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Reduction in Intraoperative Bacterial Contamination of Peripheral Intravenous Tubing Through the Use of a Novel Device

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Background: **Hand hygiene is a vital intervention to reduce health-care associated infections, but compliance remains low. The authors hypothesized that improvements in intraoperative hand hygiene compliance would reduce transmission of bacteria to surgical patients and reduce the incidence of postsurgical healthcare-associated infections.**

Methods: **The authors performed a controlled before-and-after study over 2 consecutive months. One hundred fourteen operative cases were enrolled. Two predesignated sites on the anesthesia machine were selected, decontaminated, and cultured *via* aseptic technique. These sites and the peripheral intravenous stopcock were cultured again after completion of the surgery. The treatment phase used a novel personal hand-decontamination device capable of recording hand-decontamination events.**

Results: **There were no significant differences in patient location, age, or case duration and procedure type between groups. Use of the Sprixx GJ device (Harbor Medical Inc., Santa Barbara, CA) increased hourly hand decontamination events by 27-fold as compared with baseline rates ($P < 0.002$; 95% confidence interval, 3.3–13.4). Use of the device was associated with a reduction in contamination in the anesthesia work area and peripheral intravenous tubing. Intravenous tubing contamination was identified in 32.8% of cases in the control group *versus* 7.5% in the treatment group (odds ratio, 0.17; 95% confidence interval, 0.06–0.51; $P < 0.01$). Healthcare-associated infections rates were reduced in the device group (3.8%) as compared with the control group (17.2%) (odds ratio, 0.19; 95% confidence interval, 0.00–0.81; $P = 0.02$).**

Conclusions: **Improved hand hygiene compliance through the use of a novel hand sanitation strategy reduces the risk of intraoperative bacterial transmission. The intervention was associated with a reduction in healthcare-associated infections.**

This article is featured in "This Month in Anesthesiology." Please see this issue of ANESTHESIOLOGY, page 9A.

This article is accompanied by an Editorial View. Please see: Hopf HW, Rollins MD: Reducing perioperative infection is as simple as washing your hands. ANESTHESIOLOGY 2009; 110:959–60.

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THE importance of hand hygiene in healthcare-associated infection (HCAI) was demonstrated before microorganisms were known to cause infection. In 1847, Ignaz Philipp Semmelweis, M.D. (Professor of Obstetrics at the University of Pest, Budapest, Hungary, 1818–1865), ordered all students and physicians to scrub their hands with a 4% chlorinated lime solution, yielding a 15% reduction in peripartum mortality. However, despite the continued success of this disinfection strategy, this practice was strongly opposed by his colleagues and never gained generalized acceptance.[1,2] Therefore, despite modern advances in microbiology, epidemiology, and infection control, widespread and consistent use of hand disinfection strategies continues to remain elusive more than 160 yr later.

As a result of the ineffective adherence to preventative measures, including aseptic practice, inanimate surface decontamination, barrier techniques, hand hygiene, antibiotic prophylaxis, and maximizing host defenses, 10% of hospitalized patients in the United States acquire a healthcare-associated infection. These infections contribute to the mortality of 90,000 hospitalized patients and $4.5 billion in additional healthcare costs annually.[3] With widespread adoption of these important preventative strategies, the majority of these infections can be prevented. Current rates are indefensible and, if not aggressively reduced, will serve as a disgrace to the entire healthcare community. In the near future, the Centers for Medicare and Medicaid Services may not reimburse for healthcare costs associated with these infections.[4]

Extensive work has been focused on the prevention of surgical site infections with regard to maintenance of a sterile surgical environment, preoperative antibiotics, and maintenance of patient temperature and oxygen tension. Relatively little is known about the anesthesia workspace, including the anesthesia machine, anesthesia cart, and intravascular devices. However, the risk of bacterial transmission to patients exists within the operative environment,[5] and surveys suggest that anesthesia personnel inconsistently adhere to preventative measures such as hand hygiene guidelines and aseptic technique.[6,7] In an observational study looking at physician adherence to hand hygiene, anesthesiologists were the worst performers of all specialties observed.[8] The aseptic practice of anesthesia personnel must be considered

