



# Reduction in ventilator associated pneumonia in a mixed intensive care unit after initiation of a novel hand hygiene program<sup>☆</sup>

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Multimodal;  
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infections;  
Ventilator associated  
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## Abstract

**Purpose:** Healthcare-associated infections (HAIs) impact 10% of hospitalized patients. Some of these infections result from bacterial cross contamination and poor compliance with guidelines (Pittet D: Compliance with hand disinfection and its impact on hospital-acquired infections. *J Hosp Infect* 48 Suppl A:S40-S46, 2001); (Watanakunakorn C, Wang C, Hazy J: An observational study of hand washing and infection control practices by healthcare workers. *Infect Control Hosp Epidemiol* 19:858-860, 1998). Contamination of provider hands may be a modifiable risk factor. We instituted a novel multimodal system designed to improve hand hygiene by ICU providers.

**Materials and Methods:** A before and after study design was used to evaluate the impact on the incidence of CRBSI and VAP of a multi-modal program incorporating education, performance feedback, and a body worn hand hygiene device. Compliance was communicated quarterly. Primary outcomes were CRBSIs and VAPs per 1,000 line days or per 1,000 ventilator days and compliance rates. Secondary outcomes were hospital length of stay and mortality.

**Results:** A total of 1,262 and 1,331 patients were evaluated during consecutive 12 month periods. VAP per 1000 vent days were significantly reduced after introduction of the program [3.7 vs. 6.9]  $P < .01$ . The reduction in CRBSI per 1000 line days was not significant [1.5 vs. 2.6],  $P = .09$ . Observed hand hygiene increased during the study period. There was no significant difference in mortality.

**Conclusions:** A novel multi-modal hand hygiene system resulted in a reduction in VAP. Provider hand contamination during patient care in the ICU is a modifiable risk factor for reducing ventilator associated pneumonias.

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## 1. Introduction

Healthcare-associated infections (HCAI) affect 10% of patients admitted to acute care facilities, accounting for

approximately 90,000 infections, of which many may be preventable, leading to greater than a billion dollars in excess healthcare costs annually. This is occurring within an economic environment that is charged with improving patient safety and quality while reducing healthcare costs [1]. Despite advances in surgical techniques, sterilization and disinfection programs, improvements in medical devices, therapeutic measures and evidence based guidelines, HCAI rates remain unacceptably high. Further, HCAIs have become an increasing dilemma due to the evolving, worldwide problem of multi-drug resistant bacteria and the increasing complexity of the healthcare environment [1-3]. However, the prevailing view is that many HCAIs are preventable complications, a view highlighted by the Centers for Medicaid and Medicare Services (CMS) decision to no longer reimburse for HCAIs [4].

The etiology of HCAIs in acute care settings is explained at least in part by bacterial cross contamination, a consequence of poor compliance with Center for Disease Control (CDC) guidelines for infection control, in particular hand hygiene [5-10]. Multiple interventions to improve hand hygiene compliance of healthcare workers (HCWs) have been evaluated, including but not limited to education of HCWs, patient education, provider performance feedback, and various types of hand disinfectants, proximity of disinfectants, and/or educational programs incorporated into multi-modal strategies [11-30]. Studies have yielded inconclusive evidence for the best approach to improvements in HCW hand hygiene and/or reduction in HCAIs [15,31,32]. However multimodal intervention strategies have been shown to be more effective, than single intervention approaches which are prone to failure [33-37].

Health care associated infections are particularly important in the intensive care unit where they have been demonstrated to result in increases in morbidity, mortality and cost [38-46]. We have recently demonstrated that intraoperative use of a novel hand hygiene device designed to improve intraoperative hand hygiene compliance of anesthesia significantly reduced infections in the 30-day postoperative period [47]. This quality improvement tool provided a multimodal approach to improve hand hygiene by overcoming barriers to hand hygiene compliance through proximity for provider use and provision of reliable performance feedback. We hypothesized that this approach would prove useful in the ICU, a similarly fast-paced environment, for reducing HCAIs.

