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Major Article

Covering the instrument table decreases bacterial bioburden: An evaluation of environmental quality indicators

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EQI

Background: Covering the instrument table during surgery may decrease contamination. We hypothesized that (1) covering the instrument table in an operating room (OR) during static periods of nonuse and dynamic periods of active use would dramatically decrease the bacterial bioburden on the table, and (2) the use of sterile plastic table covers would be equivalent to sterile impervious paper covers in reducing the bioburden in a dynamic environment.

Methods: Bacterial contamination of the instrument table was evaluated by settle plates in static and dynamic ORs. Airborne particulate and bacterial contaminants were sampled throughout the room. Tested groups included instrument tables covered with sterile impervious paper covers, sterile plastic covers, or no covers.

Results: Covering the instrument table during static and dynamic operating room conditions resulted in a significantly decreased bacterial load on the instrument table. No differences were seen between paper and plastic covers.

Conclusions: A significant decrease in bacterial bioburden on the instrument table when the table was covered during static and dynamic periods was observed, suggesting the utility for covering the instrument table during periods of nonuse and during active surgeries.

Surgical site infections are a costly aspect of today's health care system.[1] Therefore, finding ways to reduce surgical site infections is of utmost importance, both for patient care and for optimal resource utilization within hospital systems. In this regard, optimizing sterile conditions in the operating room may reduce airborne and subsequent surface contamination to which a patient is exposed. One way to do this while simultaneously reducing costs may be to cover the instrument table during periods of nonuse. If an operation will be delayed, this would allow the instruments and sterile equipment to be protected until the operation can commence.

The 2017 Association of periOperative Registered Nurses (AORN) "Guidelines for Sterile Technique" state, "When there is an unanticipated delay, or during periods of increased activity, a sterile field that has been prepared and will not immediately be used may be covered with a sterile drape,"[2] and also recommends that "when sterile fields are covered, they should be covered in a manner that allows the cover to be removed without bringing the part of the cover that falls below the sterile field above the sterile field."[2] The rationale for this ideology stems from the theory that bringing the part of the cover that was below the sterile field above it may allow air currents to draw microorganisms and other contaminants from the floor and deposit them onto the sterile field.[2]

Despite these recommendations, there are only limited data to support the practice of covering the instrument table during periods of nonuse. AORN previously did not support covering the instrument table with any type of drape or cover because of the potential for contamination of the table when the cover was removed. In 2013 however, they changed their guidance based on 2 studies that demonstrated a significant reduction of instrument contamination when the instruments were covered.[3,4] In one of these studies however, the findings may be more related to the use of ultraclean air

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ventilation systems and preparing the instrument tables within this system as opposed to the application of the covers themselves. The researchers found that preparing the instruments in an ultraclean air environment and covering them reduced contamination by 28-fold, whereas covering the instruments in a standard preparation room decreased contamination by only 4-fold.[3]

A 2013 study demonstrated that a sterile plastic drape placed directly on the instrument table was equally as effective as disinfecting the instrument table with 70% alcohol and 1% iodine before placing the instruments on the table.[5] However, previous studies have not examined the use of plastic drapes to sterilely cover instruments during periods of nonuse or during periods of active surgery. Therefore, it is not clear if these types of covers are effective in decreasing the bacterial bioburden on the sterile instrument table.

Realizing there is a need to develop more consistent evidence-based practices, AORN states "The health care organization should develop a standardized procedure in collaboration with infection prevention personnel for covering sterile fields to delineate the specific circumstances when sterile fields may be covered and to specify the method of covering and the length of time a sterile field may be covered."[2] They also note that an easy method of draping and removal will ultimately be most effective and that a standardized mechanism for covering instrument tables when not in use should be used.

Therefore, we set out to investigate the degree of contamination on the instrument table during both static periods of nonuse and during periods of active surgery within an operating room environment. We used a validated mock surgical procedure to test environmental quality indicators.[6] We hypothesized that (1) covering the instrument table in an operating room during static periods of nonuse and dynamic periods of active use would dramatically decrease the bacterial bioburden on the table, and (2) the use of sterile plastic table covers would be equivalent to sterile impervious paper covers in reducing the bioburden in a dynamic environment.

