Section Editor: **Sorin J. Brull**

Hand Contamination of Anesthesia Providers Is an Important Risk Factor for Intraoperative Bacterial Transmission

Randy W. Loftus, MD,* Matthew K. Muffly, MD,* Jeremiah R. Brown, PhD, MS,* Michael L. Beach MD, PhD,* Matthew D. Koff, MD,* Howard L. Corwin, MD,* Stephen D. Surgenor, MD,* Kathryn B. Kirkland, MD,* and Mark P. Yeager, MD*

BACKGROUND: We have recently shown that intraoperative bacterial transmission to patient IV stopcock sets is associated with increased patient mortality. In this study, we hypothesized that bacterial contamination of anesthesia provider hands before patient contact is a risk factor for direct intraoperative bacterial transmission.

METHODS: Dartmouth–Hitchcock Medical Center is a tertiary care and level 1 trauma center with 400 inpatient beds and 28 operating suites. The first and second operative cases in each of 92 operating rooms were randomly selected for analysis. Eighty-two paired samples were analyzed. Ten pairs of cases were excluded because of broken or missing sampling protocol and lost samples. We identified cases of intraoperative bacterial transmission to the patient IV stopcock set and the anesthesia environment (adjustable pressure-limiting valve and agent dial) in each operating room pair by using a previously validated protocol. We then used biotype analysis to compare these transmitted organisms to those organisms isolated from the hands of anesthesia providers obtained before the start of each case. Provider-origin transmission was defined as potential pathogens isolated in the patient stopcock set or environment that had an identical biotype to the same organism isolated from hands of providers. We also assessed the efficacy of the current intraoperative cleaning protocol by evaluating isolated potential pathogens identified at the start of case 2. Poor intraoperative cleaning was defined as 1 or more potential pathogens found in the anesthesia environment at the start of case 2 that were not there at the beginning of case 1. We collected clinical and epidemiological data on all the cases to identify risk factors for contamination.

RESULTS: One hundred sixty-four cases (82 case pairs) were studied. We identified intraoperative bacterial transmission to the IV stopcock set in 11.5% (19/164) of cases, 47% (9/19) of which were of provider origin. We identified intraoperative bacterial transmission to the anesthesia environment in 89% (146/164) of cases, 12% (17/146) of which were of provider origin. The number of rooms that an attending anesthesiologist supervised simultaneously, the age of the patient, and patient discharge from the operating room to an intensive care unit were independent predictors of bacterial transmission events not directly linked to providers.

CONCLUSION: The contaminated hands of anesthesia providers serve as a significant source of patient environmental and stopcock set contamination in the operating room. Additional sources of intraoperative bacterial transmission, including postoperative environmental cleaning practices, should be further studied. (Anesth Analg 2011;112:98–105)

The intraoperative environment is an important contributor to the development of health care–associated infections.[1] Increasing community awareness of this issue, pay-for-performance policies, and quality of patient care all demand the development of preventive measures.[2] A better understanding of the underlying mechanism by which bacterial transmission occurs is necessary to further this process.

We have recently demonstrated that potentially pathogenic organisms, including multidrug-resistant bacteria, are transmitted to both patients and the immediate, intraoperative patient environment (adjustable pressure-limiting [APL] valve and agent dial on the anesthesia machine) during routine administration of general anesthesia.[3] In this previous study, 61 operating rooms (ORs) at Dartmouth–Hitchcock Medical Center were randomly selected for observation during the first case of the day. Transmission events were defined by isolation of potential pathogens from the observed intraoperative environmental sites (APL valve and agent dial) and patient stopcock sets at case conclusion but not at case start. We found that the anesthesia environment became contaminated at case conclusion more frequently than at the start of the case with a mean increase of 115 (median increase 24) colonies per surface sampled ($P < 0.001$), and that contamination occurred in cases as short as 4 minutes. Increasing bacterial contamination of the intraoperative environment

From the *Department of Anesthesiology and Critical Care Medicine, Dartmouth–Hitchcock Medical Center, Lebanon, New Hampshire.

Accepted for publication April 25, 2010.

This study was funded by the Dartmouth–Hitchcock Foundation.

The authors report no conflict of interest.

Address correspondence and reprint requests to Randy W. Loftus, MD, Dartmouth–Hitchcock Medical Center, 1 Medical Center Dr., Lebanon, NH 03756. Address e-mail to randy.loftus@hitchcock.org.

DOI: 10.1213/ANE.0b013e3181e7ce18

was in turn associated with an increased risk of patient contamination via the stopcock set, and contamination of patient stopcock sets was associated with a significant increase in patient mortality.[3]

In the present study, we examined the origin of intraoperative bacterial transmission. We hypothesized that bacterial contamination of anesthesia provider hands before patient contact would serve as an important risk factor for this transmission. The primary aim for this study was to look for direct microbiological evidence to support this hypothesis. Our secondary aim was to evaluate the potential role of environmental decontamination practices in the OR in interrupting the transmission of organisms.

