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Use of an anaesthesia workstation barrier device to decrease contamination in a simulated operating room

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Abstract

Background. Strategies to achieve reductions in perioperative infections have focused on hand hygiene among anaesthetists but have been of limited efficacy. We performed a study in a simulated operating room to determine whether a barrier covering the anaesthesia workstation during induction and intubation might reduce the risk of contamination of the area and possibly, by extension, the patient.

Methods. Forty-two attending and resident anaesthetists unaware of the study design were enrolled in individual simulation sessions in which they were asked to induce and intubate a human simulator that had been prepared with fluorescent marker in its oropharynx as a marker of potentially pathogenic bacteria. Twenty-one participants were assigned to a control group, whereas the other 21 performed the simulation with a barrier device covering the anaesthesia workstation. After the simulation, an investigator examined 14 target sites with an ultraviolet light to assess spread of the fluorescent marker of contamination to those sites.

Results. The difference in rates of contamination between the control group and the barrier group was highly significant, with 44.8% (2.5%) of sites contaminated in the control group *vs* 19.4% (2.6%) of sites in the barrier group ($P<0.001$). Several key clinical sites showed significant differences in addition to this overall decrement.

Conclusions. The results of this study suggest that application of a barrier device to the anaesthesia workstation during induction and intubation might reduce contamination of the intraoperative environment.

Key words: anaesthesiology; high fidelity simulation training; infection control

Regulatory agencies have identified the reduction of health-care-associated infections as a major priority.[1] With frequent, close patient contact, anaesthetists are key players in infection control.

Appropriate and timely antibiotic administration,[2] maintenance of normothermia,[3] and adequate hand hygiene[4–6] are all areas where anaesthetists may contribute to the reduction in health-care-associated infections. A previous study attempted to tackle the reduction of cross-contamination by using a double-glove method.[7] However, anaesthesia providers (like other health-care providers) have been shown to have poor rates of adherence to hand hygiene.[8–11] Even when proper hand hygiene is adopted, after airway instrumentation bacterial contamination (with oral flora) can still be found on the anaesthesia workstation, i.v. stopcocks, and other equipment.[5 12–14] Given that the workstation is not commonly cleaned during a procedure, the reservoir of bacteria left in the anaesthesia provider's work area after airway instrumentation might render the use of gloves and

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Editor's key points

- All operating theatre personnel should be involved in strategies to reduce the incidence of surgical site infections.
- Hand hygiene should be accompanied by efforts to prevent contamination of equipment.
- Anaesthetic machines are always present, easily contaminated, and difficult to decontaminate.
- The efficacy of a physical workstation barrier in preventing bacterial spread during anaesthetic induction was studied.

hand hygiene ineffective. Although this places individual patients at risk, perhaps even more worrisome is the fact that bacterial transmission between surgical patients via an incompletely decontaminated operating room (OR) occurs frequently and is linked to an increased rate of 30 day postoperative infections.[12 15] Recent research in transmission dynamics of bacteria within ORs has shown that a contaminated environment, rather than provider hands, is the most likely source of infection.[12 16] The morbidity associated with such contamination may be substantial; patients whose i.v. tubing is colonized with bacteria in the OR have an increased risk of mortality[13 16] and an increased rate of 30 day postoperative infections.[16] One study demonstrated an 8% risk of infection associated with exposure to nosocomial Gram-negative bacteria.[12] These findings suggest that dirty provider hands, although the proximal cause of contamination, are less likely to serve as a reservoir for injurious bacterial transmission events than patient or environmental surfaces, raising the importance of interventions other than optimization of hand hygiene.

Reducing early contamination of the anaesthesia environment is a complementary step that relies less on individual practitioner compliance than does hand hygiene. Although traditional barrier techniques (e.g. gloves) are well accepted, a physical barrier covering the anaesthesia workspace might reduce health-care-associated infection rates by decreasing the initial contamination after airway management. This barrier could be present for this 'dirty' portion of the anaesthetic and would then be removed and discarded. Additionally, a barrier has the advantage of serving as a passive intervention, as opposed to hand hygiene, which necessitates active participation from clinicians to be effective. We therefore used a simulated OR and a previously described model of the intraoperative spread of infection[7 17] to determine whether implementation of this anaesthesia workstation barrier method would be effective in reducing contamination of the intraoperative environment.