METHODS

Operating room specifications

Static testing took place in 2 operating rooms in the same suite located in a surgery center that was attached to an academic medical center. The rooms had high efficiency particulate air filtration and measured 126.5 m^2 each. The dynamic tests took place in a single operating room in an academic medical center. It measured 194.5 m^2 and also had high efficiency particulate air filtration. All rooms had multiple array diffusers in the ceiling and 2 return grilles at opposite corners of the room. The academic medical center operating room was set for 22 air changes per hour, whereas the surgery center operating rooms were set for 28 air changes per hour.

Static testing

An experimental study was designed to test the effects of covering the instrument table during static conditions. Instrument tables were placed in operating rooms for 4, 8, or 24 hours (9 total tables with 3 tables tested at each time point). They were placed around the periphery of the sterile operating room a minimum of 30.5 cm from the wall, and at the edges of the ceiling diffuser arrays (Fig 1). Tables were 86.4 cm in height, 70 cm in width, and 121.9 cm in length. Standard hospital-issued impervious drapes were placed directly on the table. Several surgical instruments, and blood agar settle plates, were then placed on top of the impervious drapes (6 per table, 18 per time point) using sterile technique (Fig 1). A proprietary, commercially available plastic cover (Sterile Z-TIDI Products, Neenah, WI) was then placed with sterile technique over the top of the instruments and agar plates. Additional settle plates were placed around the periphery of the table on top of the plastic cover to assess the utility of the cover in decreasing bacterial load (6 per table, 18 per time point). After 4, 8, or 24 hours, agar plates on top of the covers were aseptically collected. Two representatives from the commercial plastic cover manufacturer then tore the drape along the proprietary seamed central pleat to remove it. The agar plates that were under the cover were then collected. All plates were stored cold per laboratory instructions for approximately 24 hours while they were shipped under chain of custody. Settle plates were analyzed by the team's microbiologist and quantified as colony forming units (CFU) per plate.

Dynamic testing

Study design

For dynamic testing, a mock surgical procedure that has previously been described was used to simulate real operating room

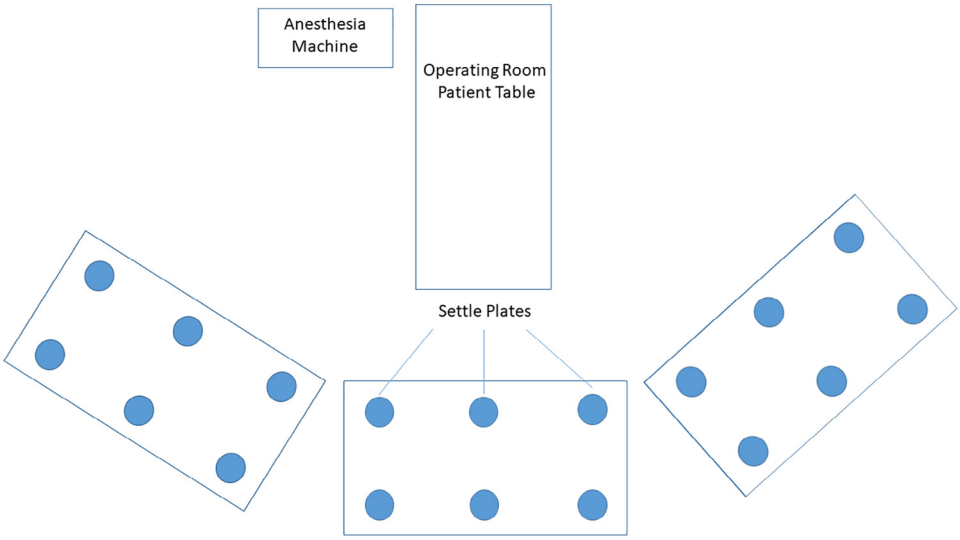

Fig 1. Static test room layout: during static testing, 3 back tables were covered, and bacterial settle plates were placed both under and over the covers for analysis.

conditions.[6,7] No patients were included in the study; therefore, institutional review board approval was not necessary. Three different instrument table settings were studied: (1) no cover; (2) a sterile impermeable paper cover which was included with the sterile instrument packs used at the facility (cover 1); and (3) a proprietary, commercially available plastic cover (cover 2). Each scenario was tested 3 times for a total of nine 1-hour tests. Scenarios were not randomized but were altered (ie, no cover, sterile paper cover, commercial plastic cover).