## 2. Materials and methods

### 2.1. General description

This was a before and after study design conducted in the multidisciplinary (medical-surgical) ICU at Dartmouth-Hitchcock Medical Center, a tertiary care and level one trauma center. Patients admitted to the ICU were followed

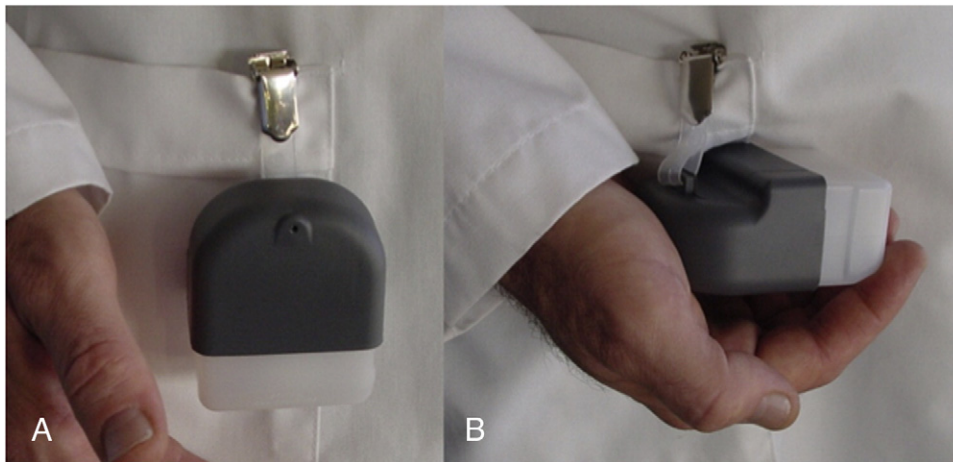
during two consecutive 12-month periods, 12/06-11/07 (control period) and 12/07-11/08 (study period). After the study period, the multimodal program was no longer supported and a washout period was observed for another 12 months (time interrupted period). The hand hygiene devices and supplies were maintained throughout the unit. Approval was obtained from the Institutional Review Board for the protection of Human Subjects following expedited review with a waiver for informed patient consent. This study was registered at *Clinicaltrial.gov* and the identifier is NCT01050608.

### 2.2. Protocol

During the study period a personalized hand hygiene device (Sprixx GJTM Harbor Medical Inc, Santa Barbara, CA.) was introduced to ICU healthcare providers (nursing staff, physicians, and respiratory therapists). At study initiation there was an in-service which included use of the device in the ICU environment and a brief educational program addressing specific barriers to hand hygiene performance in the ICU and review of the CDC guidelines pertaining to hand hygiene. This educational program also addressed specific barriers to hand hygiene performance in the ICU arena [11,20,24,34]. Voluntary use of the device by HCWs was monitored at quarterly intervals throughout the study period. Individual and group compliance was measured as hand decontamination events per hour and communicated at quarterly intervals as a method of performance feedback. Feedback was provided to both individuals and the entire group. Wall-mounted dispensers were available in the ICU for hand hygiene during both the control and study periods. HCWs during the study period were given a GJ Hand Sanitation Device in addition to available wall-mounted dispensers. The GJ Hand Sanitation Device is an alcohol-based hand cleanser that is worn on the healthcare worker (Fig. 1). The device administers 0.75 ml of solution when the plunger is activated. It provides a time stamp documenting each hand hygiene decontamination event (HHDE) recorded to an embedded digital memory chip. If multiple activations are performed within 1 min, only one HHDE is recorded. This allows hand hygiene events to be downloaded to a Microsoft Access database (Microsoft Co., Seattle, WA). Critical care personnel utilized this device during patient care in the ICU, and the recorded information was analyzed with regard to frequency and timing of use. Hand hygiene decontamination events were evaluated at quarterly intervals.

Infections, VAP and CRBSI, during the control and study periods were tracked and recorded by clinical nurse reviewers independent of the research team. HCAIs were identified by predefined NNIS criteria.[1] Both a ventilator care bundle and central line bundle were in place during the control and study periods. Observed hand hygiene was routinely recorded during both the control and study periods.

In our institution this was recorded if a provider performed hand hygiene upon entering the patient care



**Fig. 1** The Sprixx GJ device. A, Device worn by provider. B, Alcohol-based cleanser deployed by squeezing device.

environment and after leaving. This process is performed hospital-wide and the data recording and training of personnel is through the infection control department.