Methods

After being granted an exemption from written consent by the institutional review board, 42 participants, consisting of anaesthesia residents (23) and attending anaesthetists (19), were voluntarily enrolled in the study, which was carried out in the Mount Sinai Department of Anesthesiology's Simulation Center. The study was designed as a prospective, randomized controlled trial, but was not blinded given the nature of the barrier intervention. Our primary hypothesis was that the barrier device would reduce the overall rate of contamination between groups, with the secondary hypothesis that the device would primarily reduce rates of contamination of sites covered by the barrier device. The primary outcome measure was the total proportion of sites contaminated in each group. The secondary outcome measure was the rate of contamination of each individual site.

After randomization to either the control or the barrier group, participants were presented with a simulated patient requiring laparoscopic appendectomy, in which the presence or absence of the barrier was the only variable. Participants were provided with the drugs and equipment necessary for a typical induction in the sponsoring institution, which were prepared in a standardized fashion. The simulation administrator instructed all participants to wear gloves and perform all standard tasks up to the point where the patient was prepped and draped for surgery. Antibacterial hand gel was not used in this simulation.

The barrier device was fashioned from waterproof, transparent plastic, which was affixed to the anaesthesia workstation with tape and covered the surface of the anaesthesia workstation, manual ventilation bag, adjustable pressure limiting valve, ventilator switch, and ventilator monitor as seen in Fig. 1. Three pieces of plastic were used, one covering the workstation, one covering the manual ventilation bag, and one covering the ventilator monitor. In our experience, setting up the barrier took <3 min. In this study, the computerized record-keeping system was not used for logistical reasons given the set-up of our human simulator laboratory, and so this site was not targeted with a barrier cover.

A stepwise simulation sequence (Table 1) was followed for both groups, with the only difference being that in the barrier group the participants were instructed to remove the barrier as part of the surgical timeout (i.e. before surgical incision).

Fourteen target sites were used for our study, adapted from Birnbach and colleagues' model of simulation-based infection control (Table 2).[7 17] Before the entry of the subject into the laboratory, Glo-Germ fluorescent marker (Glo-Germ Company, Moab, UT, USA) 1 ml was placed in the oropharynx of the mannequin (HPS; CAE Healthcare Canada Inc., Saint-Laurent, QC, Canada).

After completion of the simulation, the barrier was removed and target sites were examined for simulated contamination using a black light and coded as either (0) not contaminated or (1) contaminated based on the presence or absence of fluorescent marker. The researcher examining sites and recording data was blinded to whether or not the barrier was used for that subject's simulation. Between simulations, the room was cleaned with soap and water wipes and again examined with a black light for residual fluorescent marker which, if identified, was removed by spot cleaning. Contaminated materials that could not be cleaned completely were discarded and replaced.

Statistical analysis

For each individual target site, the rates of contamination between the barrier device group and the control group were compared using the χ^2 test or Fisher's exact test, as appropriate. Site comparison was performed without adjustment made for multiple comparisons, and thereafter, with adjustment via step-down Bonferroni and Hochberg analysis. For the overall performance assessment, a subject-specific contamination rate was calculated first (i.e. number of contaminated sites over the 14 targeted sites for each subject). Then a two-way ANOVA was used to determine whether the overall contamination rates differed between control and barrier groups and between residents

Fig 1 Standard operating room set-up for the barrier group.

Table 1 Simulation sequence

(i) Simulator set-up before subject entry
(ii) Simulator briefing, including patient information, read to subject by investigator. Subject instructed to wear gloves and mask and to work within the environment as if it were the true clinical environment
(iii) Participants begin procedure in standard fashion:
• Preoxygenation
• Induction of general anaesthesia via rapid sequence induction; subject administers propofol and succinylcholine through i.v. stopcock
• Tracheal intubation via direct laryngoscopy
• Tracheal tube balloon inflation, circuit connected, confirmation of end-tidal CO_2
• Tracheal tube secured with tape; eye tape applied
• Maintenance of anaesthesia begun with volatile anaesthetic agent
(iv) Non-depolarizing neuromuscular blocking agent administered through i.v. stopcock at prompting of surgeon (i.e. 'Please make sure he is relaxed for trochar placement. Thank you.')
(v) Surgical time out begins. Barrier group instructed to remove barrier device. All participants instructed to remove gloves if they have not already
(vi) Procedure allowed to proceed for 5 min so each participant can be observed administering an analgesic (i.e. fentanyl) via stopcock (prompted if not)
(vii) Simulation ends

and attending anaesthetists. Furthermore, to evaluate whether contamination was more prone in senior or junior anaesthetists, the interaction between intervention group and level of training was also measured. SAS 9.4 (SAS Institute Inc., Cary, NC, USA) was used for statistical analysis. For sample size calculation using an α of 0.05 and β of 0.2, we predicted that a barrier would reduce contamination between groups by 90%, which resulted in an n=20 for each arm of the study, for a total n=40.