Personnel and mock surgical procedure

The study team consisted of a surgeon; a microbiologist; 2 engineers specializing in hospital heating, ventilation, and air conditioning; and an industrial air hygienist. These 5 people, in addition to a scrub person and medical student from the facility, performed 1-hour mock surgical experimental procedures as previously validated and described.[6,7] Study personnel wore standard hospital-issued, clean scrub attire, head coverings, surgical masks, and shoe covers. Two representatives from the commercial plastic cover manufacturer were also present in the room to facilitate placing and removing the plastic covers.

To provide consistent execution of the mock surgical procedure and to ensure unbiased repeatability, a detailed, timed process was developed and displayed on the computer monitors within the operating room. This script defined the physical actions for each of the research team members to perform in 4-minute increments during the procedure to simulate actual operating room conditions. The script defined the steps undertaken by operating room personnel and included gowning and gloving, passing instruments, entering and leaving the room to obtain supplies (15 times per experiment), and use of an electrosurgical unit on an uncooked steak (mock patient) to generate particulate tissue matter.[6] The scrub person worked from a sterile Mayo stand and did not access the instruments on the instrument table so as not to disturb the covers.

Instrument table covers

Two instrument tables were used for each experiment. Tables were 86.4 cm in height, 70 cm in width, and 121.9 cm in length. One table was not covered, was not considered sterile, and was used to deploy surface air samplers to assess airborne bacterial load, whereas the other table was covered with a sterile drape and used to perform experiments that assessed the effectiveness of instrument table covers (Fig 2). Both tables were placed in standard locations for use in the operating room. Experimental testing was conducted on instrument tables with no table cover, an impervious sterile paper cover (cover 1), and a proprietary, commercially available plastic cover (cover 2; Sterile Z-TIDI Products) (Fig 3).

Standard hospital-issued impervious drapes were placed directly on the instrument table. Several instruments and blood agar settle plates were then placed on top of the sterile drape. Settle plates were placed at designated positions on the instrument table, after which time the instruments were covered by gowned and gloved individuals. Sterile technique was used to ensure no contamination. Additional settle plates were placed on top of the covers to assess the room bacterial load. The experimental testing group was alternated between each experiment. Each scenario was evaluated 3 times (3 hours for no cover, 3 hours for paper cover, and 3 hours for plastic cover). After the experiments, the paper cover was removed. Care was taken to ensure that the sides of the paper cover did not contaminate the field. For tests with the plastic cover, 2 individuals tore the cover along the proprietary seamed central pleat to remove it effectively.

Environmental quality indicators

Assessment of airborne contamination and environmental quality indicators was performed as previously described.[6] Air velocity measurements at key locations in the rooms were measured using a calibrated air velocity meter (Model 9565; TSI Velocicalc; TSI Incorporated, Shoreview, MN). The velocities were measured every 2 minutes during the 1-hour mock procedure at the operating room table (sterile field, 90 data points per cover type) and at the instrument table (back table, 90 data points per cover type) and recorded in meters per second.