### 2.3. Statistical analysis

The primary outcomes were catheter-related blood stream infections (CRBSIs) per 1,000 line days, ventilator-associated pneumonias (VAPs) per 1,000 ventilator days, and individual and group provider hourly and observed hand hygiene compliance rates.

Secondary outcomes were duration of hospital stay and mortality. Patient demographic data were also collected. Groups were compared using student t test,  $\chi^2$  or 2-sided Fisher's exact tests as appropriate. Time interrupted data was analyzed utilizing analysis of variance. Rates of VAP and CRBSI were compared, using Poisson distribution. Statistical significance was defined as  $P \leq .05$  in a two-tailed test. All analysis were generated using the STATA 11.0 package (StataCorp LP, College Station, Texas). The baseline infection rate utilized for sample calculations was from 2005-2006 infection rates and based on an estimated 50% reduction with this intervention. Based on a retrospective incidence of total VAP and CRBSI monthly rates, power calculations were performed to determine estimates of study duration. To achieve a 50% reduction of total infections with a power of 80% and  $P = .05$  it was estimated that 9 months of study duration would be needed for VAP and 15 months would be needed for CRBSI. Because of the confounding nature of seasonal variation in infection rates we chose a 12-month interval as our overall study period [2,32,48-50].

### 3. Results

There was a total of 1,262 patients with 6463 central line days and 6171 ventilator days in the control period and 1,331

patients with 6850 central line days and 5897 ventilator days in the study period. Patients during the two time periods were comparable in age, gender, and APACHE II score (Table 1).

Ventilator-associated pneumonias per 1000 vent days were significantly reduced after introduction of the program [3.7 study versus 6.9 control,  $P < .01$ , OR 0.48 (95% CI 0.29, 0.81)]. The study period had 887 patients that were "eligible" for a VAP (>2 days mechanical ventilation) compared with 716 in the control group  $P = .01$ , OR 1.18 (95% CI 1.04, 1.33 (Table 2). However, the reduction in catheter-related bloodstream infections per 1000 line days between study and control periods was not statistically significant [1.5 study versus 2.6 control,  $P = .09$ , 95% CI (0.28-1.39)] (Fig. 1 and Table 2). There was no overall difference between time periods in either length of ICU stay or patient mortality (Table 2).

Provider hand hygiene compliance as measured by use of the device (HHDEs) was sustained throughout the study period, with an average of 4 HHDE. Due to the voluntary nature of the study, providers using the device decreased from approximately 20 users per shift at the start of the study period (100%) to approximately 10 users per shift at three months (50%) and 8 users per shift (40%) at 6 months. Device usage (for those using the Sprixx GJ device) remained constant throughout the study period. Observed

**Table 1** Patient demographics

	Study period	Control period	<i>P</i>
Age (mean $\pm$ SD)	61 $\pm$ 18	61 $\pm$ 17	.92
APACHE (mean $\pm$ SD)	17.7 $\pm$ 7.9	17.4 $\pm$ 7.8	.38
Male (%)	56	56	.98
Medicine (%)	45	48	.18
Surgery (%)	41	37	.10
Trauma (%)	14	15	.73

APACHE indicates Acute Physiology and Chronic Health Evaluation.