METHODS

General Description

This was a prospective observational study performed in 2008 in the 28 operating suites at Dartmouth–Hitchcock Medical Center. The study was designed to characterize the incidence of provider-origin intraoperative bacterial transmission. Approval and waiver of informed patient consent were obtained from the Committee for Protection of Human Subjects. Over 40 consecutive working days (Monday–Friday) during 2 consecutive months (September and October), 92 pairs of patients undergoing anesthesia according to usual practice in randomly selected ORs were evaluated. All anesthesia providers had access to intraoperative hand hygiene devices, including a wall-mounted 60% alcohol dispenser immediately available to providers upon entry to the OR and a 70% alcohol dispenser located on the anesthesia cart. Hand hygiene compliance was measured independently during the study period by infection control officers via direct perioperative observational methodology.

Protocol

Ninety-two pairs of ORs were randomly selected for study by a computer-generated list, and 82 pairs were included in the final analysis. The first and second cases of the day in each room were studied sequentially, with patients in each room receiving general anesthesia according to usual practice. We used a previously validated experimental protocol[3] to identify bacterial transmission to 2 sites in the patient anesthesia environment (APL valve and agent dial on the anesthesia machine) and each patient's IV stopcock set (Fig. 1). Concurrently, we used a validated experimental protocol (modified glove juice technique)[4] to sample the hands of anesthesia providers (attending and resident physicians and certified registered nurse anesthetists [CRNA]) caring for these patients.

As is depicted in Figure 2, we first obtained baseline bacterial cultures at case start of the case 1 operative environment after active decontamination of these sites by the study investigators with a quaternary ammonium compound (panel A). Baseline stopcock samples were not obtained, because these have been shown to be invariably negative upon removal from the sterile packaging material.[3] All patients received fresh IV stopcock sets immediately before case 1. Using the modified glove juice technique,[4] we also obtained samples from the hands of anesthesia providers as they entered the OR but before patient contact (panel B). We have a mixed-practice model that includes both solo providers and anesthesia care team providers; thus we chose to obtain 1 culture for each case. Hand samples were not obtained from providers if they had already physically contacted the patients. Providers were asked to use the

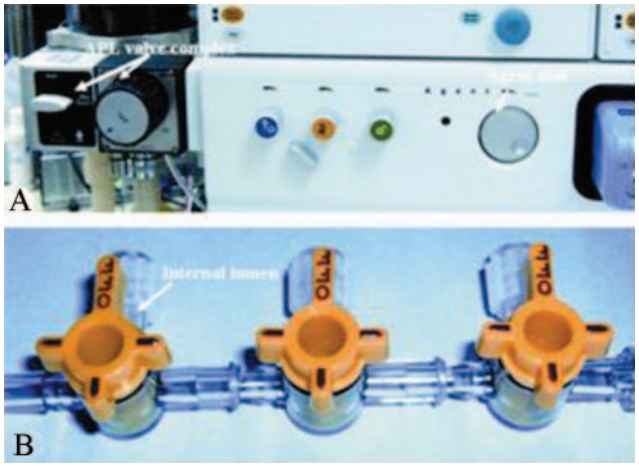

Figure 1. A and B, Sites where the anesthesia machine and the stopcock set were sampled.

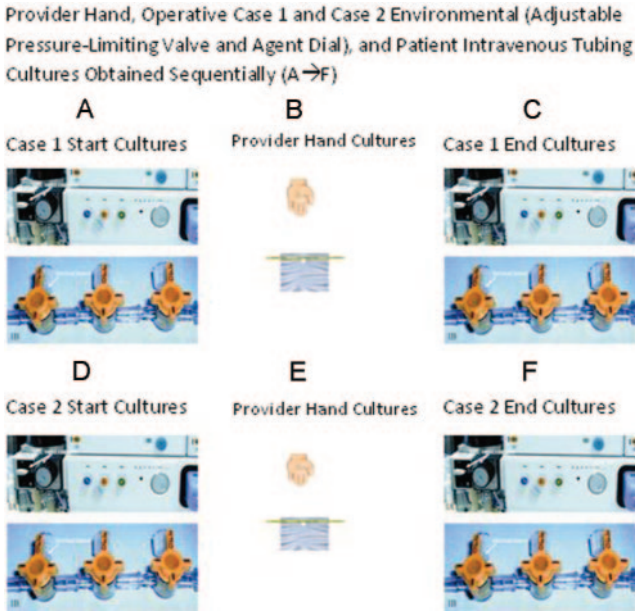

Figure 2. Intraoperative sampling schematic: case 1 and case 2 were sampled in series from A→F. A, baseline samples of the case 1 environment (adjustable pressure-limiting valve and agent dial) obtained after active decontamination by study personnel before room set-up. Cultures from stopcock sets had been previously shown to be invariably negative when removed from the packaging material. B, samples of hands obtained as providers entered the room before start of case 1. C, environment and stopcock sets cultured at case 1 end. D, cultures of the environment at case 2 start obtained after routine cleaning of this environment by operating room staff. E, hands of providers sampled before start of case 2. F, environment and stopcock set cultured at end of case 2. A transmission event was defined as the presence of a bacterial organism to any stopcock set or to any environmental site if not present in the environment at case start (panel A). Bacterial organisms found on provider hands were compared by biotype analysis to each of these transmission events.