Particle contamination was measured using a Climet Model CJ-750T 75 LPM counter (Climet Instruments, Redlands, CA). ISO 14644-1 standards.[8] were used, which required measuring the number of particles at 9 grid points throughout the room based on the size of the space (Fig 2). Each point required 2 minutes for data collection, which allowed the industrial hygienist to assess the room in approximately 20 minutes. This resulted in 3 complete passes through the 9-point grid during the 1-hour mock procedure. These passes were delineated as first pass, second pass, and third pass (Table 1). During the first pass, electrocautery was not used during

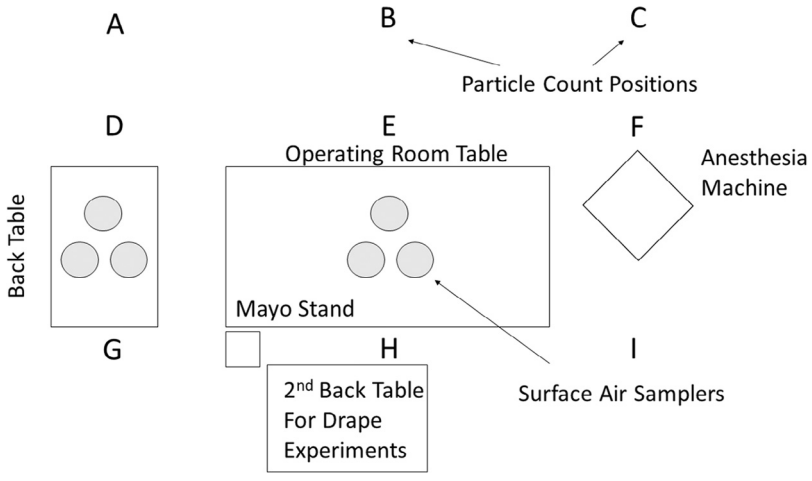

Fig 2. Room layout for measurement of environmental quality indicators. During dynamic testing, the representative layout of operating room table and instrument table along with key assay equipment is shown. Points A-I denote placement of particle counter for 9-point assessment according to ISO 14644-1 standards.

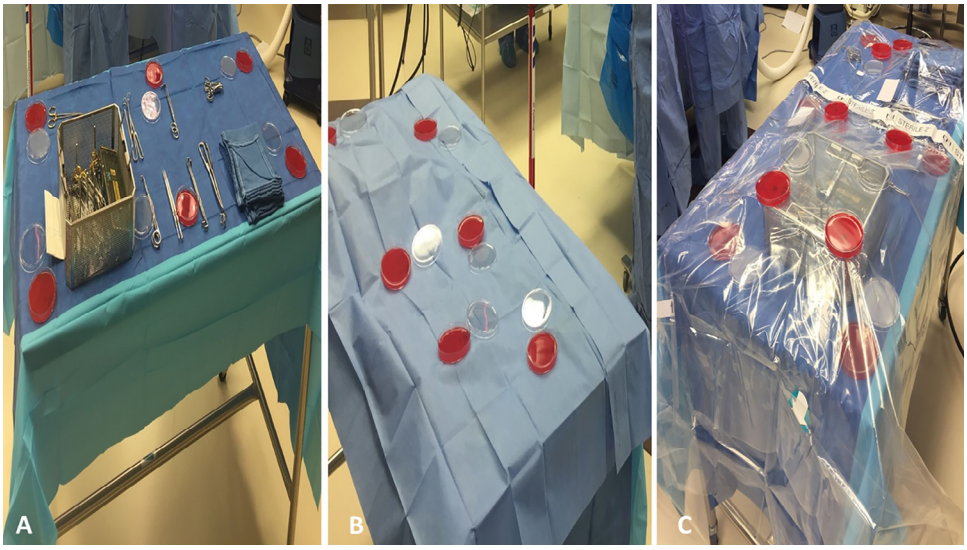

Fig 3. Instrument table cover setup: experiments with (A) no cover, (B) a sterile paper cover, and (C) a sterile plastic cover were undertaken to determine the effectiveness of decreasing the bioburden beneath the top cover.