Results

The control group consisted of 10 resident and 11 attending physicians and the barrier group consisted of 13 resident and eight attending physicians. All participants who volunteered to participate were able to complete the study.

There was a significant reduction in the proportion of sites contaminated in the barrier group [19.4% (2.6%)] compared to the control group [44.8% (2.5%); P<0.001]. In addition, the intervention effect differed depending on the level of training (interaction term, P=0.005). In the control group, residents demonstrated a much lower average site contamination rate than that of attending anaesthetists [35.7% (3.6%) *vs* 3.9% (3.5%), respectively; P=0.001]. In the barrier group, the overall site contamination rates were similar between residents and attending anaesthetists [20.9% (3.2%) and 17.9% (4.0%), respectively; P=0.561].

With regard to site-specific contamination rates (Table 3), significant differences in contamination between barrier and control groups were found for the adjustable pressure limiting, manual ventilation bag, ventilator switch, anaesthesia workstation, and circuit (each with P<0.010), and for the i.v. stopcock (P=0.029; Fig. 2). No differences were found between groups for the remainder of sites. The sites with the highest rates of contamination in the control group (contaminated >75% of the time) were the circuit, adjustable pressure limiting valve, and manual ventilation bag. Presence of the barrier device reduced the likelihood of contamination of each of these sites by roughly two-thirds, whereas contamination rates of the other sites (i.e. anaesthesia workstation and ventilator switch) were reduced by roughly half. The ventilator monitor was the only site covered by the barrier that did not experience a significant reduction in rate of contamination. Site-specific rates of contamination were highly similar between analyses with and without adjustment of multiple comparisons given the high levels of significance we describe; the only result that would change would be the significance of the i.v. stopcock, the P-value of which would increase from 0.013 to 0.091.

Discussion

The results of this study demonstrate that application of a barrier device over the anaesthesia workstation during the start of a general anaesthetic may reduce contamination of various key points in the anaesthetizing area, at least in the simulated OR.

Table 2 Sites examined for presence of fluorescent dye

Manual ventilation bag of anaesthesia machine	Adjustable pressure limiting valve	Ventilator switch	Ventilator monitor
Vital signs monitor	Anaesthesia workstation drawers and handles	Drug cart drawers and handles	I.V. stopcock
Unused laryngoscope on workstation tray	Unused oral airway on workstation tray	Anaesthesia workstation surface	Drug cart surface
Mannequin eyes	Ventilator circuit tubing		