stopcock set that the investigators identified for all medication administration during the anesthetic. Upon completion of case 1, the patient stopcock set and environmental sites were sampled (panel C). Transmission events were defined as bacterial organisms that were found at the end of a case that were not present at the start of the case. Baseline cultures for case 2 were then obtained after a standard OR cleaning procedure (panel D). Bacterial organisms that were found before the start of case 2, and that were not present at baseline before case 1, served as a measure of cleaning efficacy (panel D). We then sampled the hands of the same anesthesia providers when they entered the OR at the start of case 2 before patient contact (panel E). Finally, cultures of the environment and patient IV stopcock set were obtained again upon completion of case 2 (panel F). All transmitted organisms to the stopcock sets or patient operative environment were then compared, using biotype analysis, with samples taken from the hands of anesthesia providers. Providers were identified as the origin of this transmission only if biotype analysis confirmed (by a series of biochemical reactions) that the organism found on the hand of the provider was the exact same organism found in the stopcock or environment (Fig. 2).

The level of training of anesthesia providers (CRNA and attending and resident physicians), number of rooms simultaneously supervised by an attending anesthesiologist, patient demographics (ASA physical status, age, gender, and preoperative and postoperative locations), and surgical information (procedure type and case duration) were recorded for each case.

Definitions

1. Potential pathogen transmission event. One or more bacterial organisms isolated at case end (case 1 or 2) in the anesthesia environment (APL valve and agent dial) or the patient stopcock set that were not present at the start of case 1. Transmission events were identified by use of a previously validated protocol.[3]

2. Provider origin of the transmission event. One or more transmitted potential pathogens that were (a) also found on the hand of 1 or more anesthesia providers before the start of patient care and (b) had an identical biotype to the same organism found on the provider(s) hand.

Example. Methicillin-resistant *Staphylococcus aureus* (MRSA) (biotype 0012465) on provider is not the same organism as MRSA (biotype 1001245) found in the stopcock or anesthesia environment. MRSA (biotype 0012465) on the provider hand is the same organism as MRSA (biotype 0012465) in the stopcock or environment. This organism most likely originated from the provider, because it was not present at baseline (the start of case 1) and was obtained before patient interaction.

3. Ineffective decontamination. A potential pathogen isolated in the anesthesia environment (APL valve or agent dial) at the start of case 2 following standard OR cleaning and decontamination procedures that was not present at the start of case 1.

4. Horizontal transmission. Ineffective decontamination of an organism that was left behind by a provider (provider origin) during case 1 that ultimately contaminated the stopcock set of patient 2 during case 2.

Microbiological Methodology

Sampling of Anesthesia-Provider Hands

Participants submerged their dominant hand for 60 s into a sterile polyethylene bag of modified glove juice formula containing 50 mL of sampling solution (pH 7.9, containing 3.0 g/L NaCl, 0.1 g/L CaC_2 0.2 g/L KCl, 0.1 g/L $MgCl_2$, 0.2 g/L KH_2PO_4, 1.15 g/L K_2HPO_4). This solution was intended to neutralize residual antiseptic on the skin and facilitate identification and quantification of microorganisms by dispersing the colonies into single cells, which were then counted as colony-forming units (CFUs).[5] The sterility of glove juice solution was evaluated and confirmed at regular intervals.

Sampling of the Anesthesia Environment (T0 = Case beginning, T1 = Case end)

Two sites on the anesthesia machine previously shown to be heavily contaminated during the provision of anesthesia were used to monitor intraoperative bacterial contamination of the anesthesia work area (the patient environment). After decontamination of the APL valve complex and agent dial with Dimension III disinfectant solution according to manufacturer's recommendations, baseline cultures at case start (T0) were obtained by using sterile polyester fiber-tipped applicator swabs moistened with sterile transport medium (BactiSwab; Remel, Lenexa, KS) rolled over the entire surface area. The samples were then inoculated on sheep blood agar plates using a zigzag pattern and swab rotation to detect both Gram-positive and Gram-negative bacteria.[6] These cultures were repeated at case conclusion, time one (T1).

