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ORIGINAL ARTICLE

Surface contamination in the operating room: use of adenosine triphosphate monitoring

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Abstract

Purpose We prospectively investigated contamination of high-contact surfaces in the operating room (OR) using adenosine triphosphate (ATP) monitoring. We tested whether contamination would increase from morning (AM) to afternoon (PM), despite cleaning between cases. Second, we compared the degree of OR contamination to non-OR control sites.

Methods ORs with high case volumes were selected for the study. Ten sites in each OR were swabbed using the AccuPoint® HC ATP Sanitation Monitoring device, which provided a numerical measure of contamination (relative light units, RLUs). According to the manufacturer, surfaces are considered clean at ≤ 400 RLUs. AM measurements were taken before the start of surgical cases and PM measurements were taken after cases were completed.

Results Eighty morning and 70 afternoon samples were obtained from 8 ORs. Apart from the OR floor, laryngoscope handles had the highest level of morning contamination (1204 RLUs, interquartile range 345, 2603), with 75% of AM samples and 100% of PM samples exceeding 400 RLUs. This contamination was comparable to hospital toilet seats (87% of samples exceeding 400 RLUs). No sites showed statistically significant increases in contamination from AM to PM.

Conclusion Apart from the OR floors, laryngoscope handles emerged as a key OR site where improved cleaning practices may reduce cross-contamination risk. While some sites showed increased contamination over the course of the day, none of these met statistical significance thereby offering tentative evidence that current cleaning practices during case turnover are effective for most sites.

Keywords Adenosine triphosphate monitoring · Contamination · Operating room

Introduction

Adenosine triphosphate (ATP) is an organic compound present on all living organisms and has been used as a surrogate for microbial contamination [1, 2]. The ATP bioluminescence assay assesses surface contamination by using ATP benchmark values measured in relative light units (RLU), and has been used to monitor the effectiveness of interventions aimed at decreasing contamination of hospital surfaces and thereby infection risk. For example, a previous study used ATP bioluminescence assays to show that the cell phones of orthopedic surgeons had a large number of pathogenic bacteria and significant organic matter contamination, and subsequently recommended standard cleaning of cell phones with cleansing wipes as an intervention to decrease the incidence of surgical site infections (SSIs) [3]. Other studies have used ATP monitoring to assess the adequacy of manual cleaning of flexible endoscope channels, while at our institution, we have previously used ATP monitoring to confirm environmental contamination in the pediatric cardiothoracic intensive care unit, and to improve the effectiveness of cleaning practices [4].

Two previous reports from the neonatal intensive care unit population have linked infectious outbreaks of *Serratia marcescens* with inadequately decontaminated devices as the likely source of cross infection [5, 6]. Other reports have shown contamination of reusable laryngoscopes with organic matter capable of being a potential source

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of cross-contamination and infection [7]. In this study, we used ATP bioluminescence methods to monitor contamination of high-contact surfaces in the OR, and evaluate the effectiveness of cleaning practices during the course of a busy day in ORs with rapid turnover, high volume case lists. We hypothesized that contamination would increase from morning (AM) to afternoon (PM), despite cleaning between cases. Second, we compared the degree of OR contamination to control sites considered to have significant potential for organic contamination to assess the overall incidence and degree of contamination among the OR sites that were sampled.

Methods

The study was considered a quality improvement project by the Institutional Review Board at Nationwide Children's Hospital, and therefore was exempt from review and the need for informed consent. There was no direct patient contact or involvement for the purpose of this study. Eight ORs with high and rapid case turnover were selected for the study. Ten sites in each OR, selected based on the likelihood of high staff contact, were swabbed using the AccuPoint® HC ATP Sanitation Monitoring manufactured (Neogen Corporation®, Lansing, MI). The device measures the quantity of ATP on a given surface and provides a numerical measure of contamination in relative light units (RLUs). Based on manufacturer standards for the device used in this study, a surface was considered clean at measurements ≤ 400 RLUs (prior studies have used various thresholds for surface cleanliness, from 100 to 1000 RLUs, although the most common threshold was 250 RLUs [1]). Initial measurements were taken in the morning (AM) prior to the start of surgical cases. Afternoon (PM) measurements were taken on the same day after all of the scheduled cases were completed, but before any terminal cleaning of the OR had been completed. At our institution, terminal cleaning differs from cleaning between cases in that products, medications, or equipment which are left out are all thrown out or put away at the end of the day, but during the day (between cases) the staff clean around these items. For the secondary aim, convenience samples were taken at 3 control sites which during the pre-study planning were thought to have the potential to be highly contaminated including hospital toilet seats, staff cell phones, and staff hospital badges. Due to non-normal distribution of contamination levels, the data were summarized as medians with interquartile ranges (IQRs), and compared between sites using rank-sum tests. Data from each site were compared between AM and PM samples using sign-rank tests in Stata/IC 14.2 (StataCorp LP, College Station, TX, USA).