**Table 2** Outcomes study period vs control period

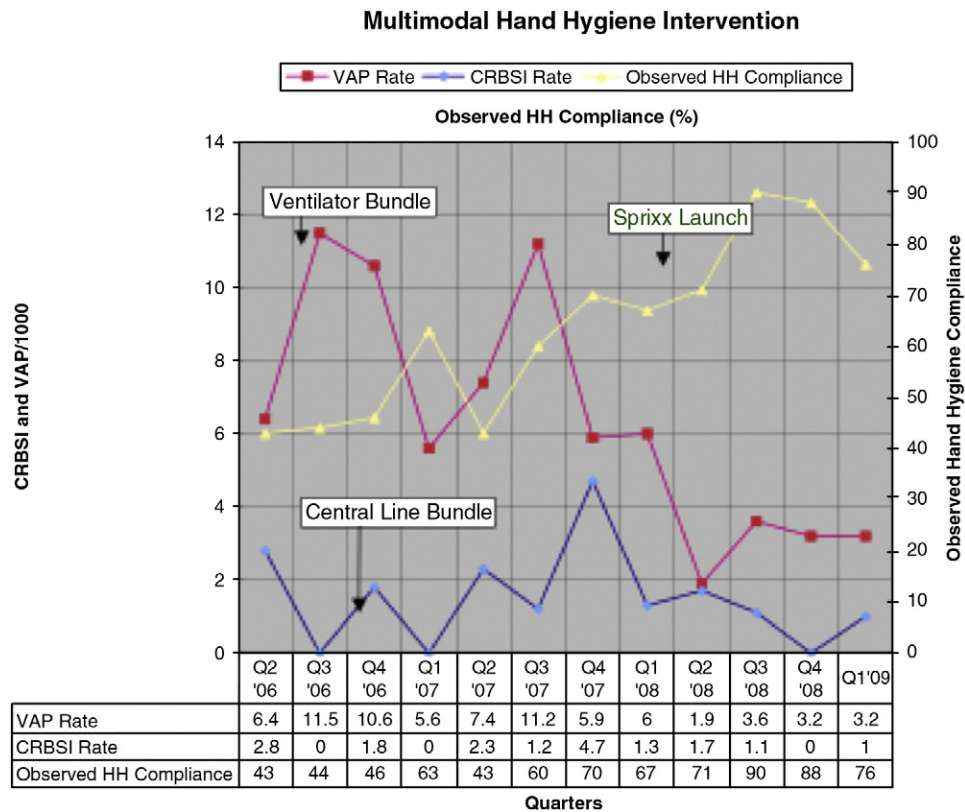
	Study period	Control period	P
LOS <sup>a</sup> d (mean ± SD)	5.9 ± 7.8	5.8 ± 8.6	.79
Mortality (%)	296/1330 (22.3)	299/1262 (23.7)	.38
VAP number (number per 1000 vent days)	22 (3.7)	43 (6.9)	<.01
Eligible VAP patients (>2 days mechanically ventilated)	887	716	.01
CRBSI number (number per 10000 catheter days)	9 (1.5)	17 (2.6)	.09

<sup>a</sup> ICU length of stay.

### 4. Discussion

In ICU’s worldwide Vincent et al. recently reported that slightly over half of the patients have infections. Of these infections 64% are respiratory in origin [51]. We have demonstrated that the introduction of a novel hand hygiene improvement system as part of a multimodal program in the ICU was associated with a significant reduction in VAP and a trend towards fewer CRBSIs. This extends our prior findings of the effectiveness of this approach in the intraoperative setting [47]. The combination of a unique educational program addressing barriers to hand hygiene specific to the ICU environment, an effective alcohol solution in close proximity to the provider, and the ability to provide reliable performance feedback due to the embedded computer chip allows this device to serve as a unique multimodal approach for the improvement of hand hygiene. Currently the Institute for Healthcare Improvement recommends utilizing a VAP bundle to reduce ventilator associated pneumonias. This bundle usually focuses on the utilization of four evidenced based interventions including, elevation of the head of the bed, daily "sedation vacations" and assessment of readiness to extubate, peptic ulcer disease prophylaxis, and deep venous thrombosis prophylaxis [52]. Other evidence based measures such as chlorhexidine mouth care, have been added to the original bundle and these

hand hygiene rates significantly improved (independent of device use) from 44-63% (mean 53%) during the control period to 67-90% (mean 75%) during the study period [*P* < .05, 95% CI -39 to -1.1] Fig. 2. During the time interrupted period. No significant differences were observed between groups based on ANOVA (see Appendix A, supplementary data table 3). During this time period, provider utilization dropped to < 10% and a return to baseline VAP rates was observed (Table 3a and Figure 3).



**Fig. 2** Hand hygiene and infection rates.

interventions appear to reduce VAP in many ICU populations [36,38,53,54]. The incorporation of hand hygiene into the VAP bundle has been recommended [36,55,56]. Hand Hygiene has been a cornerstone in many hospital wide infection prevention programs. In other studies despite transient improvements in measured compliance rates, sustained improvements were rarely coupled with significant reductions in HCAI rates [30,32,56-58]. Similarly, the implementation of a central line bundle has been the “keystone” for reduction in CRBSI rates in ICUs [59]. Hand hygiene is included in this “bundle” prior to insertion of central lines; however, the impact of hand hygiene in general on CRBSI rates has been difficult to observe either because of the inability to increase compliance rates or because of low infections rates in the studies performed [32,58]. When infection rates are high however it has been possible to show an effect when impacting poor hand hygiene rates [31].