Sampling of Peripheral IV Tubing (3-Way Stopcocks [T1stopcock])

A sterile nasopharyngeal swab (BactiSwab) moistened with sterile transport medium was inserted into the internal surfaces of each injection port of the three-way stopcocks and rotated 360° ten times to culture. Each bacterial swab of the injection port lumen was inoculated on a sheep blood agar plate using a zigzag pattern and swab rotation.[7]

Microbial Culture Conditions

All blood agar plates were incubated at 35°C for 48 h and microorganisms were quantified according to colonies per surface sampled and identified according to standard laboratory methods as described below.[6]

Bacterial Identification

Bacterial organisms recovered from provider hands, the anesthesia work area, or patient (IV stopcock sets) were presumptively identified by colony morphology, Gram stain, and simple rapid tests. These organisms then underwent further identification as described below.

Gram-positive organisms were identified using the Dade Behring MicroScan (San Diego, CA). Positive 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 use and growth in the presence of antimicrobial agents after 24 h incubation at 35°C.

Recovered organisms were identified by standard clinical microbiology techniques supplemented by chromogenic panels (Dade-Behring Microscan) and antimicrobial susceptibility by broth microdilution (Dade-Behring Microscan) or Kirby-Bauer disk diffusion. MRSA and vancomycin-resistant enterococcus (VRE) were confirmed by agar dilution minimal inhibitory concentration.[5,6]

Outcomes and Statistical Analysis

This study was powered to examine the relationship between contaminated stopcocks and provider origin of transmission. While stopcock contamination may be as high as 32%,[3] a 15% rate of stopcock transmission would clearly warrant intervention, because a single stopcock transmission event likely increases patient morbidity and mortality.[3] We hypothesized a stopcock contamination rate of 32% with an alternate rate of 15%. As such, approximately 92 pairs resulting in 184 patients allowed 0.9 power with a type 1 error rate of 0.05 to analyze provider origin of stopcock contamination.

The primary outcome in this study was the incidence of anesthesia provider origin of intraoperative bacterial transmission to the patient environment or IV stopcock set. The secondary outcomes were bacterial speciation of transmission events, provider variability in hand contamination, horizontal transmission, and the adequacy of anesthesia environment decontamination practices. The primary outcome of provider-origin bacterial transmission was considered binary and evaluated by univariate logistic regression analysis and results reported as odds ratios. The Wilcoxon rank-sum (Mann–Whitney) test was used to compare hand contamination of providers (CFU) by case 1 versus case 2. Comparisons of hand contamination (CFU) by trainee level were made using the Bonferroni analysis of variance. All other outcomes were considered continuous, and we report the mean, SD, and 95% confidence intervals (CI).

Univariate logistic regression analysis was used to examine the dependence of provider, patient, and environmental transmission on multiple covariates: primary provider type (CRNA, resident physician, or attending physician), the duration and type of surgery, the preoperative and discharge patient location (intensive care unit [ICU], inpatient ward, or same day), urgency of surgery (emergent, urgent, or elective), the ASA status, patient age, and patient gender. An α of <0.05 was considered statistically significant. All analyses were conducted using Stata 9.0 software (College Station, Texas).

RESULTS

Ninety-two ORs with 184 scheduled patients (first and second case of the day) were randomly selected for analysis. Three cases were cancelled unexpectedly, and 17 cases were excluded from analysis because of improper handling of samples ($n = 12$) or culture plates that were broken or missing ($n = 5$) (Fig. 3). Thus, 164/184 cases were included in the final analysis. Patients underwent a variety of surgical procedures, reflecting a diverse sample frame of general anesthesia (Table 1). There were no differences in the ASA status, age, gender, or surgical procedure in those patients with an intraoperative transmission event in comparison with those without such an event.

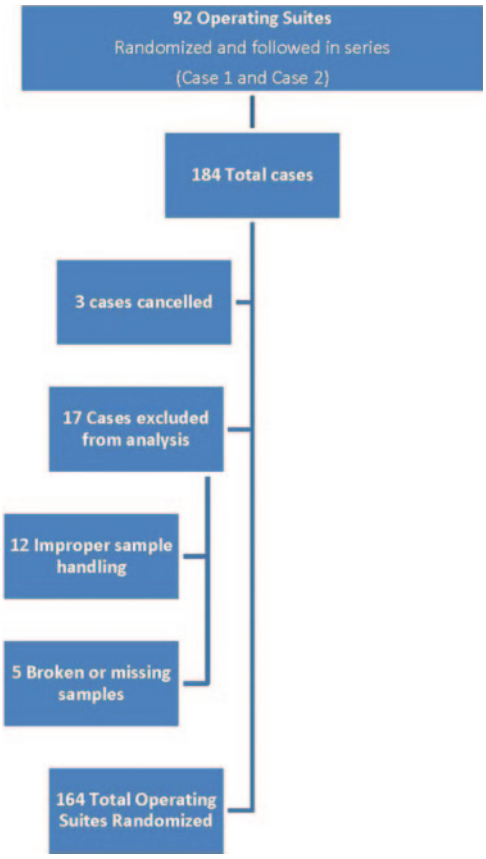

Figure 3. Operating room randomization. Ninety-two operating rooms were randomly selected for observation, but 10 of these were excluded from the final analysis.