Table 1
Particle counts with different instrument table covers

	No cover		Cover 1		Cover 2		KW
Particle size	Median	IQR	Median	IQR	Median	IQR	*P* value
0.3 μm							
First pass*	54,720	53,220	47,668	38,883	53,987	47,269	.42
Second pass	471,815	844,282	428,140	570,018	350,026	627,763	.91
Third pass	409,224	779,312	361,850	436,138	345,245	347,166	.70
0.5 μm							
First pass	37,191	27,394	31,672	29,166	34,598	29,833	.97
Second pass	226,164	268,348	175,506	241,598	193,169	225,500	.55
Third pass	132,900	215,159	128,688	153,382	117,884	109,206	.79
1.0 μm							
First pass	17,322	25,561	17,196	17,063	16,403	18,702	.75
Second pass	56,326	60,785	50,654	55,532	48,468	40,616	.66
Third pass	46,188	52,400	39,983	44,242	36,991	30,566	.74
5.0 μm							
First pass	2,346	1,893	2,646	2,112	2,179	2,126	.79
Second pass	2,053	1,453	2,159	2,226	2,313	1,793	.73
Third pass	2,466	1,273	1,926	1,380	1,900	1,953	.76

IQR, interquartile range; *KW*, Kruskal-Wallace test.
*Particle contamination was measured using ISO 14644-1 standards, which required measuring the number of particles at 9 grid points throughout the room. This resulted in 3 complete passes through the 9-point grid during the 1-hour mock procedure. The first pass did not use electrocautery during the mock procedure, whereas passes 2 and 3 did use cautery.

the mock procedure. However, during the second and third passes, electrocautery was used to generate particulate matter that would be similarly seen with the use of electrocautery during surgery. The particle sizes recorded were 0.3, 0.5, 1.0, and 5.0 μm in particles per cubic meter (81 data points for each particle size per testing group).

Microbial contamination was measured by active assessment and by passive settle plate assessment. For active assessment, viable surface air samplers (SAS180; Bioscience International, Rockville, MD) were placed at both the sterile operating field and at the instrument table to detect bacterial contaminants (Fig 2). Air samplers acquired 1,000 L of ambient air over a 5.5-minute period, and Petri plates with blood agar medium were used in the samplers to collect the microbes. The plates were changed in regular cycles to collect microbial data during the entire mock procedure (72 agar plates assessed at the sterile field and instrument table for each testing group).

Passive settle plate assessment was achieved by placing 6 blood agar settle plates around the sterile instrument table under the cover and 6 on top of the cover (if a cover was used), and allowing them to collect microbes and debris that dropped throughout the 1-hour mock procedures (18 agar plates assessed under the sterile covers for each type, and 18 agar plates on top of the covers [or on the table if no cover used]) (Fig 2). The viable microbial samples were sent under chain of custody to a third-party microbiology laboratory for qualitative and quantitative analysis of bacteria. Bacterial colonies were identified and quantified as CFU per cubic meter.

Statistics

Statistical analysis was done using GraphPad Prism 7 (GraphPad Software, La Jolla, CA). Data were assessed for normalcy by the Shapiro-Wilk and the Kolmogorov-Smirnov tests and were determined to be nonparametrically distributed. Data were reported as the median with interquartile range and compared with the Kruskal-Wallace test followed by post hoc Mann-Whitney comparison with Bonferroni correction. $P < .05$ was considered statistically significant.