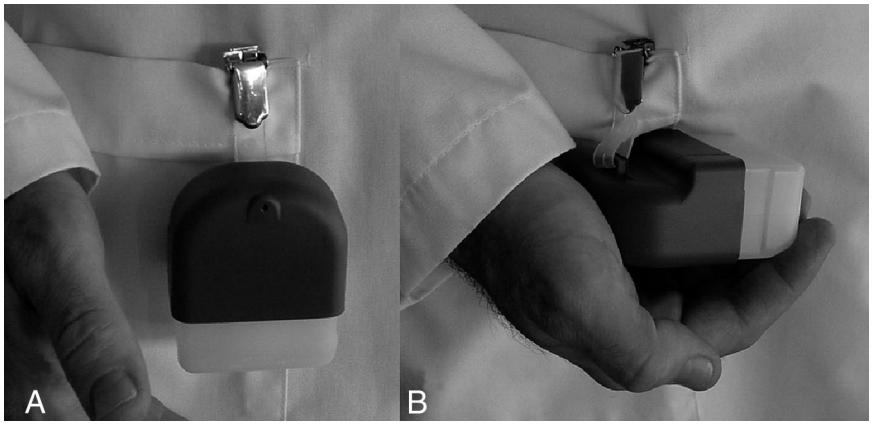

Fig. 1. The Sprixx GJ device (Harbor Medical Inc., Santa Barbara, CA). (*A*) Device worn by provider. (*B*) Alcohol-based cleanser deployed by squeezing device.

in hospital-wide approaches designed to reduce the development of HCAI.

Current Centers for Disease Control and Prevention and World Health Organization guidelines present evidence-based recommendations designed to improve and promote hand hygiene practices of healthcare workers.[9,10] Within these guidelines, the importance of the development of experimental models for the study of cross-contamination from patient to patient and from environment to patient is emphasized.

Three main techniques are important to prevent infection transmission from the provider to the patient. These include aseptic practice, proper hand hygiene, and appropriate barrier techniques.[11]

Because limited data exist with regard to direct observational studies with anesthesia provider adherence to these guidelines,[8,12,13] we performed an observational study at our institution, evaluating baseline provider adherence to these techniques. We then sought to increase hand hygiene compliance through the use of a point-of-care alcohol-based hand hygiene device. We chose an ethanol based hand-rub solution because of its efficacy, ease of use during frequent patient encounters, and low incidence of adverse skin reactions.[9] We hypothesized that increased hand hygiene compliance would reduce intraoperative bacterial transmission and associated postoperative HCAI rates.

Materials and Methods

Methods

We performed a controlled before-and-after study over 60 consecutive weekdays at Dartmouth-Hitchcock Medical Center, a tertiary care and level 1 trauma center for the state of New Hampshire with 400 inpatient beds and 28 operating suites. Approval was obtained from the institutional review board with no requirement for patient or provider consent (Committee for the Protection of Human Subjects, Dartmouth College, Hanover, New Hampshire). Study participation was voluntary for all providers enrolled in the study. Two providers (attending and resident) assigned to an operative room that was randomized to the treatment group refused to wear and use the Sprixx GJ device (Harbor Medical Inc., Santa Barbara, CA). Data from this room were collected, and the data were analyzed as intention to treat.

This was a two-component study designed to compare both standard hand hygiene practice by anesthesia providers and baseline intraoperative bacterial transmission in the anesthesia work area (before group) with hand hygiene frequency and bacterial transmission after provision of a novel device designed to improve hand hygiene compliance of anesthesia providers (after group). The observational and microbial study components were performed in parallel in both the before and after groups. A computerized medical record was also reviewed over 30 postoperative days for evidence of HCAI development and associated morbidity and mortality in both groups.

Hand Hygiene Frequency. Rooms were randomly chosen by a computer-generated list over two consecutive months. July and August 2007 served as the control and treatment groups, respectively. In the control group, providers were directly observed regarding hourly hand hygiene decontamination episodes (HHDEs) throughout the entire case. One hand decontamination event was defined as any use of either a wall-mounted alcohol-based gel dispenser or 70% ethanol liquid dispenser. The same trained research assistant recorded all observations, and providers were blinded to observational criteria and indications. Observation was voluntary, and no providers refused to participate. However, they were aware of the presence of the trained observer. Each operating room had both a wall-mounted alcohol-based gel dispenser located within three steps of the anesthesia provider and a 70% ethanol liquid dispenser on the anesthesia cart.

