

Brief Original Article

Reduction of nosocomial infections in the intensive care unit using an electronic hand hygiene compliance monitoring system

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Abstract

Introduction: Healthcare-associated infection is an important cause of mortality and morbidity worldwide. Well-regulated infection control and hand hygiene are the most effective methods for preventing healthcare-associated infections. This study evaluated and compared conventional hand hygiene observation and an electronic hand-hygiene recording and reminder system for preventing healthcare-associated infections.

Methodology: This pre- and post-intervention study, employed an electronic hand-hygiene recording and reminder system for preventing healthcare-associated infections at a tertiary referral center. Healthcare-associated infection surveillance was recorded in an anesthesia and reanimation intensive care unit from April 2016 to August 2016. Hand-hygiene compliance was observed by conventional observation and an electronic recording and reminder system in two consecutive 2-month periods. healthcare-associated infections were calculated as incidence rate ratios.

Results: The rate of healthcare-associated infections in the electronic hand- hygiene recording and reminder system period was significantly decreased compared with that in the conventional hand-hygiene observation period (incidence rate ratio = 0.58; 95% confident interval = 0.33-0.98). Additionally, the rate of central line-associated bloodstream infections and the rate of ventilator-associated pneumonia were lower during the electronic hand hygiene recording and reminder system period (incidence rate ratio= 0.41; 95% confident interval = 0.11-1.30 and incidence rate ratio = 0.67; 95% confident interval = 0.30-1.45, respectively).

Conclusions: After implementing the electronic hand hygiene recording and reminder system, we observed a significant decrease in healthcare-associated infections and invasive device-associated infections. These results were encouraging and suggested that electronic hand hygiene reminder and recording systems may reduce some types of healthcare-associated infections in healthcare settings.

Key words: Electronic hand hygiene recording and reminder system; healthcare-associated infection; hand hygiene; compliance.

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Introduction

Healthcare-associated infection (HCAI) is an important cause of mortality and morbidity worldwide, with approximately 2 million infections and 100,000 deaths per year [1]. HCAIs also increase the length and the cost of hospitalization [2]. In recent years, nosocomial infections have been the most important quality indicators of inpatient healthcare institutions. For this reason, well-regulated infection control and hand hygiene are the most effective methods for preventing HCAIs [2]. The World Health Organization (WHO) Guidelines for Hand Hygiene in Health Care recommends the use of a multimodal hand-hygiene improvement strategy [3]. However, hand-hygiene compliance is only 33–65% among healthcare workers in Turkey [4]. The guidelines emphasize monitoring

hand-hygiene compliance to provide feedback to healthcare workers through education and encouraging behavioral changes [5,6].

The gold standard for monitoring is direct observation (DO) of the hand hygiene practices of healthcare workers by trained infection control providers during five indications [3,7]. However, this method does have disadvantages, such as being time intensive, monitoring only a small portion of the total events, and being subjective because the healthcare workers are aware of the observation [8]. It does not represent actual hand hygiene events and observation durations, and training the observers is time consuming [8]. There are physical barriers to DO when healthcare workers draw a curtain or close a door during patient care. Monitoring product usage, which is the other

method for observing hand hygiene, is an indirect method. In addition, it does not represent actual hand hygiene compliance [9–11].

Monitoring hand hygiene can also be performed by automated and electronic hand hygiene reminding and recording systems (EHRRSs). Electronic systems have some advantages compared with DO, and are promising technologies for improving hand-hygiene compliance. These methods can capture more events and data, provide continuous observations and are more objective than human observers [12]. However, they have some limitations, such as poor healthcare worker acceptance due to practice issues (a sensor badge records all events and performance, and personal data are fed back to the wearer) and expensive implementation [13]. Data from McCalla *et al.* indicated that these devices changed or improved hand hygiene compliance and decreased HCAs [13].

This study evaluated and compared the use of conventional hand-hygiene observation and EHRRSs for preventing HCAs in an anesthesia and reanimation intensive care unit (ICU).

Methodology

In this prospective study, HCAI surveillance was recorded in an anesthesia and reanimation ICU with 12 beds in the tertiary Marmara University Pendik Research and Training Hospital from April 2016 to August 2016. The study protocol was approved by the institutional review board with number 09.2016.062. Informed consent was obtained from all participants including nurses, physicians, transporters, and staff of the unit.