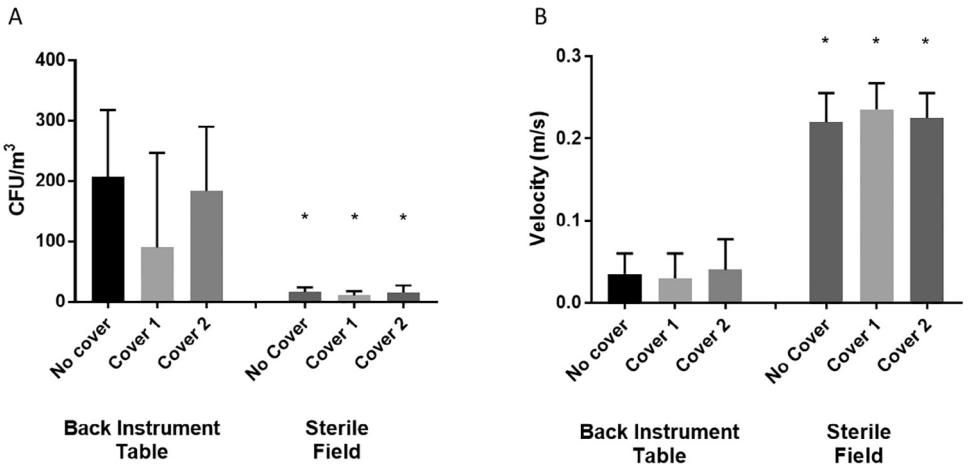

Fig 5. Active microbial assessment in a dynamic operating room environment: (A) No differences were seen in airborne microbes at the sterile field or at the instrument table relative to the type of cover used. However, there was significantly higher microbial contamination at the instrument table when compared with the sterile operating field. (B) Air velocity at the sterile field was consistently higher in all conditions compared with the instrument table. *CFU*, colony forming units. $^{*}P < .05$ versus respective instrument table values.

RESULTS

Static testing

Covering the instrument table during static, nonuse conditions resulted in a lower bacterial load underneath the cover compared with on top of the cover. Bacterial bioburden above the cover at 4 hours was significantly higher than beneath the cover (above cover, 0; interquartile range [IQR], 1; beneath cover, 0; IQR, 0; $P = .007$). Similarly, the bacterial bioburden above the cover at 8 hours was significantly higher than beneath the cover (above cover, 0; IQR, 2; beneath cover, 0; IQR, 0; $P = .02$). Interestingly, there was no difference in bacterial bioburden above and beneath the cover at 24 hours (above cover, 0; IQR, 0.25; beneath cover, 0; IQR, 0; $P = .10$) (Fig 4).

Dynamic testing

Particle contamination

There were no significant differences in airborne particle sizes for the 3 different instrument table cover scenarios (Table 1).

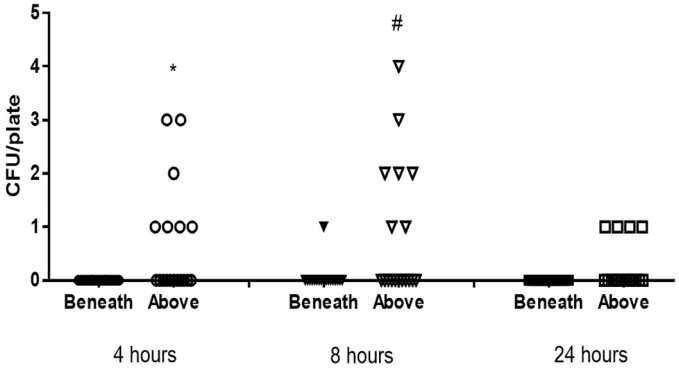

Fig 4. Static microbial testing: covering the instrument table during static nonuse in the operating room resulted in lower bacterial contamination on the table at 4 and 8 hours, but not at 24 hours. *CFU*, colony forming units. $^{*}P < .05$ versus below cover at 4 hours; $\#P < .05$ versus below cover at 8 hours.

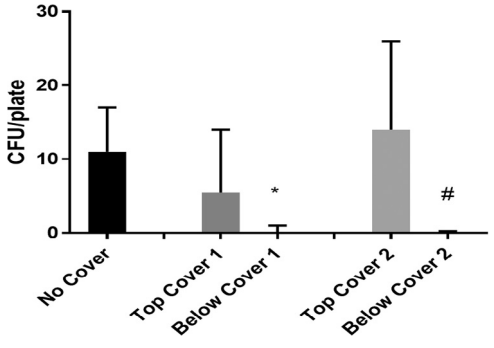

Fig 6. Settle plate analysis of instrument table covers in a dynamic operating room environment: sterile paper and plastic table covers effectively reduced the bioburden at the table during a dynamic operating room procedure. However, no significant differences were noted between the type of cover used. *CFU*, colony forming units. $^{*}P < .05$ versus top cover 1; $\#P < .05$ versus top cover 2.

