection control criteria were the same for both versions of the EQuIP standards assessed during the study period (see supplementary file 1) . Surveyors scored facilities on a five point Likert scale for each standard or criterion assessed in the survey. Scores were designated as Outstanding Achievement (OA), Extensive Achievement (EA), Moderate Achievement (MA), Some Achievement, and (LA

Little Achievement. Hospitals needed to achieve OA, EA or MA, scores in each mandatory standard or criterion in order to meet accreditation requirements.

Infection control related criteria were part of a broader standard regarding the safe provision of care and services.[7 8] To meet accreditation requirements, hospitals needed to ensure that the infection control policy: met all regulatory requirements and industry guidelines; had executive support; incorporated ongoing education activities; and, included indicators to show both compliance with the policy and effective outcome measurements. Additional activities which counted towards achieving higher (EA and OA) scores included: benchmarking of performance indicators; use of feedback to inform and improve; contributing to infection control research; and, recognised leadership in infection control systems.[7 8] Accreditation is often granted to a cluster of facilities within a local health district and therefore reflects conditions at all the facilities within that survey group. These clusters are subject to boundary changes, as seen in the NSW 2011 health system re-organisation, which took place during the study period.[29] We therefore identified the different hospitals within each cluster in order to match the accreditation scores with the hand hygiene data from individual hospitals.

Study Variables

To analyse the matched data we used hand hygiene compliance rates as our outcome of interest, expressed as a continuous outcome variable. Data were available at eight different time points from the end of 2010 to early 2013 (see Figure 1). We characterised the accreditation scores as either full or partial accreditation. Partial accreditation was defined as either accreditation being granted for a reduced time, or resulting in a recommendation for action. No hospitals in the study were refused accreditation during the study period. We included infection control scores in the model by whether hospitals achieved a higher score in one, none (our reference case) or both surveys. To test for a possible timing effect we included a variable to identify whether surveys were either carried out in the 2009 and 2011 accreditation cycle (cycle=0), or the 2010 and 2012 cycle (cycle=1).

Figure 1: Timeline of accreditation surveys and hand hygiene audits

<<<Insert Figure 1 here>>>

Acute hospitals were grouped according to the Australian Institute of Health and Welfare activity matrix, based on annual numbers of acute episodes of care adjusted for patient complexity, and geographic location (see supplementary file 2).[30] We used these groups to create a categorical variable with principal referral and specialist hospitals as the reference case (principal=0), with large hospitals scored as 1, medium hospitals as 2, and small hospitals as 3.

Analysis

The nature of the data, with irregular audit dates and clustering within hospitals, indicated that a multilevel model would be the most appropriate and would allow adjustment for hospital level variance.[31 32] After

matching the accreditation and hand hygiene data our sample comprised 96 hospitals each with two accreditation surveys. For some hospitals we were not able to match the accreditation outcomes because of changes in the accreditation clusters. Missing data were higher during the first two audits whilst the program was progressively implemented. We did not impute values for missing data as the pattern of missing results indicated these were not missing at random. For example, data from some of the smaller hospitals were not included as they did not meet the minimum publication requirements during the study period (50 moments of hand hygiene), which we determined was likely to be related to hospital size.

We tested our main model using hand hygiene data from audits 1 through 8 as the outcome variable, and accreditation outcomes, infection control scores, accreditation cycle, and peer groups as our explanatory variables. We tested the model fit versus ordinary least squares by calculating the intra-class correlation to assess the within-hospital effect. We also tested whether to use a random co-efficient or random intercept model. Analysis was conducted using Stata statistical software (version 12SE),[33] applying a two-sided significance level of 5%. We also fitted a restrictive model using data from audits 3 to 8 to determine whether the different peer group mix in the first two surveys was affecting the results.

RESULTS

Hand hygiene and accreditation data analysis

We assessed hand hygiene data on 118 hospitals from eight different audit points during 2010 to 2013. Overall, hand hygiene rates showed an improvement during the study period, with 28 out of 60 hospitals (46.7%) achieving 70% compliance rates in the first audit in 2010 versus 108 out of 117 hospitals (92.3%) in the final audit, in early 2013. Average hand hygiene compliance rates increased from 67.7% in audit 1, to 80.3% in audit 8, and remained above the 70% national target rate from audit 2 onwards. The average audit compliance rates by audit and hospital peer group are shown in Figure 2**.**

Figure 2: Mean hand hygiene compliance rates by audit and hospital peer group, 2010-2013<<<Insert Figure 2 here>>>