This study is unique in that we already had established bundled strategies for VAP and CRBSI prior to the addition of this novel hand hygiene program. We were therefore able to directly study the intervention independent of the contribution of these bundles. In contrast to other studies, we were able to demonstrate a significant reduction in VAPs associated with the intervention despite having significantly more patients “eligible” in the study period (based on CDC definitions). There was a trend towards a reduction in CRBSI rates; however, because of the low rates of infection and only 12 month study period we were underpowered for this outcome. This body-worn hand hygiene system facilitates a reliable performance feedback intervention, which serves as a novel method to facilitate improvements in hand hygiene. It counters barriers of priority of care, forgetfulness, insufficient time and high workload through its proximity to the provider and the 62% alcohol solution utilized minimizes skin irritation through an emollient additive. An additional unique characteristic of this system is its ability to both improve and monitor hand hygiene compliance during patient care through use of the embedded computer chip. A lack of emphasis on hand hygiene compliance in the patient environment (as recommended by the WHO) in favor of compliance measures tracking provider entry and exit from the patient care environment, may in part explain why interventions targeting improvements in hand hygiene as is currently measured have failed to reduce HCAs [33]. The efficacy of this device in targeting improvements in hand hygiene during direct patient care (and not just upon patient room entry and exit) may explain its profound impact on ICU infections. In effect, the body-worn device may make it easier for a provider to perform hand hygiene at every available opportunity. This was similarly observed by anesthesia providers during a recent intraoperative study [47].

However, we believe the success of the body-worn device in reducing infections is in large part due to the design as a multi-modal system. This system incorporates a diverse set of educational approaches. Education has been shown to be

an important factor in improving hand hygiene compliance. Further, educational programs incorporating multiple components are thought to be more efficacious than programs utilizing a single modality [13,24]. We suspect that the multi-modal program used in this study (provider specific education, performance feedback, peer pressure and a brief review of Center for Disease Control (CDC) guidelines) is more effective than educational programs incorporating only baseline Center for Disease Control (CDC) guidelines and universal precautions [14,16]. Similar to all behavioral interventions, continued use of this modality will likely require educational “boosters” for maximal success, but further study is required to determine the best approach [58]. Consistent with the need for “boosters” is the decline in voluntary device use we observed during the study period.

It is impossible to determine whether any specific component of the program is in fact responsible for the reduction in infections observed. Similarly, the findings may result from a Hawthorne effect from instituting “any” program. In fact, the observed hand hygiene compliance, independent of the program, was significantly higher during the study period. This increase in hand hygiene and/or the hand hygiene device may explain the reduction in infections.

However, either explanation supports the role of hand hygiene in infection reduction. The before and after design used in the study has inherent problems related to secular trend confounding. The bundles were standard of care during the control and study periods as well as a hospital wide hand hygiene program initiated several months prior to the start of the control period which included the placement of wall mounted dispensers and educational materials. An additional limitation of the study was the voluntary participation of providers.

Despite a decline in participation over the study period, the program was still able to have a profound impact on infections. Another hand-hygiene study in the operating room at Dartmouth-Hitchcock was initiated during the control period of this study [47]. These two studies overlap in data collection during August 2007. In the operating room (OR) based study, 3 patients in the study group were admitted to the ICU. It is theoretically possible that the hand hygiene intervention in the OR affected the rates of CRBSI and/or VAP in these 3 patients while in the ICU. Since >1000 patients were in the control group of the current study, any changes in these 3 patients is unlikely to have a significant effect on the control group values. At no time has the GJ device been employed in our OR for “regular use” by providers. In fact this device and program has not been offered to our providers during any other part of the study period. Any effect by this overlap could have impacted baseline rates (lowering). And would not have effected the treatment period of the study.

In conclusion, we have demonstrated that the introduction of a personalized hand hygiene device as part of a multi-modal program into the ICU was associated with both a significant increase in observed hand hygiene compliance

and reduction in VAPs. This approach may provide a simple and effective approach to reduce HCAI in other clinical settings. As with other behavioral interventions, further work is required to reduce intrinsic fatigue of the system.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jcrc.2010.12.013.

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