Study population and design

All unit caregivers with direct patient contact were considered as participants, including nurses, physicians, transporters, and other staff. The HCAs rates were calculated among inpatients in the anesthesia and reanimation ICU. Handhygiene compliance was observed by conventional methods in the first 2 months and by EHRRS in the second two months.

Conventional hand hygiene observation (CHHO) period

In April and May 2016, hand hygiene compliance was monitored by DOs performed by trained infection control personnel. Data were recorded and stored in our central database. Handhygiene compliance as monitored by DO was defined as using an alcohol-based swab or soap and water according to the five

indications of the WHO guidelines. The rates of HCAs and hand hygiene compliance were recorded.

EHRRS period

In June and July 2016, hand-hygiene compliance was recorded by an EHRRS and stored in our central database. The EHRRS (Hygreen® the hand hygiene reminding and recording system, Hygreen Inc.) recorded all hand-hygiene events at the hospital, certifying the time and place, and reminded healthcare workers that they must apply hand hygiene before interacting with a patient. Every healthcare worker had a hand-hygiene sensor badge. Sensors that detected hand hygiene compliance were placed at the bedsides and at hand washing stations. After the healthcare worker applied hand soap or gel, the hand-hygiene sensor turned green. If the badge was green, the sensor on the bedside recorded it as a correct event while the patient was being provided care. If the healthcare worker did not apply hand hygiene, the badge did not turn green, the bedside sensor recorded it as an incorrect event, and it reminded the healthcare worker to perform hand hygiene via vibration. The rates of HCAs and hand hygiene compliance were recorded.

Conventional hand-hygiene observation was also continued throughout the second period, which is the routine mandatory policy of the healthcare facilities.

Infection rates

HCAs and colonization rates were recorded. Data on the number of HCAs were collected by routine hospital infection surveillance. HCAs were defined according to the guidelines [14]. HCAs rates were calculated for each month of the evaluation interval. The number of healthcare-associated infections was divided by the number of patients and multiplied by 100. Additionally, HCAI rates were calculated for each study period. T invasive device-associated infections were calculated as the number of invasive device-associated infections divided by the number of invasive device days multiplied by 1,000.

Statistical analysis

Patient demographic data were represented as total numbers and percentages with medians and ranges. Healthcare-associated infections were analyzed to compare the odds ratio (OR), relative risk (RR), incidence rate ratio (IRR) and relative risk reduction (RRR) with 95% confidence intervals (CIs) between the two periods. Central line-associated bloodstream infection (CLABSI), ventilator-associated pneumonia (VAP), and catheter-associated urinary tract infection

Table 1. Patient demographic characteristics in anesthesia and reanimation intensive care unit, April-July 2016 and comparison of two groups.

Characteristic	CHHO* period	EHHRRS** period	p	Difference (95% CI)
Total patients, n (%)	116 (46.7 %)	141 (56.9 %)	0.1	10.2% (-2.03 to 22.03)
Female, n (%)	41 (35.3%)	52 (36,8 %)	0.80	1.5% (-10.25 to 13.03)
Male, n (%)	75 (64.6 %)	89 (63.2%)	0.80	1.5% (-10.25 to 13.03)
Age, y (range)	55.2±20.2 (15-100)	57.1±19.5 (14-93)	0.44	1.9 (-2,99 to 6,79)
Causes of hospitalization				
Surgical procedures	57 (49.1%)	68 (48.2%)	0.88	0.9% (-11.20 to 12.98)
Trauma	22 (19.0%)	20 (14.2%)	0.30	4.8% (-4.27 to 14.21)
Respiratory distress	18 (15.5)	17 (12.1%)	0.43	3.4% (-5.02 to 12.25)
Mean length of ICU† stay, d (range)	7.6±12.4 (1-61)	6.6±9.8 (1-61)	0.47	1 (-3.72 to 1.72)

† Intensive care unit; * Conventional hand-hygiene observation period; ** Electronic hand hygiene recording and reminder system period; HCAI: Healthcare-associated infection.

(CAUTI) rates were represented as the IRR and the RRR with 95% CIs for the two periods.

Results

Hand-hygiene compliance rates

During the CHHO period, hand hygiene compliance was 49.1%. After the EHHRRS intervention, hand-hygiene compliance increased to 89.2%.

