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Efficacy of a hospital-wide environmental cleaning protocol on hospital-acquired methicillin-resistant *Staphylococcus aureus* rates

Paul Andrew Watson[1], Luke Robert Watson[2] and Alfonso Torress-Cook[3]

Abstract

Background: Environmental contamination has been associated with over half of methicillin-resistant *Staphylococcus aureus* (MRSA) outbreaks in hospitals. We explored if a hospital-wide environmental and patient cleaning protocol would lower hospital acquired MRSA rates and associated costs.

Objective: This study evaluates the impact of implementing a hospital-wide environmental and patient cleaning protocol on the rate of MRSA infection and the potential cost benefit of the intervention.

Methods: A retrospective, pre-post interventional study design was used. The intervention comprised a combination of enhanced environmental cleaning of high touch surfaces, daily washing of patients with benzalkonium chloride, and targeted isolation of patients with active infection. The rate of MRSA infection per 1000 patient days (PD) was compared with the rate after the intervention (Steiros Algorithm®) was implemented. A cost–benefit analysis based on the number of MRSA infections avoided was conducted.

Results: The MRSA rates decreased by 96% from 3.04 per 1000 PD to 0.11 per 1000 PD (P <0.0001). This reduction in MRSA infections, avoided an estimated $1,655,143 in healthcare costs.

Discussion: Implementation of this hospital-wide protocol appears to be associated with a reduction in the rate of MRSA infection and therefore a reduction in associated healthcare costs.

Keywords

Infection prevention, methicillin-resistant *Staphylococcus aureus* (MRSA), environmental cleaning

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Background

Hospitalised patients can acquire methicillin-resistant *Staphylococcus aureus* (MRSA) infections from many places including the hospital environment, other carriers or their own skin. Contaminated environmental surfaces have been associated with over half of MRSA outbreaks in hospitals (Rampling et al., 2001) and can harbour MRSA for weeks (Dancer et al., 2009; Kramer et al., 2006; Goodman et al., 2008). Patients also may acquire MRSA from touching either the hands of carriers or from their own skin or nose (Rohr et al., 2004). Most nasal carriers also culture positive at more than one extra-nasal site (Rohr et al., 2004) and are more likely to acquire MRSA infections than non-carriers (Kluytmans et al., 1997; Perl and Golub, 1998; Wenzel and Perl, 1995). For this reason, a hospital-wide environmental and patient cleaning protocol, which reduces

[1]Lakeside Orthopedics, Omaha, NE, USA
[2]College Medical Center, Long Beach, CA, USA
[3]Alta Hospital System, Los Angeles, CA, USA

Corresponding author:
Paul Andrew Watson, Lakeside Orthopedics, 16909 Lakeside Hills Ct, Ste 208, Omaha, NE 68130, USA.
Email: kwatson73@gmail.com

MRSA contamination from the patient's environment, should lower hospital-acquired MRSA rates and associated healthcare costs. This study evaluates a hospital-wide environmental and patient cleaning protocol on MRSA rates and the associated infection cost avoidance in a single acute care hospital.