During the study period, 2009-2013, 61 hospitals underwent an accreditation survey in cycle 0, and 44 in cycle 1. The accreditation outcomes showed that 59% of organisations were granted full accreditation in the first survey in each cycle (during 2009-10) versus 77% in the second survey (2011-12). The number of hospitals receiving higher infection control scores also increased over time, with 13% receiving a high~~er~~ score (EA) in the first survey of each accreditation cycle versus 18% in the second surveys during 2011 and 2012. No hospitals received an OA score for infection control during the study period. We further examined whether there was a difference between meeting, or not meeting, the target compliance rates by comparing the partial data from audit 1 when the program was being rolled out, and the final audit in our study, audit 8 (see Figure 3). Large hospitals showed the biggest increase, with 30% meeting the target in audit 1, rising to 100% by audit 8.

Figure 3: Percentage of hospitals meeting hand hygiene targets by audit and hospital peer group

<<<Insert Figure 3 here>>>

We also noted that principal and large hospitals comprised 51.7% of hospitals in audit 1 versus 39.3% in audit 8, suggesting they were early adopters in the program. We tested whether this would influence the results using the restricted model (comprising data from audits 3 to 8). The infection control outcomes also improved over time with 3% of organisations receiving high scores in both surveys in cycle 0 versus 17% in cycle 1, however, we note the absolute small numbers involved (n=8). A size effect was noted with 6.5% (n=2) of smaller hospitals receiving a higher infection control score in ~~at least one~~ one or both surveys versus 35.7% (n=10) of principal and 46.2% (n=6) of large hospitals (see Table 1).

Table 1: Summary characteristics of accreditation and infection control scores

Table 1: Summary of accreditation and infection control scores, breakdown by peer group and timing of surveys				
	Hospital Peer Group			
	Principal	***Large***	***Medium***	***Small***
	N=28	*N=13*	*N=24*	*N=31*
Full accreditation on both surveys	*57.1%*	*61.5%*	*33.3%*	*3.2%*
Full accreditation in cycle 0 (surveys in 2009 and 2011)	*58.8%*	*62.5%*	*21.4%*	*0.0%*
Full accreditation in cycle 1 (surveys in 2010 and 2012)	*54.5%*	*60.0%*	*50.0%*	*10.0%*
High~~er~~ IC scores in one survey	*25.0%*	*30.8%*	*8.3%*	*3.2%*
High~~er~~ IC scores in both surveys	*10.7%*	*15.4%*	*8.3%*	*3.2%*
~~Higher IC scores in either survey~~	***~~35.7%~~***	***~~46.2%~~***	***~~16.7%~~***	***~~6.5%~~***
High~~er~~ IC scores in cycle 0 (surveys in 2009 and 2011)	*29.4%*	*25.0%*	*7.1%*	*0.0%*
High~~er~~ IC scores in second survey of each cycle (2011 or 2012)	*45.5%*	*80.0%*	*30.0%*	*20.0%*
IC=infection control				
Peer group as defined by the Australian Institute of Health and Welfare [30]				

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Testing the model

The intra-class correlation co-efficient indicated that 38% of the variance was due to within-hospital effects, indicating sufficient variance for using a random intercept model.[32] We ran a likelihood ratio test using a null model (without the random intercept). This gave a chi-squared test result of 190 (p=0.001), which confirmed our approach versus using ordinary least squares. We also tested the model using infection control scores as a random co-efficient, but the results (chi squared= 0.81, p=0.67) indicated that the random intercept model was more appropriate. We noted a ceiling effect in our data with 100% of large hospitals and 92% of all hospitals meeting the target compliance rates by audit 8, with less incentive to reach higher levels (see Figure 3). Although hospitals were incrementally enrolled in the hand hygiene program, the lack of hand hygiene compliance data in the un-enrolled hospitals meant we were not able to use a stepped wedge design to

provide controls, or evaluate a before and after effect and our results are also subject to omitted variable bias. A fixed effects panel data model might be a more traditional approach to reduce sample variation, but we determined that the random intercept model would be more appropriate due to the policy requirement for all public hospitals to submit hand hygiene data, and the presence of time-invariant variables.[34]