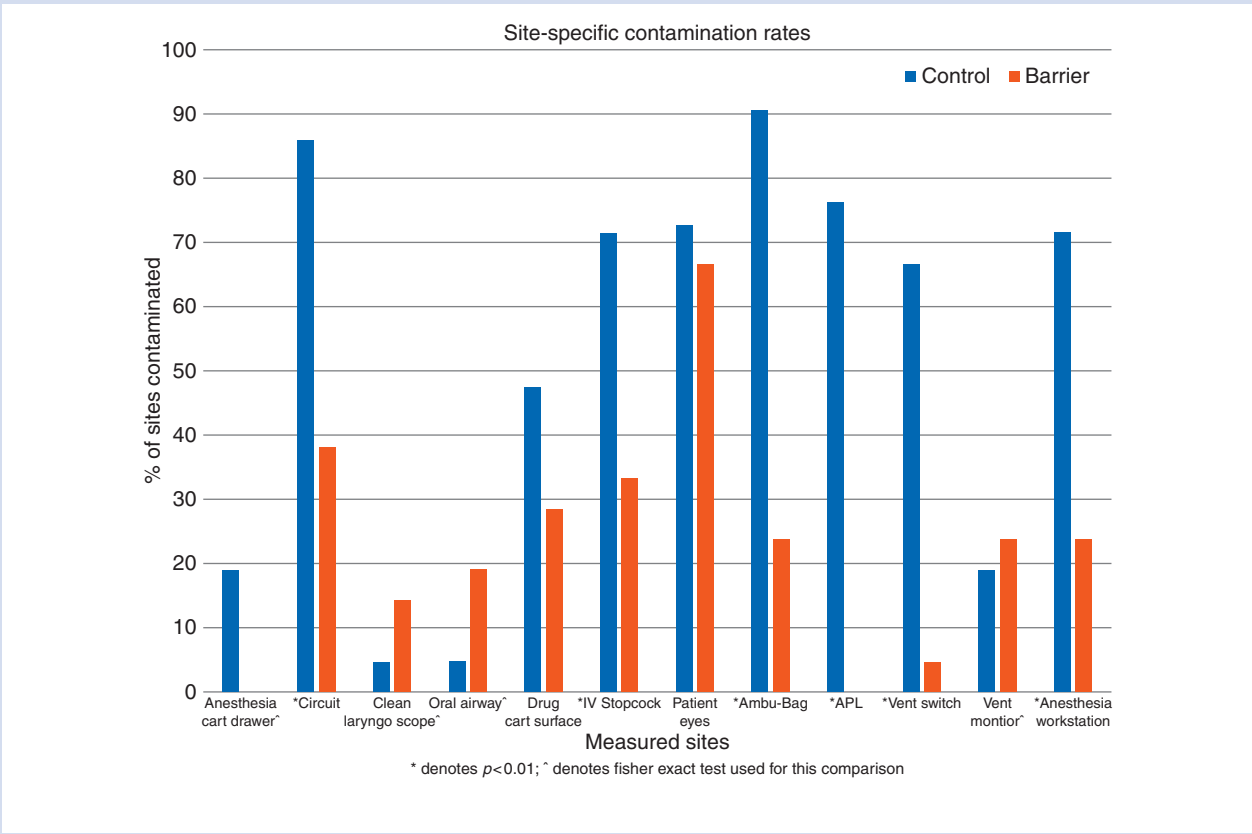

Fig 2 Site-specific contamination rates.

Table 3 Comparison of contamination rates of target sites

Site	Control group (%)	Barrier group (%)
Anaesthesia cart drawer	19.0	0
Circuit	85.7	38.1
Clean laryngoscope	4.8	14.3
Oral airway	4.8	19
Drug cart surface	47.6	28.6
I.V. stopcock	71.4	33.3
Patient eyes	72.6	66.7
Ambu bag	90.5	23.8
Adjustable pressure limiting valve	76.2	0
Ventilator switch	66.7	4.8
Ventilator monitor	19.0	23.8

A significant decrease in the overall proportion of contaminated sites was found between the control and barrier groups, and these decreases occurred for both attending physicians and residents. The site-specific results show a marked decrease in rates of contamination for almost every site covered by the barrier, and are robust in that they remain significant even in multivariate analysis.

The earlier work of Birnbach and colleagues[7] examined the effectiveness of the double-glove method in the simulated OR, whereby the anaesthesia provider removes the outer pair of gloves after instrumenting the patient's mouth in order to limit contamination of the anaesthetic workstation. In their study, double gloving was found significantly to reduce the number of sites contaminated by residents, representing a decline from 50.8 to 12.5% ($P<0.001$) of sites, and similar to the magnitude of reduction that we observed in our study (i.e. from 44.8 to 19.4%), albeit with a different double-barrier protocol.

Although our protocol was based on methodology described by Birnbach and colleagues,[7 17] the intervention we examined was chosen because it is possible that practitioners may not widely use the double-glove method. The conceptual approach to this problem has proved similarly effective in that despite moving the second barrier from the outer glove (as with the study by Birnbach and colleagues) to the anaesthesia workstation (as with ours), decrements in contamination were similar. Therefore, our model is a representation of the previously reported protocol, but there are methodological differences that might be easier to adopt universally because our model relies less on individual practitioner compliance compared with hand hygiene.