The spectrum of bacterial contamination found on provider hands before intraoperative patient care is shown in Table 2. Overall, 66% of provider hands were contaminated with 1 or more major pathogens (MRSA, VRE, methicillin-sensitive Staphylococcal aureus, *Enterococcus*, and Enterobacteriaceae). The overall mean number of total CFUs found on the hands of providers was 1045 (95% CI: 210 to 2000). Attending anesthesiologists had significantly less overall hand contamination than did both residents and CRNAs (attending mean 655, 95% CI: 150 to 1150; resident mean 1201, 95% CI: 250 to 2000; CRNA mean 1014, 95% CI: 200 to 2000) (mean difference attending vs. resident physician -545, $P < 0.001$; mean difference attending vs. CRNA -358, $P = 0.021$). There was no difference between residents and CRNAs in terms of total hand contamination (mean difference -186, $P =$ NS). The magnitude of contamination (number of CFUs) found on provider hands before case 1 was higher than that before the start of case 2 (case 1 mean 1224, 95% CI: 1000 to 2000; case 2 mean 883, 95% CI: 900 to 2000) ($P < 0.001$).

Overall bacterial transmission to the intraoperative environment occurred in 146/164 (89%) of cases, and providers were identified as the origin of this transmission in 12% (17/146) of cases. Overall bacterial transmission to the patient IV stopcock set was identified in 19/164 (11.5%) of cases, and anesthesia providers were identified as the origin of this transmission in 47% (9/19) of cases. Contamination of the environment before the start of case 2 (a

Table 1. Patient and Provider Characteristics

	N (%)
Number of cases	164
Age, years (mean, [SCAP]SD[R])	50.3 ± 20.7
Gender (male)	86 (53.1)
ASA* physical status	
I	21 (13)
II	87 (53)
III	51 (31)
IV	5 (3)
SENIC (mean, [SCAP]SD[R])	1.3 ± 0.9
Location of case	
Same day	145 (88)
Floor	16 (10)
ICU	3 (2)
Emergent status	
Elective	148 (91)
Urgent	12 (7)
Emergent	3 (2)
Procedure	
Orthopedic	54 (33)
General abdominal	27 (16)
Gynecologic	13 (8)
Vascular	12 (7)
Ear, nose, throat	12 (7)
Neurosurgical	11 (7)
Neurological	4 (2)
Plastics	9 (5)
Urological	6 (4)
Breast	4 (2)
Thoracic	3 (2)
Other	9 (5)
Training	
Resident	81 (49)
CRNA	55 (34)
Attending	28 (17)
Rooms >1	128 (78)
Duration >2 hours	73 (45)

ASA = American Society of Anesthesiology health classification system; SENIC = Study on the Effect of Nosocomial Infection Control; ICU = intensive care unit; CRNA = certified registered nurse anesthetist.

Table 2. Baseline Provider Hand Contamination[a]

Organism	Providers *N*/total (%)
MRSA	12/164 (7%)
MSSA	18/164 (11%)
VRE	4/164 (2%)
Enterococcus (non-VRE)	1/164 (0.6%)
Staph other	164/164 (100%)
Micrococcus	110/64 (67%)
Corynobacterium	14/164 (9%)
Streptococcus	128/164 (78%)
Gram negative[b]	81/164 (49%)

MRSA = methicillin-resistant Staphylococcus aureus; MSSA = methicillin-sensitive Staphylococcus aureus; VRE = vancomycin-resistant Enterococcus.
[a] Samples taken upon entry to the patient environment but before patient contact and after an opportunity to perform hand hygiene.
[b] E. coli, Klebsiella, Serratia, Pseudomonas, and Acinetobacter.

measure of the efficacy of decontamination practices) occurred in 7% of ORs analyzed (6/82) and was linked to stopcock contamination in 5% (1/19) of cases. All identified transmission events are described in Table 3.

In this experimental model we were able to confirm 1 occurrence of intraoperative horizontal transmission (1%, 1/92 pairs of ORs): ineffective decontamination of provider hands before case 1, leading to contamination of the environment and stopcock during case 1, followed by ineffective decontamination of the environment after case 1, followed by ineffective hand decontamination while interacting with the environment in case 2, followed by contaminated patient IV stopcock set at the end of case 2 (Table 3).

A univariate logistic regression analysis identified no independent risk factors for provider-origin transmission. However, independent predictors of environmental contamination not linked to a provider source included surgery involving the first case of the day, anesthesia provider supervision of more than 1 room, increasing patient age, and discharge to the ICU from the OR (Table 4).