In the treatment group, anesthesia providers were given a GJ Hand Sanitation Device in addition to the wall-mounted and 70% alcohol 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

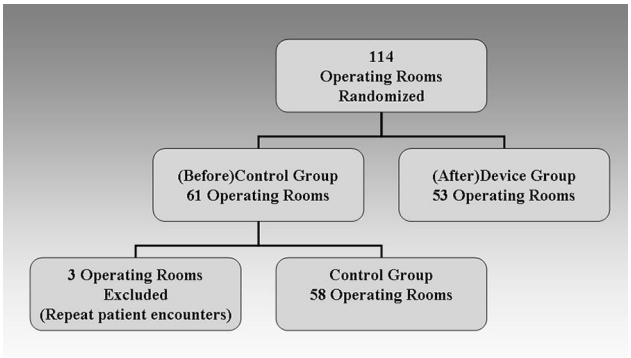

Fig. 2. Operating room and patient enrollment.

hand decontamination event 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). An efficacy study voluntarily enrolling 20 anesthesia residents and culturing the dominant hand (palmar aspect only) yielded a 99% reduction in colonies per surface sampled (CPSS) 1 min after performing HHDE (actual data not shown). Providers were briefly instructed regarding proper use of the device with further assistance and support available by pager. An audible alarm set for 6 min prompted providers to perform hand hygiene if there were no events recorded in the 6-min interval. Anesthesia personnel throughout the entire surgical case wore this device, and recorded information was then analyzed with regard to frequency and timing of use.

The HHDEs in the control group were then directly compared with the HHDEs in the treatment group as measured by the device. In the before and after groups, 46 and 97 providers were evaluated, respectively.

Intraoperative Bacterial Transmission. Over a 2-month consecutive period, operative suites were randomly selected for analysis by a computer-generated list. The first month (July 2007) served as a control and involved data collection on patients without use of the hand sanitation device. The following month (August 2007) served as the treatment group, with institution of the GJ Hand Sanitation Device. Patients who underwent multiple trips to the operating room were analyzed only on the first trip (fig. 2). In the before and after groups, 58 and 53 patients were enrolled, respectively.

One patient to receive general anesthesia according to usual practice was followed in each operative suite during the first case scheduled in the room for the day. This was to avoid the possibility of case-to-case transmission. Each patient received a sterile set of intravenous tubing and stopcock set, 24 inches with three gang four-way and T-connector (SetSource, San Clemente, CA), by nursing staff in the preoperative holding area. Alternatively, the sets were provided by anesthesia providers intraoperatively on arrival from the inpatient or intensive care units. In cases of patients with multiple intravenous sets, the anesthesia provider was asked to use only one intravenous set, and only the intravenous set used by the anesthesia provider was cultured. Culture of the intravenous stopcock set immediately on removal from the packaging material was invariably negative.

The anesthesia pressure-limiting valve and agent dial were sanitized with a quaternary ammonium disinfectant (Dimension III; Butcher's, Sturtevant, WI) solution according to protocol. Baseline cultures were then obtained from these sites at time 0 (T_0) and once again after completion of the case or time end (T_E) but before disinfection according to current protocol. In addition, the internal lumens of all three intravenous stopcock ports were cultured by the end of the surgical case as described by Loftus *et al.*[5]

Time zero cultures were considered to represent a baseline, such that any new pathogen cultured at the end of surgery was presumed to be acquired in the operating room. The primary outcomes were bacterial CPSS (cells per surface sampled) above baseline (T_0) and number of positive stopcock sets at T_E. The number of anesthesia providers, level of training, surgical procedure and duration, anesthesia type and duration, American Society of Anesthesiologists physical status, and age and sex of patients were also recorded.