Patient demographic characteristics

During this study, 248 patients were observed over 4 months. The characteristics of the patient population before and after implementation of the EHHRRS are shown in Table 1. The number of patients during the CHHO and EHHRRS periods was 116 and 141, respectively. The age, length of hospital stay, and causes of ICU admission were similar during the CHHO and EHHRRS periods (Table 1).

HCAI rates

The rates of HCAs were recorded during the DO and EHHRRS periods. The rates of nosocomial infections by month were as follows: 33.33% in April 2016, 24.63% in May 2016, 20.73% in June 2016, and 11.84% in July 2016 (Table 2). The rate of HCAs during the EHHRRS period was significantly lower when compared with the CHHO period (31.89% vs. 18.43%, OR = 2.07; 95% CI = 1.16–3.69, p = 0.013, RR = 0.58, 95% CI = 0.37–0.89, p = 0.014). The RRR for

HCAs was 51.73%, 95% CI = 27.13–68.02. The IRR for HCAs was 0.58, 95% CI = 0.33–0.98. The most commonly detected HCAs were VAP and CLABSIs during both study periods.

During the CHHO period, the rate of CLABSI was 25.46 per 1,000 catheter days (n = 11 CLABSIs). This rate decreased to 10.63 per 1,000 catheter days during the EHHRRS period (n = 5 CLABSIs) (Table 3). The RRR for CLABSI was 58% (25.46 per 1,000 catheter days vs. 10.63 per 1,000 catheter days, RRR = 58.22%, 95% CI = -19.27% to 85.37%). The IRR for CLABSI was 0.41 (95% CI = 0.11–1.30).

During the CHHO period, the rate of VAP was 29.11 per 1,000 ventilator days (n = 20 VPA). This rate decreased to 19.76 per 1,000 ventilator days during the EHHRRS period (n = 12 VAP) (Table 3). The RRR for VAP was 43% (29.11 per 1,000 ventilator days vs. 19.76 per 1,000 ventilator days, RRR = 43.41%, 95% CI = -19.94% to 73.30%). The IRR for VAP was 0.67 (95% CI = 0.30–1.45).

During the CHHO period, the rate of CAUTIs was 2.24 per 1,000 catheter days (n = 2 CAUTIs). This rate was similar to that of the EHHRRS period at 2.25 per 1,000 catheter days (n = 2 CAUTIs) (Table 3). There was no difference between the two periods.

Discussion

In our study, after implementing the EHHRRS, hand-hygiene compliance in the Anesthesia and Reanimation ICU increased from 49.1% to 89.2%.

Table 2. Comparison of HCAs ratio with respect to study period.

	HCAI Incidence rate)†	Odds ratio (OR) (95% confidence interval)	p	Relative Risk (RR) (95% confidence interval)	p	Relative Risk Reduction (RRR) (95% confidence interval)	Incidence rate ratio (95% confidence interval)
CHHO* period	31.89 % (37/116)	2.07 (1.16-3.69)	0.013	0.58 (0.37-0.89)	0.014	51.73% (27.13-68.02)	0.58 (0.33-0.98)
EHHRRS** period	18.43% (26/141)						

† Infections per patient number multiplied by 100; * Conventional hand-hygiene observation period; ** Electronic hand hygiene recording and reminder system period; HCAI: Healthcare-associated infection.

Furthermore, we observed a significant decrease in HCAs from 31.89% to 18.43%.

It was shown that the EHHRRS increased hand hygiene compliance and therefore improved infection control and prevention measures. Several previous studies have demonstrated an improvement of hand-hygiene compliance when using electronic or automated monitoring systems like our findings [15–18]. Michael *et al.* showed an increase of hand-hygiene compliance over 90% by automated observation. In addition, they also observed an ongoing- longitudinal effect on good hand-hygiene compliance during the first year after discontinuation of the intervention [16]. Knepper *et al.* similarly found significantly improved hand-hygiene compliance from 47% at baseline to 77% after intervention (i.e., an automated hand hygiene monitoring system combined with education, troubleshooting and feedback). In line with the previous study, they also demonstrated a sustained effect as the rate of compliance remained > 70% throughout the 18 month period after discontinuation of the interventions [17]. As electronic systems record hand hygiene automatically, one concern could be that the higher ratios of compliance may be the result of more accurate recording with these systems compared to DO. However, studies have demonstrated that both methods report similar rates of hand-hygiene compliance for the same time period [16,19]. In line with the literature, the rate of hand-hygiene compliance was increased from 49.1% to 89.2% after the intervention in our study.