DISCUSSION

In this study, we evaluated the potential link between provider hand contamination immediately before patient contact and intraoperative transmission of the same bacterial organisms. We validated our prior observations pertaining to intraoperative bacterial transmission of potentially pathogenic bacterial organisms to both the patient stopcock set and the patient care environment during the routine practice of general anesthesia. Previously, we demonstrated that such transmission was associated with increased patient mortality.[3] The current study extends these observations by demonstrating that provider hand contamination immediately before patient care was a source for some, but not all, of the intraoperative contamination that we observed. In addition, the findings of this study provide insight into other, potentially modifiable, risk factors for intraoperative bacterial transmission, including ineffective decontamination strategies.

The spectrum of bacterial contamination found on the hands of the providers in this study is not unlike that described for health care workers in similarly fast-paced environments.[8] The reason for the magnitude of hand contamination despite a 90% reported perioperative hand hygiene compliance rate during the study time period is unclear and requires further study. It is likely due to ineffective hand decontamination practices despite adequate decontamination events. As is suggested by the difference between providers in total contamination, as was shown in this study, there may be educational deficits among certain types of providers regarding hand hygiene importance, technique, and efficacy. Similar to survey reports of the attitudes and beliefs of anesthesia providers regarding hand hygiene,[9] this study suggests that there is a need for further education even at the level of experienced health care providers.

The most striking finding of this study was the evidence that bacterial organisms found on the hands of providers in a "snap shot" in time immediately before patient contact explained a fairly large proportion of the subsequent overall environmental and patient IV stopcock set contamination. Repeated measurements of hand contamination throughout the period we studied (case 1 and case 2) might have explained an even larger portion of the overall bacterial transmission. This concept is supported by the univariate logistic regression analysis, which suggests that the risk of bacterial transmission events that were not linked to providers is independently predicted by an anesthesia attending physician caring for patients in more than 1 room. In concordance with the World Health Organization

Table 3. Evidence for Intraoperative Transmission of Bacterial Pathogens from Anesthesia Provider Hands to the Anesthesia Environment and Patient IV Catheters

	Case 1			Case 2			
	Before case 1	End case 1		Before case 2		End case 2	
	Provider hands (site B)	Stopcock	Machine APL/D	Machine APL/D	Provider hands (site E)	Stopcock	Machine APL/D
Direction of transmission →							
Organism							
Micro	Attending		X				
S. epi	Attending	X					
S. hae	Attending	X					
S. epi	Attending	X					
S. epi	Attending				Attending[a]		
S. epi	Attending		X			X	X
Micro	Attending		X			X	
S. epi	Attending		X	X			X
Strep	Resident	X					X
Pseudo	Attending						
Pseudo	Resident		X				X
Micro	Resident	X		X		X	X
MRSA	Resident		X	X	Attending[a]		X
MSSA	Resident		X				X
S. auric	CRNA		X	X			
Micro	CRNA			X	Attending[a]		X
S. epi	CRNA			X			
Micro					CRNA[a]	X	X

Sites were cultured as described, and pathogens were found at the times and locations noted.

APL = anesthesia machine adjustable pressure limiting valve; D = anesthesia machine inhaled agent concentration dial; X = transmission event confirmed by biotype analysis; S. epi = Staphylococcal epidemidis; S. hae=Staphylococcal haemolyticus; Strep = streptococcus; Pseud = pseudomonas; MRSA = methicillin-resistant Staphylococcal aureus; MSSA = methicillin-sensitive Staphylococcal aureus; S. auric = Staphylococcal auricularis; CRNA = certified registered nurse anesthetist.

[a] Provider was negative at the start of case 1; hands contaminated by bacterial organisms brought in by other providers.

Table 4. Risk Factors for Transmission

	Provider			Other			Other adjusted		
Risk factors	OR	95% CI	*P* value	OR	95% CI	*P* value	OR	95% CI	*P* value
Resident	0.91	0.2–3.7	0.899	0.29	0.0–2.4	0.254			
CRNA	0.83	0.2–3.8	0.813	0.29	0.0–2.6	0.272			
Rooms	0.8	0.2–2.7	0.757	1.0	0.3–3.3	0.977	8.2	1.0–66	0.049
Attending not solo	0.7	0.2–2.3	0.562	0.5	0.1–2.2	0.350	0.1	0.0–0.6	0.022
Patient age	1.0	1.0–1.0	0.925	1.0	0.9–1.0	0.056	1.0	0.9–1.0	0.029
Patient gender	1.7	0.7–4.4	0.259	0.6	0.3–1.5	0.301			
Patient ASA	0.9	0.4–1.8	0.737	0.5	0.3–1.0	0.059			
Duration >2 hours	0.7	0.2–2.1	0.539	0.5	0.2–1.3	0.146			
Urgent case	0.3	0.1–1.3	0.109	0.31	0.1–1.3	0.109			
Emergent case	0.2	0.4–56	0.209	0.2	0.0–2.5	0.213			
Floor[b]	1.3	0.3–6.4	0.726	1.7	0.2–14	0.603			
ICU[b]	[a]			0.1	0.0–0.7	0.023	0.0	0.0–0.3	0.007

Resident and *CRNA* are in reference to attending level of training. OR = operating room; CI = confidence interval; CRNA = certified registered nurse anesthetist; ICU = intensive care unit.