Laboratory Investigations

Sampling of the Anesthesia Environment (T_o and T_E). After decontamination of the anesthesia pressure-limiting valve complex and agent dial with Dimension III disinfectant solution according to the manufacturer's recommendations, baseline cultures were obtained by using sterile polyester fiber–tipped applicator swabs moistened with sterile transport medium (BactiSwab, Remel collection and transport system, Lenexa, KS) to roll over the entire surface area of the selected sites two times followed by culturing on sheep blood agar plates with a zigzag pattern and swab rotation to detect both gram-positive and gram-negative bacteria.[14]

Sampling of Peripheral Intravenous Tubing (Three-way Stopcocks). A sterile nasopharyngeal swab (BactiSwab) moistened with sterile transport medium was inserted into the internal surfaces of each port of the three-way stopcocks and rotated 360° ten times to culture. Each swab potentially containing bacteria from any of the three lumens of the single stopcock set was then inoculated onto a sheep blood agar plate using a zigzag pattern and swab rotation.[14]

Microbial Culture Conditions. All blood agar plates were incubated at 35°C for 48 h, and microorganisms were quantified according to CPSS and identified according to standard laboratory methods.

Bacterial Identification. Bacterial organisms found within the anesthesia work area but without associated stopcock contamination or hemolysis were presumptively identified by colony morphology, Gram stain, and

simple rapid tests. All organisms associated with stopcock contamination and/or hemolysis underwent further identification.

Gram-positive organisms were identified using the Dade Behring MicroScan Positive panels (Dade-Behering, San Diego, CA) identification type 2 panel intended for identification of rapidly growing aerobic and facultative gram-positive cocci (some fastidious aerobic gram-positive cocci and *Listeria monocytogenes*). Organism identification was based on modified conventional and chromogenic tests using pH changes, substrate se, and growth in the presence of antimicrobial agents after 16–44 h of incubation at 35°C.

Recovered organisms were identified by standard clinical microbiology techniques supplemented by chromogenic panels (Dade-Behering Microscan) and antimicrobial susceptibility by broth microdilution (Dade Behering Microscan) or Kirby-Bauer disk diffusion. Methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococcus were confirmed by agar dilution minimal inhibitory concentration.[15]

Analysis of Healthcare-associated Infections. For 30 postoperative days, our institution's proprietary computerized medical record was used to review all available inpatient and outpatient documentation for evidence of healthcare-associated infections in both groups. Inpatient and outpatient notes, antibiotic use, and microbial culture results were assessed and recorded. The reviewers were blinded to the presence or absence of stopcock contamination. Patients who developed HCAI but underwent multiple trips to the operating room were considered to have only one infection. HCAI were identified based on current Centers for Disease Control and Prevention definitions.[16] No patients were lost to follow-up, including their 6-week postoperative visit, which detailed the presence or absence of infection.

Statistical Analysis

Analysis. The primary outcomes in this study were the presence of a positive culture from the peripheral intravenous tubing (stopcock) set and frequency of hourly hand decontamination events. Secondary outcomes were the number of colonies on the anesthesia machine (anesthesia pressure-limiting valve and agent dial) as well as the presence or reduction of HCAI and any subsequent reduction in morbidity and mortality.

Univariate analysis for binary variables consisted of either Fisher exact test or chi-square test as appropriate. We considered the number of colonies on either the stopcock or on the two anesthesia sites as a Poisson process. Generalized linear models with either logistic link or log link were used to model binary and count data, respectively. Covariates used for adjustment included duration of surgery; level of training of the provider; patient age, sex, and American Society of Anesthesiologists physical status; and the emergent nature of the procedure. A P value of 0.05 was taken to indicate statistical significance without adjustment for multiple comparisons. Ninety-five percent confidence intervals (CIs) are reported.

Power. For the microbial study, we hypothesized a baseline rate of culture-positive peripheral intravenous tubing (stopcock set) to be approximately 20% and considered the number of colonies recovered from the anesthesia work area as the primary predictor of a positive stopcock. Assuming an odds ratio (OR) of at least 2, approximately 50 sites in each group would provide a power of 0.95 with a type I error rate of 0.05 as described by Loftus *et al.*[5] For the observational study, we hypothesized a 50% increase in hourly hand-decontamination event frequency with device use. Approximately 45 patients in each group were required to provide a power of 0.95 with a type I error rate of 0.05.