Results

A total of 80 morning and 70 afternoon samples were obtained from eight operating rooms over a 2-week period. In one of the ORs, afternoon samples could not be collected in time before terminal cleaning was performed on the day the morning samples were taken. The highest contamination level was found on operating room floors both in the morning and in the afternoon (AM median 2347 (IQR 1253, 9257 RLUs); PM median: 13,275 (IQR 2354, 27, 889) RLUs). Several sites had contamination levels ≥ 400 RLUs including the top of the Pyxis™ work station, the surface of the anesthesia machine, the bed controller, the Bair™ Hugger hose, computer keyboard, and hospital badges. The contamination level of all sites that were monitored is summarized in Table 1. No OR sites showed statistically significant increases in contamination from the AM to the PM samples. Among OR sites other than the floor, laryngoscope handles had the highest level of contamination in the AM [median 1204 (IQR 345, 2603 RLUs)], with 75% of AM samples and 100% of PM samples ≥ 400 RLUs. This level of contamination was comparable to data from hospital toilet seats (95% confidence interval of difference -957, 1733 RLUs; $p = 0.790$; 87% of samples exceeding 400 RLUs).

Discussion

Due to significant morbidity and mortality as well as the added health care costs associated with surgical site infections, ongoing vigilance and quality improvement are needed to minimize potential sources of infection and cross-contamination. The contamination of OR surfaces remains a potential contributing factor of surgical site infections. The incidence and degree of contamination may be particularly significant in areas subject to high or repeated contact such as computer keyboards, devices such as laryngoscopes, or physiologic monitors. In the current study, we used ATP monitoring to evaluate the contamination of high-contact areas in ORs with high case volumes and rapid turnovers. Aside from the operating room floors, of the surfaces and sites included in the study, the highest contamination was found on laryngoscope handles. The magnitude of the contamination was as high as sites which most would consider highly contaminated such as toilet seats.

As noted above, laryngoscope handles had the highest levels of contamination in both the morning and afternoon samples. The laryngoscope blades are changed between patients and these are handled in our sterile supply processing in the

Table 1 Contamination levels at the study sites

Site	Number of samples	Greater than 400 RLUs (*n*, %)	Contamination level (RLUs)		
			Median	IQR	*p* value of change from AM to PM
Pyxis work surface					
AM	8	4 (50%)	751	120, 1588	0.866
PM	7	5 (71%)	518	157, 2566	
Anesthesia machine					
AM	8	6 (75%)	99	65, 296	0.612
PM	7	5 (71%)	273	58, 807	
Floor					
AM	8	2 (25%)	2347	1253, 9257	0.028
PM	7	2 (29%)	13,275	2354, 27,889	
Light switch					
AM	8	3 (38%)	243	30, 567	0.149
PM	7	1 (14%)	62	0, 240	
Phone handle					
AM	8	3 (38%)	388	147, 893	0.176
PM	7	2 (29%)	211	114, 410	
Bed controller					
AM	8	5 (63%)	744	114, 1156	0.499
PM	7	5 (71%)	930	395, 1300	
Laryngoscope handle					
AM	8	6 (75%)	1204	345, 2603	0.866
PM	7	7 (100%)	2064	568, 2670	
Bair hugger connection site					
AM	8	6 (75%)	870	506, 2811	0.917
PM	7	7 (100%)	1067	914, 1438	
Physiologic monitor screen					
AM	8	1 (13%)	110	30, 222	0.499
PM	7	1 (14%)	61	0, 164	
Computer keyboard					
AM	8	6 (75%)	691	455, 1244	0.398
PM	7	4 (57%)	498	40, 1239	
Provider cell phone	17	6 (35%)	285	182, 586	
Toilet seat	10	9 (90%)	1154	901, 1988	
Hospital badge	15	10 (67%)	495	340, 1326	

IQR interquartile range, *RLU* relative light units

same manner as surgical equipment with standard sterilization and processing in sterile peel packs for single patient use. However, the handles are kept in the operating room and replaced into the charging unit, thereby being used for multiple patients. At our institution, decontamination of the laryngoscope handles occurs after the blade is removed, and is performed using Sani-Cloth AF3 Germicidal Disposable Wipes (Sani Professional, Montvale, NJ, USA), wiping up and down the handle 3 times in a rotating motion.