Multilevel model

After matching the hand hygiene data with hospitals that underwent two accreditation surveys, our main model included data from 661 hand hygiene audits from 96 hospitals, an average of 6.9 audits per hospital. The results (Table 2) show that achieving full accreditation for both surveys was not significantly associated with higher hand hygiene rates versus those hospitals achieving full accreditation in only one survey. The association between hand hygiene rates and infection control scores is less clear. Hospitals achieving high~~er~~ infection control scores (EA) in one survey (n=14) showed 4.2 percentage point (pp) lower hand hygiene rates than hospitals who just met the accreditation standard (MA score), and this result was significant (p=0.033). Hospitals achieving high~~er~~ infection control scores in both surveys (n=8) showed higher rates (2.1 pp) but this was not significant (p=0.40). Small and medium sized hospitals experienced significantly higher hand hygiene compliance rates (7.8 pp for small hospitals and 3.5 pp for medium hospitals) compared to principal hospitals. The restricted model, using data from audit 3 onwards, also showed a negative relationship between higher infection control scores and hand hygiene audit results. However, the effect was smaller (2.9 pp) and the results were no longer significant (p=0.14). The size effect in the restricted model was consistent with the main model, with small and medium hospitals showing significantly higher hand hygiene rates than principal referral hospitals. These results do not lend support to our study hypothesis that high~~er~~ infection control scores are associated with higher hand hygiene rates.

Table 2: Multilevel model to show effect of accreditation outcomes on hand hygiene audit rates

Table 2 - Multilevel model showing association of accreditation outcomes on hand hygiene compliance rates						
Variables	**Main Model (audits 1-8)**			**Restricted Model (audits 3-8)**		
	Mean values	**Standard error**	***p values***	**Mean values**	**Standard error**	***p values***
Full accreditation in both surveys	0.004	0.016	*0.809*	0.0077	0.016	*0.620*
High~~er~~ infection control scores in one survey	**-0.042**	**0.020**	***0.033***	-0.029	0.020	*0.135*
High~~er~~ infection control scores in two surveys	0.021	0.025	*0.404*	0.033	0.024	*0.172*
Later cycle (surveys in 2010/2012	0.024	0.014	*0.073*	0.0205	0.013	*0.123*

Hospital peer group* (principal referral=0)						
Large	0.024	0.020	*0.247*	0.0233	0.023	*0.244*
Medium	**0.035**	**0.017**	***0.046***	**0.0343**	**0.034**	***0.045***
Small	**0.078**	**0.018**	***<0.001***	**0.0807**	**0.081**	***<0.001***
Number of observations	661			563		
Number of hospitals	96			96		
Average compliance rates	0.741			0.744		
Log likelihood	662			634		
Peer group as defined by the Australian Institute of Health and Welfare [30]						

DISCUSSION

Our analysis of 118 NSW hospitals showed that hand hygiene rates increased from 67.7% in audit 1 in late 2010 to 80.3% by audit 8 in early 2013. This compares to rates of 62.2% from a sample of NSW hospitals in February 2007 which were observed following the introduction of the Clean Hand Saves Lives campaign during 2006-2007,[15] and continues the improvement shown nationally in Australia with average hand hygiene rates estimated at 68.3% in 2011.[35] It is challenging to compare these results internationally. A US study estimated average hand hygiene rates of 56.6% in 40 hospitals using data collected for one year before and after the introduction of national hand hygiene guidelines in 2002.[36] However, it must be noted that this program was different to that followed by Hand Hygiene Australia and so the results would not be directly comparable.

Smaller hospitals in our study had higher hand hygiene compliance rates but the relationship between accreditation outcomes and hand hygiene data was less clear. This hospital size effect on hand hygiene compliance has been confirmed by other research investigating the link between hand hygiene rates and health care associated *Staphylococcus aureas* bacteraemia.[37 38] We consider the results from small and medium hospitals in our study can be explained by looking at the organisational infrastructure necessary to meet the hand hygiene and accreditation requirements. Both are dependent on a widespread organisational response in terms of education, monitoring, infrastructure and management involvement.[6] Achieving higher infection control scores requires additional benchmarking, feedback and research capabilities.[7 8] The organisational size effect suggests that small and medium sized hospitals can effectively embrace multimodal quality improvement strategies as seen by the higher compliance rates. However, the requirements for achieving high infection control scores within an accreditation survey may be measuring different aspects of quality that are not reflected in the hand hygiene compliance rates. The results indicate that smaller hospitals are able to focus on the practical implementation of a national hand hygiene policy. Having the resources to meet the requirements for higher infection control scores, in terms of conducting research or being recognised leaders in infection control, may not be practical for these smaller organisations. Although some smaller hospitals will be accredited as part of a larger cluster of hospitals, which includes principal and large

hospitals, this is not always the case. Our hypothesis that higher accreditation scores would be reflected in hand hygiene rates appears to be confounded by an accreditation program that makes it more difficult for smaller hospitals to achieve high infection control scores.