Results

During the study period, a total of 111 operative cases were enrolled for microbial analysis, with 58 and 53 randomized to the control and treatment groups, respectively. Three cases were excluded from the analysis because of multiple trips to the operating room (fig. 2). For the observational study, 46 providers were evaluated in the before (control) group and 97 providers were evaluated in the after (device) group.

Patients underwent a variety of surgical procedures with baseline comparisons between groups, shown in table 1. There were no significant differences in patient location, type of surgery, or surgical duration. As compared with the treatment group, there were more patients in the control group with American Society of Anesthesiologists physical status II ($P = 0.04$; 95% CI, 0.17–0.97).

In addition, we explored the Study on the Efficacy of Nosocomial Infection Control Index as a potential predictive measure for the development of infections in the treatment and control groups.[17] This score was used to evaluate whether the difference in infection rates between groups could be explained by prior risk. However, the Study on the Efficacy of Nosocomial Infection Control scores were nearly identical in both groups (data not shown).

Table 2 compares baseline hand hygiene events with providers who used the device. Attending physicians had approximately 6.9 times more hourly HHDEs than observed baseline rates ($P = 0.002$; 95% CI, 1.9–11.0). Other providers used the device 8.3 times more than observed baseline rates ($P = 0.002$; 95% CI, 3.3–13.4).

Table 3 compares likelihood of contamination of the anesthesia machine (anesthesia pressure-limiting valve) and peripheral intravenous tubing in the control and treatment groups. Use of the hand sanitation device

Table 1. Patient Demographics

	Device, n = 53		Control, n = 58		Comparison		
	Mean or Percent	n	Mean or Percent	n	Odds Ratio/ ¥Difference	95% CI	*P* Value
ASA physical status							0.20
I	30.2%	16	25.9%	15	1.24	(0.55 to 2.82)	0.61
II	18.9%	10	36.2%	21	0.41*	(0.17 to 0.97)	0.04
III	37.7%	20	31.0%	18	1.35	(0.62 to 2.94)	0.46
IV	13.2%	7	6.9%	4	2.05	(0.60 to 6.99)	0.27
ASA physical status III or IV	50.9%	27	37.9%	22	1.70	(0.80 to 3.60)	0.17
SENIC index	1.26	53	1.28	58	0.98	(0.64 to 1.50)	0.94
Emergent	18.9%	10	13.8%	8	1.45	(0.54 to 3.91)	0.47
Location							0.95
Intensive care unit	5.7%	3	6.9%	4	0.81	(0.19 to 3.42)	0.79
Floor	9.4%	5	10.3%	6	0.90	(0.27 to 2.99)	0.87
Same-day patient	84.9%	45	82.8%	48	1.17	(0.44 to 3.15)	0.76
Mean age, yr	45.7	29.1	50.7	24.5	¥−5.0	(−15.1 to 5.2)	0.34
Female sex	64.2%	34	51.7%	30	1.67	(0.78 to 3.56)	0.19
Mean duration, min	107.5	109.0	148.1	137.0	¥−40.6	(−87.0 to 5.8)	0.09
Procedure							
Neurosurgery	5.7%	3	4.9%	3	1.16	(0.26 to 5.27)	0.86
Otolaryngology	5.7%	3	9.8%	6	0.55	(0.14 to 2.13)	0.41
Cardiothoracic	5.7%	3	9.8%	6	0.55	(0.14 to 2.13)	0.41
General	28.3%	15	25.9%	15	1.13	(0.45 to 2.85)	0.77
Urologic/gynecologic	5.7%	3	14.8%	9	0.35	(0.10 to 1.26)	0.11
Orthopedic	17.0%	9	13.1%	8	1.36	(0.50 to 3.70)	0.56
Pediatric	22.6%	12	14.8%	9	1.69	(0.66 to 4.31)	0.28
Vascular	9.4%	5	3.3%	2	3.07	(0.65 to α)	0.17

¥Difference. *Statistically significant.

ASA = American Society of Anesthesiologists; CI = confidence interval; SENIC = Study on the Efficacy of Nosocomial Infection Control.

significantly reduced contamination of the anesthesia machine (78 fewer colonies per surface sampled; $P = 0.01$; fig. 3) with an associated reduction in contamination of peripheral intravenous tubing (OR, 0.17; $P < 0.01$). It is interesting to note that the mean CPSS is reduced more than the median CPSS (table 3) and that the CPSS is fairly symmetric on the log scale (fig. 3). This suggests that the device may work by reducing the proportion of CPSS rather than a fixed number.