To our knowledge, only a few studies have evaluated the effect of electronic and automated systems on more solid outcomes (i.e., infection rates) other than hand hygiene compliance. Kelly *et al.* demonstrated a significant correlation between electronic monitoring compliance and reductions in methicillin resistant *Staphylococcus aureus* infection rates [18]. Also, Knepper *et al.* demonstrated an improvement in healthcare facility-onset *Clostridioides*

difficile infection rates after implementation of the intervention, although there was no effect on other hospital acquired infections rates [17]. However, studies investigating the effect of these systems on HCAs and invasive device-associated infections rates are scarce, since they are new and expensive technologies. McCalla *et al.* showed that an automated hand-hygiene compliance system was associated with decreased rates of HCAs [13]. In our study, the EHHRRS was associated with a reduction in HCAs from 31.89% to 18.43%. As we did not change any other infection prevention interventions in our hospital, we concluded that this reduction was directly related to the effect of the EHHRRS.

Conclusions

In our study, we observed a dramatic reduction in the rate of CLABSIs from 25.46 per 1,000 catheter days to 10.63 per 1,000 catheter days during the EHHRRS period. A similar reduction has also been observed in other studies, however they implemented additional interventions, such as training in central line insertion and maintenance [13]. By contrast, in the current study, we did not make any changes related to the prevention of CLABSIs. Moreover, we also observed a reduction in the rate of VAP from 29.11 per 1,000 ventilator days to 19.76 per 1,000 ventilator days during the EHHRRS period without having taken any additional measures to prevent VAP. Data about the effects of EHHRRSs on VAP are lacking. However, Koff *et al.* revealed that after using personal alcohol-based hand cleansers (providing alcohol solutions and recording hand hygiene events but not reminding workers to perform hand hygiene events), the rate of VAP was significantly reduced [20]. During the current study, we did not observe a change in the rate of CAUTIs. This could have been because we did not observe a sufficient number of infections during the study period. By

Table 3. Comparison of invasive device associated infections ratios with respect to study period.

Infection	CHHO* period	EHHRRS** period	Incidence rate ratio (95% confidence interval)	RRR (95% confidence interval)
CLABSI Incidence rate (infections per 1,000 central line days for central line-associated bloodstream infections)	25.46	10.64	0.41 (0.11-1.30)	58.22 % (-19.27- 85.37)
VAP Incidence rate (infections per 1,000 ventilator days for ventilator associated pneumonia)	29.11	19.77	0.67 (0.30-1.45)	32.09 % (-37.75-66.52)
CAUTI Incidence rate (infections per 1,000 catheter days for catheter associated urinary tract infection)	2.24	2.25	1.00 (0.07-13.85)	0.45 % (-611.54-85.82)

* Conventional hand-hygiene observation period; ** Electronic hand hygiene recording and reminder system period; CLABSI: Catheter line associated bloodstream infection; VAP: Ventilator associated pneumonia; CAUTI: Catheter associated urinary tract infection.

contrast, McCalla *et al.* demonstrated a significant reduction in CAUTIs by using electronic systems [13].

There were some limitations to our study. The major limitation of was the short study duration, because healthcare workers were resistant to wearing the tracking device badge the study period was only 4 months because of healthcare workers' concerns. Additionally, consultants did not wear a badge so their hand hygiene events could not be recorded by the EHHRRS. Furthermore, the EHHRRS records and measures hand-hygiene events t before patient contact and after patient contact and patient's surroundings contact of the 5 WHO-recommended moments for performing hand hygiene [13,15,18]; however, these moments encompass the majority (78.8%) of the all 5 WHO-recommended moments for observation [7]. Moreover, CHHO was also proceeded throughout our study period for the other moments, such as after body fluid exposure and before aseptic procedures. A strength of our study is defining more solid outcome as frequency of HCAs, besides hand hygiene compliance rates.

Despite the short study duration, these encouraging results suggested that EHHRRSs may increase hand-hygiene compliance and reduce HCAs in healthcare settings. These systems maybe complicated to use and to implement in practice, which could cause hesitancy and unwillingness among healthcare workers to wear a sensor badge. However, our promising results may encourage healthcare workers to use these systems. as they indicate that EHHRRs reduce HCAs.

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