Methods

A retrospective, pre-post interventional study design was used to review the hospital's infection control database for all hospital acquired invasive MRSA infections from 1 January 2005 to 30 September 2009 at one acute care teaching hospital in California in the United States of America. National Health Safety Network (NHSN) and Centers for Disease Control and Prevention (CDC) criteria were used in determining invasive MRSA infections which consists of the following: isolation of MRSA from a normally sterile site and the MRSA culture was obtained after 48 h of hospitalisation or any time after a surgical procedure (CDC, 2016). We compared the rate of MRSA infection per 1000 patient days (PD) before and after implementation of the hospital-wide environmental and patient cleaning protocol on 1 January 2006 and based our cost–benefit analysis on these rates. Prior to 1 January 2006, the following community standard infection control practices were in place: (1) environmental services personnel (EVS) supervisor trained the EVS personnel to clean the hospital (patients' rooms, floors and bathrooms) on a daily basis using Environmental Protection Agency registered disinfectant products (3M Neutral Quat, 3M, St Paul, MN, USA, and Clorox Bleach, Clorox, Oakland, CA, USA). This was done without any specific decontamination training and mostly to remove dirt from the hospital environment; (2) nursing and ancillary staff washed patients with soap and water only as needed; (3) hand washing/sanitiser use was an integral part of infection control including easy access to soap/water/hand sanitiser and yearly training on the importance of hand hygiene; (4) isolation protocols were used for patients with a history of a multi-drug resistant organisms (MDRO) (both colonised and infected, e.g. history of MRSA). All patients with transmissible diseases were isolated as per CDC guidelines (Seigel et al., 2007); (5) compliance was monitored by the infection control department and retraining on isolation procedures and hand hygiene was performed as needed. After 1 January 2006 a hospital-wide environmental and patient cleaning protocol (Steiros Algorithm®, Steiros, Long Beach, CA, USA) was implemented. The process is a multi-tiered, whole hospital environmental and patient cleaning method for the hospital and patient environment using embedded products as previously described (Everett et al., 2014). This bundled process was implemented in 2006 by two of the authors as part of their infection control practitioner roles at this hospital facility following recommendations of the California Department of Health Services Healthcare Associated Infection Advisory Working Group for infection prevention in hospitals in the state of California (Chavez et al., 2005). This bundle had been developed by one author and utilised over years at different healthcare facilities with success. Ethical approval was sought and approval given by the hospital's Medical Executive Committee and Chief Executive Officer. The interventions are summarised in Table 1 and include the following: (1) EVS were trained quarterly with a 1-h presentation given by one of the authors to do daily cleaning of very specific high touch areas (e.g. doorknobs, hand rails, tables, remote controls, etc.) throughout the facility using embedded quaternary ammonium cleaning products (Steiros Hard Surface Wipes, Germcure, Houma, LA, USA); (2) nursing staff were trained yearly how to use a skin sanitiser (active ingredient 0.13% benzalkonium chloride) to wash patients on a daily basis until discharge from the hospital. The United States Food and Drug Administration (FDA) registered skin sanitiser is a 'wipe on and leave on until dry' product and was utilised based on previous experience with its efficacy, ease of use and low allergic reaction rate as no CDC patient washing product guidelines were available during the study period; (3) hand washing/sanitation was re-emphasised as an integral part of infection control including quarterly training on hand hygiene and monthly unit specific reporting on hand hygiene compliance rates with retraining as necessary; (4) a yearly 1-h educational meeting was attended by all hospital employees involved in patient care which introduced the infection control process and emphasised the importance of cleaning all equipment including nursing stations, transport beds, monitors and other common areas; (5) isolation protocols were held to strict CDC mandatory isolation guidelines only (e.g. actively draining culture positive wounds or active tuberculosis) and not for history of disease only (e.g. history of MRSA) (Seigel et al., 2007); (6) awake patients signed daily room EVS cleaning checklist to ensure compliance; and (7) compliance was monitored on a systematic and periodic basis by the infection control department by: (i) performing unit specific swab cultures of the high touch areas to verify cleaning and quarterly retraining as needed, (ii) regular monitoring of electronic and patient signed checklists to verify daily room and patient cleaning, and (iii) spot checks by the infection control department of all units where infections occurred with retraining performed as needed. No admission MRSA screening cultures were performed during the study period.

All data were collected monthly via the Hospital Infection Control and Safety Department database using standard surveillance for reporting to the CDC and NHSN using criteria in determining invasive MRSA infections which consists of the following: isolation of MRSA from a normally sterile site and the MRSA culture was obtained after 48 h of hospitalisation or after a surgical procedure (CDC, 2016). Infections were identified by analysing

Table 1. Infection control practices before and after 1 January 2006.

Before	After
General daily cleaning of hospital environment to remove dirt	Daily hospital environmental cleaning concentrating on specific high touch areas including door knobs, bed rails, television remote, telephone, over bed table, computer keyboards, bed surface, intravenous pump, supply cart, blood pressure cuff, bed pan with daily checklists. Compliance checked with routine cultures and spot checks by the infection control department
Patients washed with soap and water as needed	Patients washed daily with rub on and let dry 0.13% benzalkonium chloride skin sanitiser/cleanser
Hand washing/sanitising encouraged including easy access to soap and water/ alcohol based hand sanitiser with yearly training on hand hygiene	Hand washing/sanitising emphasised including quarterly training on hand hygiene with monthly unit specific reporting on hand hygiene compliance rates with retraining as necessary. 0.13% benzalkonium chloride hand sanitiser used
Isolation for history of MRSA or any multi-drug resistant organisms	Targeted isolation protocols held to strict CDC mandatory isolation guidelines including no isolation for history of MRSA; targeted isolation for active, draining, open MRSA wounds only
Medical personnel infection training done as needed, usually due to outbreaks	Yearly 1-h infection control education required for all hospital staff both medical and nonmedical staff emphasising daily cleaning of all equipment including nursing stations, computers, transport beds, monitors and common areas
Compliance and retraining done in response to infections or outbreaks	Room cleaning checklists with routine cultures and spot checks to verify compliance with retraining as needed

current procedure terminology (CPT) codes and International Classification of Diseases-9 coding. This standardised MRSA surveillance program was used throughout the study period. During the study period, the hospital infection control database tracked infection rates per 1000 patient days. Daily checklists for compliance of both EVS room cleaning and patient washing were reviewed and the percent compliance was calculated. The studied time frame was used because a modification to the standardised surveillance program and reporting was made in October of 2009 and would have confounded the comparison rates. Also, prior to 2005, MRSA-specific infection data were not available in the infection database which limited our pre-intervention data to 1 year.