As shown in table 4, we further investigated the extent to which HHDEs reduced stopcock contamination through logistic regression analysis. Without adjustment, HHDEs were associated with a significant reduction in contamination of peripheral intravenous tubing colonies per surface sampled (OR, 5.31; $P < 0.01$). Accounting for potentially confounding variables such as American Society of Anesthesiologists physical status, age, and inpatient and outpatient locations, we observed a much larger reduction in the likelihood of bacterial contamination attributed to use of the hand decontamination device (OR, 10.2; $P < 0.01$). Subgroup analysis also revealed that in providers without the device who cared for patients in this group (control), case duration was significantly associated with an increased likelihood of developing nosocomial infections (OR, 1.54; $P < 0.01$). This relationship was not observed in the treatment group.

We also analyzed the extent to which level of training was associated with stopcock contamination. Solo attending anesthesia providers had the lowest rate (0 of 8, 0%), followed by clinical anesthesia year 3 (CA-3) residents (2 of 23, 8.7%), CA-2 residents (7 of 29, 24.1%), CA-1 residents (4 of 22, 18.1%), and certified registered nurse anesthetists (10 of 26, 38.5%). Logistic regression showed an overall trend toward statistical significance of the association of provider level of experience with stopcock contamination ($P = 0.08$).

Table 2. Comparison of the Hourly Hand-decontamination Events of the Observational Study with the Device Group

	Device		Control		Comparison		
	Mean (SD)	n	Mean (SD)	n	Difference	95% CI	*P* Value
Attending physicians	7.1 (1.4)	52	0.15 (0.05)	17	6.9 (2.51)	(1.9 to 11.0)	0.008*
Other providers	8.7 (2.0)	45	0.38 (0.12)	29	8.3 (2.5)	(3.3 to 13.4)	0.002*

*Statistically significant.

CI = confidence interval.

Table 3. Outcomes

	Device Group, n = 53		Control Group, n = 58		Comparison		
Continuous Variables	Mean, Median	SD, IQR	Mean, Median	SD, IQR	Mean Difference	95% CI of Mean	*P* Value
CPSS baseline (n = 52‡)	33.6	106.7	19.8	69.7	13.8	(−20.8 to 48.4)	0.43
	3	1–75	4.5	1–10			0.17
CPSS T_E (n = 51‡)	54.3	100.4	132	201.6	−77.7*	(−137.3 to 18.1)	0.01
	13	2–66	28.5	9–129			0.15
Binary Variables	Percent	Count	Percent	Count	Odds Ratio	95% CI	*P* Value
Stopcock positive	7.5	4	32.8	20	0.17*	(0.06 to 0.51)	< 0.01
Nosocomial infection	3.8	2	17.2	10	0.19*	(0.00 to 0.81)	0.02
Death	0.0	0	3.4	2	0.00	(0.00 to 2.09)	0.17
Postoperative location							
Same-day surgery	84.9	45	82.8	48	1.17	(0.44 to 3.15)	0.76
Hospital ward	9.4	5	10.3	6	0.9	(0.27 to 2.99)	0.87
Intensive care unit	5.7	3	6.9	4	0.81	(0.19 to 3.42)	0.79

*Statistically significant. ‡Because of missing data, denominators were slightly different in the treatment group and are listed in parentheses.
CI = confidence interval; CPSS = cells per surface sampled; IQR = interquartile range; T_E = end of surgery.

A computerized medical record review over 30 postoperative days revealed a reduction in HCAI infection rates (3.8% in the device group, 17.2% in the control group; $P = 0.02$; 95% CI, 0.00–0.81). Device use by 7.4 providers was required to prevent one infection (number needed to treat, 7.4; 95% CI, 1.3–13.5). No significant reduction in mortality was observed.