[a] Denotes risk factor predicts perfectly. [b] Compared with same-day unit.

(WHO) and Hand Hygiene Task Force guidelines recommending performance of hand hygiene before entering the patient room as part of the number 1 preventative measure,[10,11] it seems likely that organisms were brought to the patient and the environment as providers moved from room to room with continued lapses in hand decontamination. Furthermore, patient age and patient discharge location (to the ICU) were also independent risk factors. These may be a marker of both disease severity and associated competing agendas: hand hygiene versus expedited patient care.[12] Additional work is indicated to further verify these results.

Interestingly, our results suggest that the first case of the day is associated with a larger magnitude of overall bacterial transmission. Though speculative, incorporation of a surgical scrub, interventions targeting hand hygiene, or both during this time period may be effective in reducing both the quality and number of overall contamination events. This could significantly reduce postoperative infections.[1]

The findings of this study are important because they simultaneously provide direct microbial evidence that anesthesia providers are involved in intraoperative bacterial

transmission to patients and substantiate the current Centers for Disease Control and Prevention and WHO stance that hand hygiene is important hospital-wide.[10,11] This information is especially important for the intraoperative environment because, although aseptic technique and use of barrier techniques are widely accepted and implemented for certain well-defined components of this particular clinical arena,[13] hand hygiene is not met with the same degree of rigor, especially among anesthesia providers.[9,14] Furthermore, there is reasonable evidence that the anesthesia environment poses a risk to patient safety through the development of health care–associated infections and that improvements in hand hygiene reduce this risk substantially.[1,15–17] The finding that there are substantial unidentified sources of bacterial transmission should provide a powerful impetus for further investigation in this area and facilitate the development and implementation of infection control guidelines.

Similar to interventions in other fast-paced environments, future quality improvement strategies should consider barriers specific to the OR, such as pressure to work more efficiently, because prior work suggests that this may play a significant role.[18] Finally, insight into mechanisms of bacterial cross-contamination gleaned from this experimental model might ultimately prove useful for implementation of more global infection-control measures and, ultimately, reduce hospital-wide health care–associated infections.

The major limitation of this study is the potential insensitivity of the methodology. We elected to sample hands only in a single time window, immediately before patient contact. We chose this period of time because hand hygiene performance during this period is currently emphasized by WHO.[6] Our results support this emphasis, but we believe that our results may underestimate the importance of hand hygiene throughout the entire process of patient care. In addition, because provider hands were not sampled if prior physical patient contact had occurred, a number of potential provider-origin transmission events were potentially left unidentified and may have explained at least some of the transmission events not linked to providers in this study. Finally, provider knowledge of the study may have led to exaggerated hand hygiene compliance and therefore underestimated the significance of provider hand contamination before patient care.

Despite these limitations, we note that even with the study of only 82 surgical case pairs, our experimental model was able to confirm 1 occurrence of intraoperative horizontal transmission. We suspect that this sequence occurs to a much greater extent than we were able to detect with our limited sampling methodology, providing support for continued hand hygiene while caring for patients. As such, further study is warranted to assess the potential impact of this sequence.

In conclusion, we have found that the hands of anesthesia providers are contaminated immediately before patient care with a wide range of bacterial pathogens. Furthermore, contamination of patient IV tubing and the immediate patient environment is common in the intraoperative setting and is partially explained by bacterial transmission from the contaminated hands of anesthesia providers. Contamination of provider hands before patient care therefore represents an important modifiable risk factor for bacterial cross-contamination. These findings support initiatives designed to improve intraoperative hand hygiene of anesthesia providers both before and during patient care, as well as intraoperative decontamination strategies. These findings also challenge the commonly held belief by physicians that they play little or no role in bacterial transmission.[19]

DISCLOSURE

Name: Randy W. Loftus, MD.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Attestation: This author has seen the original study data, reviewed the analysis of the data, approved the final manuscript, and is the author responsible for archiving the study files.
Name: Matthew K. Muffly, MD.
Contribution: This author helped conduct the study.
Attestation: This author approved the final manuscript.
Name: Jeremiah R. Brown, PhD, MS.
Contribution: This author helped analyze the data and write the manuscript.
Attestation: This author has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.
Name: Michael L. Beach, MD, PhD.
Contribution: This author helped analyze the data.
Name: Matthew D. Koff, MD.
Contribution: This author helped in manuscript preparation and to conduct the study.
Attestation: This author approved the final manuscript.
Name: Howard L. Corwin, MD.
Contribution: This author helped write the manuscript.
Attestation: This author approved the final manuscript.
Name: Stephen D. Surgenor, MD.
Contribution: This author helped write the manuscript.
Attestation: This author approved the final manuscript.
Name: Kathryn B. Kirkland, MD.
Contribution: This author helped write the manuscript.
Attestation: This author approved the final manuscript.
Name: Mark P. Yeager, MD.
Contribution: This author helped design the study and write the manuscript.
Attestation: This author has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.