Airborne bacterial contamination

Active bacterial air sampling did not detect any differences in airborne bacterial contamination between any type of cover that was used. Interestingly though, the number of airborne bacteria detected at the instrument table was consistently and significantly higher than at the sterile field (Fig 5A). This observation negatively correlated with air velocity within the room, which demonstrated that velocities at the instrument table were significantly lower than at the sterile field (Fig 5B).

Instrument table cover analysis

Passive settle plate bacterial assessment on the instrument tables demonstrated a significant difference between the bacterial bioburden on top of the covers versus beneath the covers (above cover 1, 5.5; IQR, 9.5; beneath cover 1, 0; IQR, 1; $P < .0001$; above cover 2, 14; IQR, 22.5; beneath cover 2, 0; IQR, 0.25; $P < .0001$). There was no statistical difference between the bacterial bioburden on top of each of the covers or when no cover was used at all ($P = .19$) (Fig 6). Similarly, there was no difference in the bioburden beneath the covers when the sterile paper and plastic covers were directly compared.

DISCUSSION

Under normal circumstances, it is rare for instruments to be open and unattended in the operating room. Short delays may occur, such as when surgeons or anesthesiologists are delayed in another operating room or at another hospital, or if patients require extensive radiographic tests immediately prior to surgery. In these situations, the instruments may realistically be covered for a short period prior to the start of the operation. However, it would be rare for a set of instruments to sit in a room for 4, 8, or even 24 hours. Current alternatives to the use of a cover would be to break down and reprocess all of the instruments involved, which could add operating costs to hospital budgets.

Although not used routinely, the use of instrument table covers may be extremely useful in other situations. For example, orthopedic or cardiac implants may be on the back table and open while a surgery is ongoing, and during these situations, it may be advisable to cover the implant to reduce potential contamination. An additional use for covering instruments, although not standard in practice, would be at a major trauma center, where instruments could be left out, covered, and ready for the next major operative trauma surgery. This would allow for near instantaneous access to instruments for the patient once they reach the operating room and would decrease the wait time that was needed for instrument setup by nursing staff.

Prior to 2013, instrument tables were not routinely covered. However, in 2013, AORN changed their recommendations to suggest covering the field during extended periods of nonuse.[9] Interestingly, the most recent update from the Association of Surgical Technologists still does not endorse the use of instrument table covers. Their 2011 "Standards of Practice for Creating the Sterile Field" states, "Removing the cover in an aseptic manner that prevents contamination of the sterile field cannot be achieved since the sides of the cover are below the level of the surface of the table and most likely will touch the sterile field upon removal. Additionally, moving the cover upward stirs the air current in an upward direction causing airborne contamination of the sterile field.[10]" Although there is limited evidence to show that covering sterile tables reduces contamination,[3,4] there is no evidence to show that removal of the cover contaminates the sterile field.

After the publication of a 1996 study examining the effectiveness of covering instruments in an ultraclean environment,[3] a 2008 study further demonstrated increased contamination of operating room trays in rooms with traffic, and decreased contamination when trays were covered.[4] However, covered trays were assessed in a locked static operating room, and it is unclear how well covering the instrument table decreased bacterial load on the table in a dynamic operating room setting. A 2013 study examining the effectiveness of covering spine implants while on the instrument table before surgical implantation showed that 16.7% of uncovered implants became contaminated, whereas only 2% of covered implants showed contamination.[11]

Herein, we noticed that in static conditions of nonuse, covering the instrument table reduced bacterial load at 4 and 8 hours, but not at 24 hours. This was certainly interesting because it was surmised that 24 hours of exposure would certainly allow for buildup of bacteria on top of the cover. Two possible reasons for this discrepancy are that the 4- and 8-hour tests were performed in one room, whereas the 24-hour test was performed in an adjacent room. In addition, the rooms were not in overnight setback modes, which usually consist of 5 air changes per hour to save costs. Instead they were in an active mode with an average of 28 changes per hour. Because of this, the heating, ventilation, and air conditioning system may have had more of an opportunity to cleanse the air, therefore lowering the room bacterial bioburden at 24 hours.