For the cost analysis, our objective was to compare hospital-acquired MRSA infection healthcare costs 12 months before and 45 months after institution of the protocol to determine if the protocol avoided overall healthcare costs related to hospital-acquired MRSA infections. The hospital direct material and manpower costs before and after implementation of the protocol were not available for collection for this analysis. However, a previously published cost–benefit analysis (Everett et al., 2014) showed that implementation costs of this protocol in a similar community hospital were cost-neutral. The costs associated with the products, cleaning and training were offset by the reduction in isolation costs. Based on this previous research we assumed the implementation of the protocol to be cost-neutral in the cost analysis. Previously published costs associated with hospital-acquired MRSA infections of $6916 dollars per infection were used for the infection cost estimates (Scott, 2009; Tubbicke et al., 2012). We multiplied the number of infections in 2005 by $6916 dollars and divided that by 12 months and used this as a pre-protocol cost per month. We then multiplied the number of infections of years 2006–2009 (45 months) by $6916 dollars and subtracted this number from the pre-protocol cost per month times 45 months to get the total cost avoidance.

A portion of the MRSA infection reduction seen in our study was likely associated with an overall decline in MRSA rates. National and California specific studies show that invasive MRSA rates gradually decreased over the study period. The CDC reported a national downward trend in invasive MRSA rates between 2005 and 2011 of 54% without year-specific data (Dantes et al., 2013). The CDC Active Bacterial Core surveillance reports of MRSA in 2005–2009 show a national decrease of hospital onset MRSA by 37% (CDC, 2015). Using a state-wide database, Tehrani et al. reported the rates of hospital onset invasive MRSA infections specifically in all California hospitals from 2005 to 2010 by year (Tehrani et al., 2013). In 2005–2009 the hospital-acquired MRSA rates in California fell from 1.4 to 1.2 per 1000 admissions, a decrease of 14%. For this reason, we multiplied the total cost avoidance by four different estimate models (0%, 14%, 37%, 54%) based on MRSA trends from the state of California and the USA

during that time period. (CDC, 2015; Dantes et al., 2013; Tehrani et al., 2013) to get the best and worst case total cost avoidance scenarios.

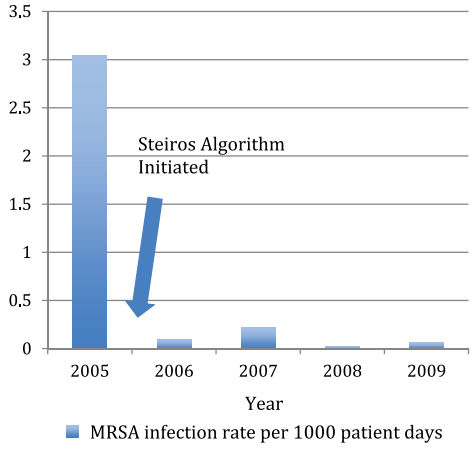
No patient specific data were obtained or recorded and therefore review and approval by the Institutional Review Board was not necessary. No additional infection control processes were introduced or changed during the study period. The two tailed Pearson chi-square with a Yates' correction was used to determine the *P* value.

Results

The results are summarised in Figure 1. The MRSA rates declined by 96% from 3.04 per 1000 PD (128/42136) before to 0.11 per 1000 PD (19/170,072) after institution of the protocol. This was statistically significant (P <0.0001). Specifically, there were 128 hospital-acquired MRSA infections in 2005 (3.04/1000 PD), four in 2006 (0.095/1000 PD), nine in 2007 (0.21/1000 PD), one in 2008 (0.022/1000 PD) and two in 2009 (0.057/1000 PD). There was a small increase in 2007 compared to years 2006, 2008 and 2009 thought to reflect a normal variation of infection rates from year to year. However, this small increase in 2007 was still 93% lower than the MRSA rate in 2005.

Table 2 summarises the healthcare MRSA infection cost avoidance due to the avoidance of 239.32 MRSA infections using four different models to estimate MRSA reduction trends from the state of California and the USA during that time period. Avoided overall healthcare infection costs ranged from $1,655,143 to $3,310,286 over a 45-month period. In 2006–2009, the compliance for daily patient washing and EVS checklist completion was 94%.

Figure 1. MRSA infection rate over the study period.