Seventeen percent of patients (10 of 58) in the control group developed HCAI, including ventilator-associated pneumonia (2), wound (5), bloodstream (2), and urinary (1). Two patients in this group ultimately died after a prolonged stay in the intensive care unit. Four percent of cases (2 of 53) in the treatment group developed healthcare-associated wound infections, and there were no patient deaths in this group. Of the 5 patients who had both positive bacterial growth obtained by culture of their stopcocks and HCAI as determined by retrospective chart review, all 5 had the same organism (by morphology) was recovered from the stopcock and/or the anesthesia workspace. Intraoperative transmission of multidrug-resistant bacterial organisms to intravenous stopcocks occurred in three cases in the control group, 2 methicillin-resistant *Staphylococcus aureus*, and 1 vancomycin-resistant enterococcus. Two of 3 of these patients died after intensive care unit stays. In contrast, no multidrug-resistant bacteria (0 of 53) were recovered in the stopcocks of the treatment group.

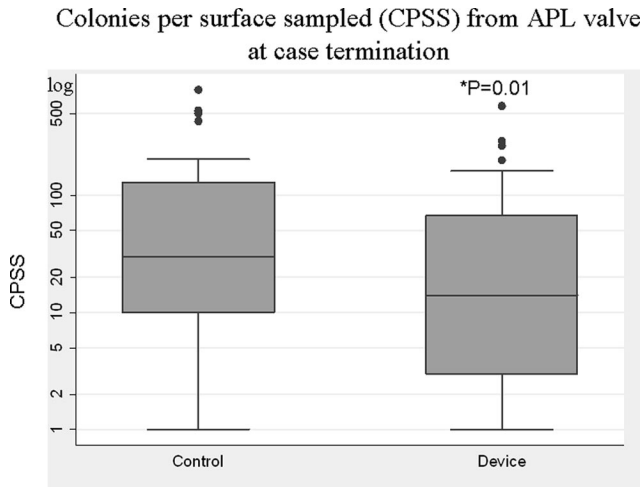

Fig. 3. Box plot of colonies per surface sampled (CPSS) recovered from the anesthesia machine at case termination in the before group (control) and after group (device) ($P = 0.01$). APL = anesthesia pressure-limiting valve. * indicates statistical significance.

Discussion

A reduction in the incidence of HCAI will improve the quality of health care and patient safety. Hand hygiene compliance has been shown to be useful in achieving

Table 4. Logistic Regression Models for the Odds of Nosocomial Infection

	Odds Ratio	95% CI	*P* Value
Unadjusted			
Device	5.31*	(1.11 to 25.50)	0.037
Adjusted			
Device	10.20*	(1.42 to 73.25)	0.02
Log (CPSS) baseline	0.65	(0.34 to 1.25)	0.20
Location (same day)			
Floor	0.99	(0.09 to 10.74)	1.0
Intensive care unit	2.34	(0.09 to 58.94)	0.61
ASA physical status (I)			
II	0.09	(0.00 to 4.53)	0.22
III	0.92	(0.04 to 20.13)	0.96
IV	8.29	(0.25 to 272.15)	0.23
Duration, h	1.54*	(1.10 to 2.14)	0.01
Age, yr	1.03	(0.98 to 1.08)	0.26
Male sex	2.70	(0.50 to 14.73)	0.25

* Significant odds ratio.
ASA = American Society of Anesthesiologists; CI = confidence interval; CPSS = colonies per surface sampled.

this goal throughout the healthcare environment,[18–23] but global acceptance and application of this critical component of aseptic practice remain elusive.

Recently, intraoperative bacterial contamination of both the anesthesia workspace and patient intravenous tubing with pathogenic bacterial organisms has been demonstrated and was associated with an increase in overall patient mortality.[5,24] Given the recent increase in community spread of pathogenic, multidrug-resistant bacterial organisms, this is a major public health concern.[25]

The primary intent of this study was to reduce overall bacterial contamination of both the anesthesia work area and patient intravenous tubing through improvements in hand hygiene compliance of anesthesia providers. We then evaluated the overall impact of this intervention on the subsequent development of HCAI. We have shown that a simple, cost-effective device designed to improve hygiene practice markedly reduces intraoperative bacterial transmission and subsequent postoperative infection development. This intervention, along with proper instruction of aseptic practice techniques and barrier precautions, could markedly reduce intraoperative patient transmission of potentially pathogenic bacterial organisms and ultimately reduce the incidence of HCAI.