A recent case report highlights the potential impact of laryngoscope handle contamination, outlining the death of two infants in a California neonatal intensive care unit secondary to an outbreak of *Pseudomonas aeruginosa* in the setting of cross-contamination via reusable laryngoscopes [8]. Per the Centers for Disease Control and Prevention, laryngoscope blades are categorized as semi-critical in the United States and thus must be subjected to high-level disinfection after each use [9]. Similarly, practice guidelines of the Association of Operating Room Nurses (AORN) and the American Association of Nurse Anesthetists distinguish between the different components of the laryngoscope and classify the handle as non-critical, suggesting low-level decontamination, which involves the use of agent that destroys all vegetative bacteria (except tubercle bacilli), lipid

viruses, some non-lipid viruses, and some fungi, but not bacterial spores, is adequate [10, 11]. In contrast, the American Society of Anesthesiologists (ASA) practice guidelines classify the laryngoscope blade and handle as a whole entity and recommend high-level decontamination [12]. A general consensus regarding the classification and appropriate decontamination practices of laryngoscopes may help to clarify these issues and aid in standardizing measures to prevent cross-contamination. At our institution, the current practice is to clean the handles using disinfectant wipes between each use, consistent with decontamination practices for devices considered to be non-critical. Although contamination was not shown to increase from AM to PM studies, the fact that the level of contamination was significantly elevated even prior to starting cases in the morning suggests that a review of these practices is needed.

Several interventions could enhance the effectiveness of laryngoscope decontamination and reduce the potential risk of this contamination. One such intervention currently being debated involves the use of single-use disposable laryngoscopes versus reusable laryngoscopes handles and higher level sterilization processes [13]. Other potential interventions to decrease contamination rates which were not studied in the current project include double-gloving by practitioner performing endotracheal intubation or the use of a disposable protective sheath which is placed over the handle of the laryngoscope. Reusable laryngoscopes have a well-established track record, but require sterilization or high-level decontamination after each use, and are composed of parts that require frequent maintenance with a greater potential for failure. Advantages of the single-use disposable laryngoscope handles and blades include a new and reliable battery sources and the potential for improved sterility with no need to decontaminate [14–16]. The major disadvantage is that this practice is potentially inefficient and may contribute to increased environmental pollution and health care costs. A secondary disadvantage is that use of disposable laryngoscopes does not address infection risk with videolaryngoscopes, for which no disposable alternative is available. Other interventions that could potentially aid in decreasing the contamination of laryngoscope handles include wearing double gloves during endotracheal intubation or the use of protective sheaths to store contaminated blades [17, 18]. These options may be preferred as the clinical experience of some practitioners has suggested that the glottic illumination and exposure provided by disposable blades and handles is inferior to that provided by reusable laryngoscopes.

At our own institution, the ATP monitoring device was used to identify high-risk contamination sites in the cardiothoracic intensive care unit during QI measures to limit SSIs (personal communication). Others have used ATP monitoring to assess the level of contamination on cell phones of members of the orthopedic surgical team with a recommendation of at least weekly cleaning of cell phones with decontamination wipes when high-level contamination was noted [13]. Another study used ATP monitoring, in addition to microbiological load and measures of residual protein, for assessing the cleanliness of flexible gastrointestinal endoscopes and concluded that it was a rapid and reliable tool to assess endoscope cleanliness in the clinical setting [19]. These studies, along with the findings from the current study, demonstrate that high touch surfaces and devices, including laryngoscope handles, may benefit from frequent monitoring using ATP sampling to guide decontamination practices.

Limitations of the current study include a somewhat limited sample size. However, this was meant to be a preliminary study to define high-risk surfaces and devices. Although data collection was performed by only 3 of the investigators, there was the potential for inconsistency in sampling methods between investigators collecting ATP data as this was our first investigation using this device. Furthermore, our study did not differentiate among types of rooms and surgical procedures, which may have had different levels of contamination and certainly varying infection risk. Our study lacked confirmatory analysis, which could include sampling using other devices or using other methods, such has microbiological load and measurements of residual protein, to confirm contamination burden. Our study also mirrored recent work in attempting to quantify surface contamination [1, 20], rather than measuring infection outcomes directly. Because ATP monitoring captures contamination by all organic matter, not limited to bacteria, its correlation with infection risk is inexact. Nevertheless, contamination detected by ATP monitoring correlates strongly with specific microorganisms associated with hospital-acquired infection [21]. Finally, our study aimed to characterize the adequacy of existing cleaning practices but not to evaluate specific interventions to reduce contamination, nor to determine the immediate efficacy of cleaning by comparing ATP monitoring data before and after standard cleaning was performed. Other potential interventions to decrease contamination rates, which were not studied in the current project, include double-gloving by practitioner performing endotracheal intubation, or the use of a disposable protective sheath which is placed over the handle of the laryngoscope.

In summary, ATP monitoring of OR sites revealed that laryngoscope handles are a key site where improved cleaning practices at the start of the day may reduce contamination and potentially decrease risk of infection due to cross-contamination. Our results did not show statistically significant differences in contamination between the AM and PM samples of OR sites, offering tentative evidence that current cleaning practices during case turnover are generally effective. Continuation of ATP monitoring will better define the utility of this method for guiding OR decontamination

and infection control. Future studies are needed to define optimal practices for cleaning of high contamination surfaces and devices.

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