Discussion

This hospital-wide environmental and patient cleaning protocol appears to be associated with a reduction in hospital-acquired MRSA rates. We believe that the ease of implementation, the daily cleaning of very specific high touch areas and patients, universal decolonisation with a benzalkonium chloride sanitiser and targeted isolation is what separates this hospital-wide environmental and patient cleaning protocol from other bundles. In this bundle, decontamination of the environment along with universal decolonisation allowed for minimal isolation which improves patient satisfaction (Abad et al., 2010; Masse et al., 2013; Mehrotra et al., 2013). Also, the efficacy of isolation precautions in protecting patients from MRSA has recently come into question (Harris et al., 2013; Lopez-Alcalde et al., 2015). For this reason, we believe with this process isolation can be minimised with good results. In addition, from an overall healthcare perspective, this protocol appears to be associated with the reduced hospital-acquired MRSA costs.

There are many limitations to our study. The non-randomised study design limited to only one hospital and a retrospective control, limits our ability to link causation of the decline in MRSA infection rate to the specific changes that were implemented (Harris et al., 2005). The study type was chosen due to administrative and financial constraints. Multiple factors were changed as part of the intervention including environmental cleaning, patient washing, personnel training and a large reduction in numbers of patients under isolation precautions. Use of a prospective randomised protocol would better demonstrate causation and the most efficacious factors in the protocols (environmental cleaning or other factors including patient washing, isolation reduction or hand hygiene). Future research on this topic would be beneficial. In addition, without patient-specific data, bias may be introduced depending on the health of the population and underlying MRSA colonisation rate. In this medium-sized community hospital, we had a stable population base over time making this type of bias less likely. Due to limitations of our infection control database, MRSA-specific data from years prior to 2005 were not available. An outbreak occurring in the year 2005 could bias the data. However, the quarterly data from 2005 are evenly distributed throughout the year making a focal outbreak less likely.

Additionally, the CDC and California Department of Public Health made efforts to reduce the rates of invasive MRSA during the study period with success. National and California specific studies show that invasive MRSA rates were gradually decreasing over the study period. (CDC, 2015; Dantes et al., 2013; Tehrani et al., 2013). We presented a range of downward assumptions of MRSA rates presenting the best and worst case scenario for cost avoidance caused by the national and regional MRSA rate trends, especially given the lower decreases reported in California. Therefore, to avoid overestimating the cost avoidance, our cost analysis used a 0–54% reduction in MRSA rates to give a range of possible cost avoidance that may be achieved with this protocol (Drummond et al., 2005).

Table 2. MRSA infection cost avoidance estimates.

Estimate model	Cost avoidance
Assumption that there was no national or regional downward MRSA infection trend	$3,310,286
Tehrani et al. reported a California specific 14% decrease in the rate HA MRSA infections from 2005 to 2009 (Tehrani et al., 2013)	$2,846,846
CDC Active Baterial Core surveillance reported national decrease of HA MRSA infection rates of 37% in 2005–2009 (CDC, 2015)	$2,085,480
Dantes et al. reported a national HA MRSA infection rate downward trend of 54% during 2005–2011 without year-specific data (Dantes et al., 2013)	$1,522,732

HA, hospital acquired; MRSA, methicillin-resistant *Staphylococcus aureus.*

Multiple previous studies had suggested that environmental cleaning reduces MRSA rates by reducing contamination (Dancer et al., 2009; Everett et al., 2014; Goodman et al., 2008; Hayden et al., 2006). Our data further support an association between environmental contamination and transmission of MRSA and that a protocol that includes hospital-wide environmental cleaning protocol appears to contribute to protecting patients. In addition, this particular protocol has been shown elsewhere to decrease all hospital-acquired infection (HAI) rates. When used in a large acute care teaching hospital, Everett et al. showed that this hospital-wide environmental and patient cleaning protocol decreased all HAI rates 64% overall, including a reduction of MRSA infection rates by 63%, and reduced associated hospital costs (Everett et al., 2014). In addition, Watson et al. showed that this protocol reduced SSI rates to zero over a 2-year period (Watson et al., 2012).

Conclusion

In summary, institution of a hospital-wide environmental and patient cleaning protocol comprising enhanced cleaning of the patient environment, daily patient cleaning with benzalkonium chloride sanitiser and targeted use of isolation appears to be associated with a reduction in the rate of hospital-acquired MRSA infection and therefore a reduction in associated healthcare costs.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Two of the authors declare that they are infection prevention consultants for and part owners of Steiros, Inc., Long Beach, CA, USA and part owners of Bioblockade Inc., Coto De Caza, CA, USA. The third author declares no conflict of interest.

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