This study uses one indicator for evaluating accreditation whereas multiple measures may be more effective.[39] For example, outcome indicators are widely used in the US hospital system,[40-42] and include hospital acquired SAB rates and surgical site infection rates. These incorporate a broader mix of the anti-microbial, hand hygiene, and specialist cleaning practice modules of the infection control standard. Using outcome indicators would complete Donabedian's triad of performance measures to include structural (accreditation results), process (hand hygiene compliance rates) and outcome (*Staphylococcus aureas* infection rates) measures.[43 44]

Measurement issues in our study include a possible observer effect since the hospital staff might be aware the audit was taking place. However, although this may increase the compliance rate, the results would still be valid as the standards include requirements for staff education and installation of appropriate infrastructure. Increased rates during an audit imply that the correct infrastructure is in place, in terms of availability of functioning hand washing stations, and that staff are aware of the hand hygiene policies. In addition, any observer effect is likely to be mitigated as all the hospitals used the same methods for collecting data and thus are equally subjected to this bias. Other methods to measure hand hygiene activity include measuring consumption rates of hand hygiene products, such as alcohol rubs, [45] and electronic systems for monitoring compliance,[46] but WHO guidelines suggest direct observation is still the gold standard.[40] We also note that although accreditation surveys are assessed on a five point scale, only two scores (MA and EA) were used in the infection control standard during the four surveys in our study. The lack of granularity in the accreditation scores makes it difficult to differentiate accreditation performance. Inter-surveyor reliability is recognised as a limitation of audit systems that are based on subjective assessments.[47] To reduce idiosyncratic scoring, ACHS surveyors need to provide evidence to ACHS for their scoring methods, and in the decision to award higher scores, but some variation between surveyors may remain.

Limitations of the model include reverse causality in that higher compliance rates could lead to higher infection control scores at the next survey where hand hygiene audit rates are used as evidence of implementation during an accreditation survey. This would likely be the case going forward as ACSQHC includes hand hygiene audit results as part of the evidence of implementation of standard 3 under the new national standards.[9 48]

Implications

Different indicators will give different perspectives on how an organisation approaches and implements relevant policy. However, the costs of measurement in health care should be balanced against using a range of indicators to capture a broader mix of infection control policies, and across the different standards assessed during accreditation surveys. Indicator selection should include both process indicators, recognised as a method of measuring organisational changes,[49] and outcome indicators. Public reporting of indicator data

further increases the requirement to accurately identity and measure the parts of the patient safety and quality spectrum that are being addressed. In this study, a focus on the accreditation results would underestimate the successful implementation of the hand hygiene policy by smaller hospitals. Conversely, just using hand hygiene results would underestimate the research and leadership investment in infection control by larger hospitals. Disentangling these two outcomes within the same safety and quality initiative is a pre-requisite to understanding how they can be effectively assessed and monitored. For example, consideration could be given to changing criteria for awarding higher scores for infection control such that achieving higher scores was evidence based and could be feasible for all hospitals. Although we focus on Australian hospitals in our study, international accreditation programs will also need to ensure that indicators accurately capture outcomes and reflect performance across a range of hospital size and type.

CONCLUSION

Identifying indicators to measure the effectiveness of accreditation is challenging due to the complexity of implementing a wide range of accreditation related processes across multiple hospital activities. Our results do not support ~~-~~our study hypothesis that high~~er~~ infection control scores are associated with higher hand hygiene rates. Instead, this study suggests that accreditation outcomes and hand hygiene audit data measure different parts of the quality and safety spectrum. Developing a framework to identify suitable indicators is an important contribution to understanding the impact of hospital accreditation internationally. Policy makers need to appreciate the assumptions behind the choice of indicator and understand exactly what is being measured to ensure that key performance indicators encourage quality improvements in the delivery of hospital services.

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Ethics: Human Research Ethics Committee approval for this study was granted by UNSW (approval number HREC 10274).