Application of the barrier device significantly reduced contamination of every site involved, with the exception of the ventilator monitor. It is possible that a barrier is not an effective method of reducing contamination of this site, but equally possible that our study was not powered to detect a difference here given the markedly lower rates of contamination of the ventilator monitor overall compared with the other sites covered by the barrier. Two sites, the i.v. stopcock (on raw but not multivariate analysis) and the anaesthesia circuit, were found to have significantly lower rates of contamination in the barrier group, despite not being covered by the barrier device. It is possible that a Hawthorne effect explains this (it was impossible to blind participants to their group assignment), wherein the presence of the barrier made participants more attentive to hand hygiene than they might otherwise have been. Alternatively, it is possible that the lower residual contamination of the workstation meant that several minutes after removal of the barrier, there was no reservoir for repeated contamination in the environment, leading to less contamination of these key sites. If this is the case, this is very important given the direct route the i.v. stopcock represents for introduction of oral flora into the patient's bloodstream.[13 18]

One unexpected result of our study was the difference in outcome dependent on level of training. Attending physicians' rates of site contamination were affected more dramatically by the implementation of the barrier device than were residents' rates. This finding might represent some difference with regard to the effect of length of training on infection control practices, a result which goes against data on wound infection rates in the emergency department.[19] Another possibility is that our department communicates the importance of hand hygiene on a regular basis to residents, which might render residents more attuned to differences in standard infection control protocols.

The present study has several limitations. The most immediately apparent is that although the simulator model on which we based our protocol has been used elsewhere,[12 13] the behaviour of personnel in a live OR and the spread of real oropharyngeal flora might differ from what we observed in our simulated OR. Furthermore, the standardized procedure we presented was relatively non-complex; real patients with more complex pathology might present additional difficulty during induction and intubation, which might lead to different behaviours, potentially with less compliance with standard infection control practices and increased environmental contamination. Also, contamination is not limited to induction of anaesthesia; as Prielipp and Brull[20] accurately note, there are ample opportunities for spread of infection during placement of orogastric tubes, bougies, and other similar devices that occur outside of the period we studied. Finally, we identified 14 target sites for this study, but in an real OR there are innumerable possible potential sites of contamination that we did not observe; importantly, these sites include the computerized record-keeping system, because this is a site with which providers interact during induction and intubation, and one which may not be cleaned routinely between patients. That being said, future studies may be able to address whether the computerized record system could possibly be targeted with a disposable keyboard or screen cover. Antibacterial hand gel was not provided during this simulation as subjects had already donned gloves at the time of interaction with the fluorescent marker, and so combination of these two infection control methods would not have been feasible in this context. Despite these limitations, we believe our results demonstrate that a barrier method of infection control is a worthwhile target of further investigation given reported difficulties in achieving adequate rates of compliance with hand hygiene.[5–8 21] Further studies should attempt to determine the utility of this device in a live OR to see whether results are generalizable to real patients. Additionally, although we have demonstrated the efficacy of the barrier device, subjects' satisfaction with utilization of the device was not assessed, nor was the feasibility of implementation of the barrier device. Future research should address these important points and may result in a more refined version of what we have presented, but we believe that creation and deployment of the barrier device is not effort- or cost-prohibitive as, in our experience, both of these tasks took <5 min and were easily taught to simulation administrators.

Health-care-associated infections remain a challenge for anaesthetists.[21] Although various measures have been taken to improve practitioners' compliance with best practices, more steps can be taken to bolster the OR environment and make prevention of health-care-associated infections easier via integration into natural workflow. Introduction of oropharyngeal bacteria into the anaesthetist's environment creates opportunities for recontamination of practitioners' hands even if adequate hand hygiene is performed diligently. A barrier device frees the anaesthetist from having to divert attention from the high task burden associated with induction and airway management to perform hand hygiene, and helps to ensure a clean work area thereafter. This also obviates the need for a second pair of gloves, which may not be desirable to some anaesthetists. The cost of materials for furnishing our barrier device was minimal, and the time required to implement the barrier was also marginal; the device could probably be implemented easily into a standard operating room turnover between patients. Our findings demonstrate that a barrier device is effective in a simulated OR environment and should be considered for further investigation in a live OR to determine whether the benefit we demonstrated translates to that setting.

Authors' contributions

Study design: S.H., D.K., A.G., S.D.
Institutional review board submission: S.H., S.D.
Data collection: S.H., R.P., B.L.G., S.D.
Statistical analysis: H.-M.L.
Manuscript preparation: S.H., A.G., H.-M.L., R.P., G.B.
Manuscript revision: S.H., D.K., A.G., H.-M.L., G.B., B.L.G., S.D.

Declaration of interest

None declared.

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