These data are alarming with regard to patient safety, especially in light of recent attempts by organizations to reduce HCAI and medical errors.[26] Providers in the observation group performed such infrequent HHDEs along with findings in this study that as anesthesiologists we may be directly contributing to HCAI and, until now, unknowingly exposing our patients to harm. We hope that this work serves as a call for future prevention and widespread change in practice patterns. It has also been suggested that specific patient populations may be at higher risk for morbidity and mortality than others if infected during concurrent illness.[27]

However, we recognize several limitations to this study. First, some contamination of both the anesthesia work area and stopcock sets remained despite use of the device. On analysis of the context by which stopcocks from patients in our treatment (device) group became contaminated, it was determined that 50% (2 of 4) were due to refusal to use the device by providers and/or major breaches in aseptic practice. Therefore, we acknowledge that hand decontamination alone will not eliminate all bacterial transmission and that further study is required to maximize provider compliance with the device.

Though device use significantly reduced the development of postsurgical HCAI in the 30-day postoperative period, a potential limitation was reliance on medical record review without a standardized surveillance system. There were, however, no significant differences between the two groups that might otherwise serve as potential etiologies for the healthcare-associated infections, including glycemic and temperature control, prophylactic antibiotic provision, and inspired oxygen concentrations.

It also has been suggested that in academic centers, surgical infections increase in the July–August months compared with September–June months. Presumably this is related to errors by resident physicians while they learn new roles and procedures. Therefore, the rates that we observed in this study may actually overrepresent baseline annual HCAI rates at our institution.

Further, although the GJ device could record the number of HHDEs, we recognize the limitation that it does not derive the number of available opportunity–based hand hygiene events by anesthesia providers. This will require further study. Given the reasonable assumption that aseptic practice at our institution reflects average aseptic practice, we viewed the results of this study as both a reasonable measure of HHDEs by providers at our institution and that of general anesthetic practice.

We recognize that the success of the Sprixx GJ device in reducing bacterial transmission is likely related to multiple factors, including alcohol-based cleanser 70% ethanol and the proximity and ease of use for a highly mobile and high opportunity-linked anesthesia provider. The Hawthorne effect may have also played some role in hand hygiene compliance improvements, but this effect was likely balanced by the lack of a formal educational program or provision of evidence-based recommendations to providers before or after issuing the device. These efforts would have likely yielded a higher HHDE.[28–30]

Also, though increased hand hygiene compliance through use of the device in the treatment group nearly eliminated bacterial contamination in patients' peripheral intravenous tubing, we did not study a threshold for the number of HHDEs required for reduction of such bacterial contamination. The literature, however, provides us with some insight into such a threshold. It has been reported that intensive care unit nurses have 20 hand hygiene opportunities per hour, and it is likely in many surgical cases that anesthesia providers may surpass this.[8,9] It can be inferred from our data that a potential initial goal is to seek 8 HHDEs until further study is performed.

Finally, because this study was a controlled before-and-after design (time trend study) in 2 consecutive months, future studies to randomize operating rooms and providers to a device and standard practice should be performed to further verify these results. However, as of yet, interventions to improve hand hygiene compliance have not achieved a sufficient level of evidence to be recommended by evidence-based organizations such as the Cochrane group.[31]

Despite these limitations, the reductions in both intraoperative contamination and postoperative HCAI in our study is striking, and at the very least shows that hand hygiene is a potential part of a long-term solution to improved aseptic practice in the anesthesia work area. This is also supported

by other evidence suggesting that increased device proximity improves hand hygiene compliance in a variety of settings.[29,30,32,33] The results of this study are similar to data available in other areas of healthcare practice with regard to improved hand hygiene and reduction in healthcare-associated infection and mortality.[9,18,19,21–23,34]

In conclusion, our results demonstrate that the provision of a simple, cost-effective device containing an alcohol-based solution significantly reduces intraoperative transmission of potentially pathogenic bacterial organisms. Our study also suggests that use of this device reduces the incidence of postoperative healthcare-associated infections, but further study is required to verify these results. This, in addition to other strategies to improve aseptic practice and prevent spread of bacterial organisms, should be applied to current anesthetic practice.

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