Figure Legends

Figure 1: Timeline of accreditation surveys and hand hygiene audits

Figure 2: Mean hand hygiene compliance rates by audit and hospital peer group, 2010-2013

Figure 3: Percentage of hospitals meeting hand hygiene targets by audit and hospital peer group

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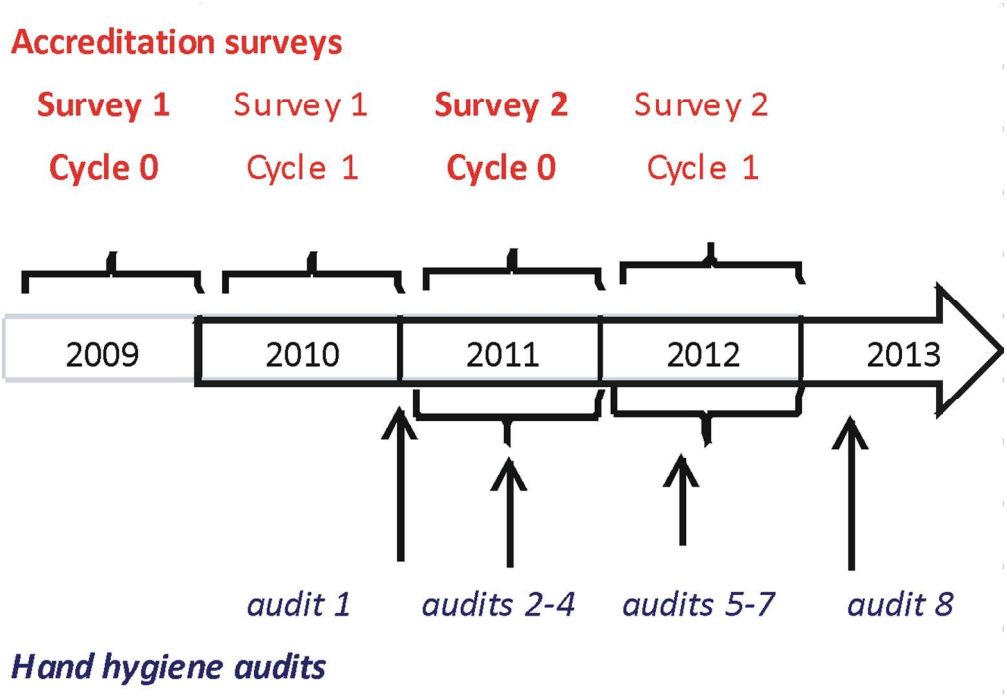

Figure 1: Timeline of accreditation surveys and hand hygiene audits

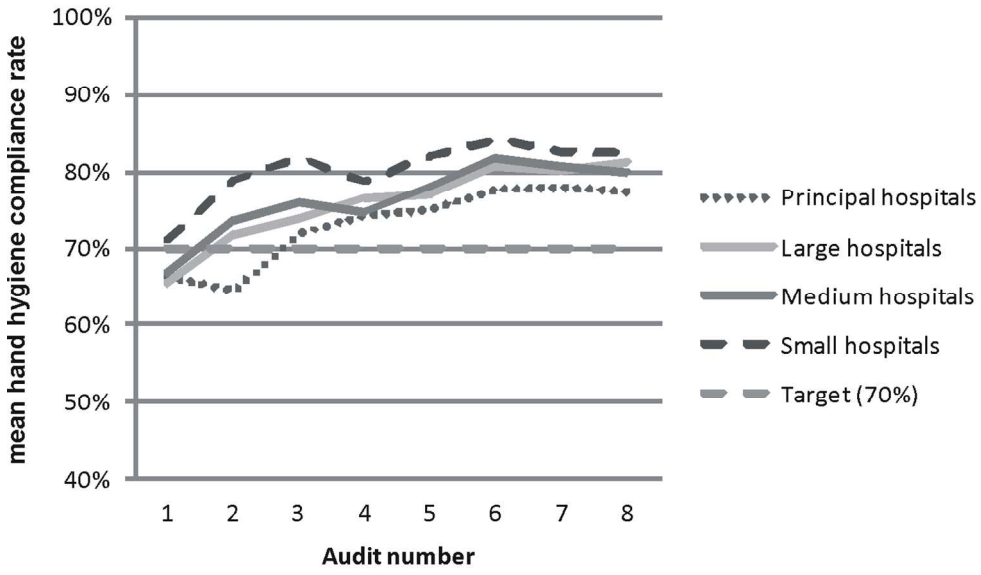

Figure 2: Mean hand hygiene compliance rates by audit and hospital peer group, 2010-2013