ACKNOWLEDGMENTS

We thank Tammara A. Wood, MT (AMT), and Corey C. Burchman, MD, of the Department of Anesthesiology and Critical Care Medicine, Dartmouth–Hitchcock Medical Center for their assistance.

REFERENCES

1. Koff MD, Loftus RW, Burchman CC, Schwartzman JD, Read ME, Henry ES, Beach ML. Reduction in intraoperative bacterial contamination of peripheral intravenous tubing through the use of a novel device. Anesthesiology 2009;110:978–85
2. Department of Health and Human Services and Centers for Medicare & Medicaid Services. Medicare program: proposed changes to the hospital inpatient prospective payment systems and fiscal year 2008 rates: proposed rule part II. 42 CFR parts 411, 412, 413, and 489 [CMS–1533–P] RIN 0938–AO70. Federal Register 5–3-2008;72(85):38–48

3. Loftus RW, Koff MD, Burchman CC, Schwartzman JD, Thorum V, Read ME, Wood TA, Beach ML. Transmission of pathogenic bacterial organisms in the anesthesia work area. Anesthesiology 2008;109:399–407
4. Zuckerman JB, Zuaro DE, Prato BS, Ruoff KL, Sawicki RW, Quinton HB, Saidman L. Bacterial contamination of cystic fibrosis clinics. J Cyst Fibros 2009;8:186–92
5. Lemmen SW, Hafner H, Zolldann D, Stanzel S, Lutticken R. Distribution of multi-resistant gram-negative *versus* gram-positive bacteria in the hospital inanimate environment. J Hosp Infect 2004;56:191–7
6. Wikler M, Cockerill F, Craig W, Dudley M, Eliopoulos G, Hecht P, Hindler J, Low D, Sheehan D, Tenover F, Turnidge J, Weinstein M, Zimmer B. Clinical and Laboratory Standards Institute: Performance Standards for Antimicrobial Disk Susceptibility Tests. 9th ed. Wayne, PA: Clinical and Laboratory Standards Institute, 2006: M2–A9
7. Casey AL, Burnell S, Whinn H, Worthington T, Faroqui MH, Elliott TS. A prospective clinical trial to evaluate the microbial barrier of a needleless connector. J Hosp Infect 2007;65:212–8
8. Cook HA, Cimiotti JP, Della-Latta, P, Saiman L, and Larson EL. Antimicrobial resistance patterns of colonizing flora on nurses' hands in the neonatal intensive care unit. Am J Infect Control 2007;35(4):231–6
9. Tait AR, Tuttle DB. Preventing perioperative transmission of infection: a survey of anesthesiology practice. Anesth Analg 1995;80:764–9
10. World Health Organization. WHO Guidelines on Hand Hygiene in Health Care (Advanced Draft). World Health Organization Health System Policies and Operations Evidence and Information for Policy 2005. 9–13-0007
11. Boyce JM, Pittet D. Guideline for hand hygiene in health-care settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force Society for Healthcare Epidemiology of America/Association for Professionals in Infection Control/Infectious Diseases Society of America. MMWR Recomm Rep 2002;51:1–45
12. Kretzer EK, Larson EL. Behavioral interventions to improve infection control practices. Am J Infect Control 1998;26:245–53
13. Dellinger E, Gordon S. Surgical-associated infection in today's operating room. Special report. Anesthesiology, General Surgery, and OB/GYN News 2007;1–10. http://www.anesthesiologynews.com
14. Askarian M, Ghavanini AA. Survey on adoption of measures to prevent nosocomial infection by anaesthesia personnel. East Mediterr Health J 2002;8:416–21
15. Fukada T, Tachibana C, Tsukazaki Y, Satoh K, Furuya Y, Ohe Y. [Bacterial contamination of anesthesiologists' hands and the efficacy of hand washing]. Masui 1996;45:1026–30
16. Lessard MR, Trepanier CA, Gourdeau M, Denault PH. A microbiological study of the contamination of the syringes used in anaesthesia practice. Can J Anaesth 1988;35:567–9
17. Mizuta M, Shime N, Matsuda T, Yoshioka M. [Local survey of practice patterns for barrier precautions during anesthesia practice]. Masui 2007;56:208–12
18. Pittet D, Hugonnet S, Harbarth S, Mourouga P, Sauvan V, Touveneau S, Perneger TV. Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. Infection control programme. Lancet 2000;356:1307–12
19. Pittet, D, Simon A, Hugonnet S, Pessoa C, Sauvan V, Perneger TV. Hand hygiene among physicians: performance, beliefs, and perceptions. Ann Intern Med 2004;141:1–8