During dynamic testing, there were no observed differences in room particle contamination or overall airborne bacterial loads between experiments. This phenomenon was expected and serves to indicate that the methodology was consistent between all 1-hour mock experiments. One notable observation though was that the air flow at the back table was consistently lower than at the surgical sterile field. The air speed was typically higher at the sterile field because of the cold air dropping more rapidly, which led to readings of 0.18-0.23 m/sec. Although at the back table, the air flow often ranged from 0-0.08 m/sec. The design of many operating rooms is to direct the largest airflow to the sterile field, which leaves the instrument table to receive less clean air. Because of this lower air velocity, we noted a consistently higher microbial burden at the instrument table than the sterile field, therefore making the concept of effective table covers more prudent. Other mechanisms to decrease bacterial contamination at the instrument table would be to ensure that in-ceiling diffuser arrays effectively cover the instrument table area, thereby ensuring adequate ventilation to the instrument table in addition to the sterile operating room table.

When instrument table settle plates were examined, the bacterial bioburden on the table when no cover was used was equivalent to the bioburden on top of each cover, again confirming there was no break or bias in the methodology. However, there were noted differences in the bioburden when CFU were compared above and below both of the instrument table covers. With both cover types tested (ie sterile paper cover and sterile plastic cover), the bacterial load was significantly decreased underneath the cover compared with the top of the cover. However, when the paper and plastic covers were compared with each other directly, no statistically significant differences were noted in CFU below the drape.

Two of the 3 experiments examining the paper cover had elevated CFU levels on the plate at one of the corner positions below the cover. In one experiment, there were 16 CFU, in the second there were 4 CFU, and in the third there were 0 CFU. When compared with this same position with the plastic cover, there were 0, 0, and 0 CFU, respectively. Although there were no statistically significant differences in overall contaminants between the paper and plastic covers, the corners of the paper cover could be a source of contamination for this style of cover. With only 3 data points at this specific location, there was not enough statistical power to reach a definitive conclusion. There were no obvious differences at any of the other corners. It is unclear if this occurred because of air flow in and around the cover or if it occurred when the cover was removed.

LIMITATIONS

There were several limitations in this study which should be noted. First, our experiments were performed during a mock procedure rather than during a real operation with patients. Because of health privacy laws and ethical considerations, we were not able to perform these experiments during patient operations. However, the conditions of the mock procedure were very similar to that of a real operation; therefore, the data are likely able to be extrapolated. In this regard, we think this study represents the best scientific attempt to assess instrument table covers in both a static and a dynamic operating room.

Another potential limitation could be that the scrub person did not access the instrument table during the mock procedure. Accessing the instrument table may have been more realistic but would have disturbed the covers that were being assessed for sterility. Additionally, the study was not blinded or randomized. The study personnel could not be blinded by the type of table cover being used. Study bias could therefore be a criticism. However, given that the room contaminants and levels of microbes on top of the covers were similar throughout the experiments, we feel that bias could

effectively be eliminated. Furthermore, the results of this study were not able to be correlated to surgical site infections, which is a limiting factor in translational effect.

An additional limitation is that the static tests were not performed for shorter periods of time to mimic shorter operations or periods of time such as when an implant sits open on the instrument table prior to starting a surgery. In addition, the dynamic procedures were only an hour long and therefore may not appropriately mimic longer and more complex cases. Finally, we realize that a criticism of this study may be that a single sterile paper cover was used and it was not applied per AORN recommendations. However, there is little evidence to direct best practices for instrument table covers in the operating room; furthermore, additional evidence to support or refute the method of drape application should be considered.

CONCLUSIONS

Practices to reduce the bioburden in the operating room are of utmost importance, particularly to reduce surgical site infections. Although there is no ability to correlate the findings of this study with surgical site infections, we think there is ample evidence to suggest that covering the instrument table can reduce the bacterial bioburden at this area. Although current AORN recommendations suggest covering the instrument table during periods of nonuse, the results of this study would suggest that covering the instrument table during surgical procedures may be of significant benefit. Novel devices to permit table coverage during surgery, while allowing for sterile access at critical times, should therefore be considered.

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