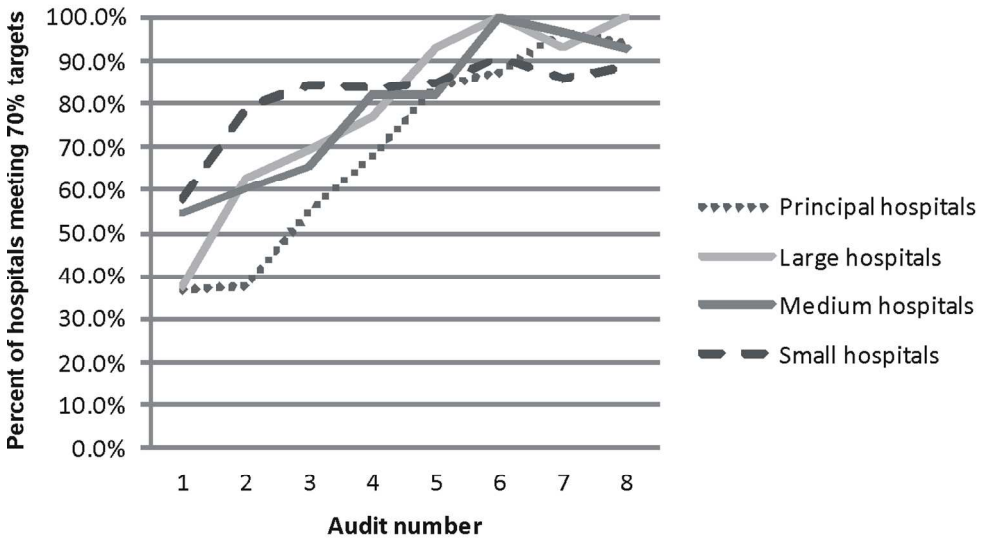

Figure 3: Percentage of hospitals meeting hand hygiene targets by audit and hospital peer group

Mandatory criteria assessed during EQuIP 4 & 5 surveys
Care is planned and delivered in collaboration with the consumer/patient and when relevant, the carer, to achieve the best possible outcomes
Consumers/patients are informed of the consent process, and they understand and provide consent for their care
Outcomes of clinical care are evaluated by healthcare providers, and where appropriate, are communicated to the consumer/patient
Processs for clinical handover, transfer of care and discharge, address the needs of the consumer/patient for ongoing care
The health record ensures comprehensive and accurate information is collaboratively gathered, recorded, and used in care delivery
Medications are managed to ensure safe and effective consumer/patient outcomes
The infection control system supports safe practive and ensures a safe environment for consumers/patients and healthcare workers
The organisation's continuous quality improvement system demonstrates its commitment to improving the outcomes of care and service delivery
The integrated organisation-wide risk management framework ensures that corporate and clinical risks are identified, minimised, and managed
Healthcare incidents are managed to ensure improvements to the systems of care
Processes for credentialling and defining the scope of clinical practice support safe, quality clinical care
Documented corporate and clinical policies and procedures assist the organisation to provide safe, quality health care
Safety management systems ensure safety and wellbeing of consumers/patients, staff, visitors and contractors
Emergency and disaster management supports safe practice and a safe environment
Standards for EQuIP 4 and 5 [7 8]

Hospital Peer Groups		AIHW Definition	Study Definition
Principal referral and specialist women's and children's	A1	Major city hospitals with > 20,000 acute case-mix adjusted separations and Regional hospitals with >16,000 acute case-mix adjusted separations per annum	Principal
	A2	Specialised acute women's and children's hospitals with >10,000 acute case-mix adjusted separations per annum	
Large hospitals	B1	Major city acute hospitals treating > 10,000 acute case-mix adjusted separations per annum	Large
	B2	Regional acute hospitals treating > 8,000 acute case-mix adjusted separations per annum, and remote hospitals with > 5,000 case-mix adjusted separations per annum	
Medium hospitals	C1	Medium acute hospitals in Regional and Major city areas treating between 5,000 and 10,000 acute case-mix adjusted separations per annum	Medium
	C2	Medium acute hospitals in Regional and Major city areas treating between 2,000 and 5,000 acute case-mix adjusted separations per annum, and acute hospitals treating <2000 acute case-mix adjusted separations per annum but > 2,000 separations per annum	
Small acute hospitals	D1	Small Regional acute hospitals treating < 2000 acute case-mix adjusted separations per annum	Small
	D3	Small remote hospitals (< 5,000 acute case-mix adjusted separations per annum), most are < 2,000 separations	

Australian Institute of Health and Welfare peer groups [30]