



## Original Research

## Effectiveness of Manual Terminal Cleaning Varies on High-Touch Surfaces Near the Operative Field

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## ABSTRACT

**Background:** Periprosthetic joint infection may result from pathogen to patient transmission within the environment. The purpose of this study is to evaluate the contamination level of selected high-touch surfaces in the operating room (OR) using a blacklight fluorescent marking system after a manual terminal clean.

**Methods:** Prior to the manual terminal clean, 16 high-touch surfaces were marked using a blacklight fluorescent gel. The marked areas were assessed the next morning for thoroughness of cleaning. Surfaces were categorized based on the average percent of the marks removed as “clean” (>75%), “partially clean” (26%–74%), or poorly cleaned (<25%). This process was repeated randomly 12 times. Terminal cleaning was done in the standard fashion, and the perioperative team was unaware of the initiation of this study. **Results:** A total of 936 marks were analyzed. There was a significant difference in the number of marks completely clean (29.1%, 272/936) vs marks that were not touched (40.8%, 382/936),  $P < .001$ . Only the OR back table (75%) had a rating of clean. Partially clean areas included Mayfield table (72%), overhead lights (70.1%), infusion pump (61.1%), clock reset button (58.3%), table remote control (50%), tourniquet machine (50%), and the OR table (33.3%). Poorly cleaned surfaces included anesthesia medication cart (21.8%), door handles (20.8%), phone (16.7%), electrocautery unit (16.7%), foot pedal (16.7%), anesthesia cart (16.2%), nurses' station (14.1%), and supply cabinet doors (6%).

**Conclusions:** Effectiveness of manual terminal cleaning varied greatly across surfaces. In general, surfaces further from the operative field were less likely to have markings removed.

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## Introduction

The prevention of surgical site infection and periprosthetic joint infection (PJI) in orthopedic surgery is multifactorial [1–6]. Of the potential modifiable risk factors, pathogen to patient transmission within the environment has been an area of focus in total joint arthroplasty (TJA) [1]. Most arthroplasty surgeons believe there is a proportional relationship between colony forming units in the environment and the incidence of PJI in TJA [1].

High-touch surfaces in the operating room (OR) at risk for gaps in cleaning have been identified in previous studies [7–10]. These studies have suggested many surfaces in the OR (ie, anesthesia cart, nurses station, OR bed) have been inadequately cleaned which has led to recommendations for improvements in targeted cleaning and staff education. There is growing evidence that the hospital environment, including the OR, is often not cleaned thoroughly or in a manner consistent with relevant hospital policies [8–12]. These surface areas in the OR may be an area of intracase cross-contamination if not cleaned and disinfected appropriately. Theoretically, direct contamination or airborne bacterial contamination may lead to an increase risk of PJI [7,10,12–17].

Ideally, prevention of PJI is the preferable treatment in terms of both patient outcomes and cost. Prevention requires the

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identification and control of the potential sources of microbial contamination. A terminal room disinfection has been the widely accepted standard of practice; however, deficiencies in this process have been reported [18,19]. These studies have shown that visual inspection is a poor indicator of cleaning efficacy and have targeted other means for clinical evaluation (ie, fluorescent, adenosine triphosphate bioluminescence). The importance of this cannot be overemphasized particularly in TJA surgery where “contaminated” cases are typically performed at the end of the day. These deficiencies in terminal cleaning may lead to an increase in OR bacterial burden which may have a direct impact on aseptic cases the following day. Therefore, the purpose of this study is to evaluate the contamination level of selected high-touch surfaces in the OR using a blacklight fluorescent marking system after a manual terminal clean.

## Material and methods

This was a prospective observational study performed at a single institution. Approval from our institutional review board was obtained prior to initiation of the study. This study was conducted between February 2020 and January 2021. The gap encountered was secondary to the COVID-19 pandemic and a brief pause in our research capabilities at our institution. The ORs utilized were rooms designed specifically for and only have primary and revision TJA procedures routinely performed during the day. A transparent, easily removable gel solution that dries rapidly and fluoresces when exposed to ultraviolet (UV) light was used to mark 16 selected (78 predetermined areas within the surfaces) OR high-touch surfaces (Table 1, Fig. 1) after the last procedure of the day and prior to the manual terminal clean. A small drop of the fluorescent marking gel was placed on a nonporous surface and lightly spread with a cotton swab (Q-tip) in a circular pattern to make a dime-sized mark (5–10 mm) until the surface gel was no longer visible. Similar techniques with the use of a UV gel have been validated in previous studies [20,21]. The predetermined number of spots were recorded for each surface. The gel was allowed to dry. Manual terminal cleaning was done in the standard fashion, and

the perioperative team was unaware of the initiation or completion of this study. The terminal clean at our institution is standardized, and the same staff performs this process daily.

The marked areas were assessed the next morning for the thoroughness of cleaning. Throughout the study, only 1 member of the research team performed the application and observations of the UV markers. Surfaces were categorized based on the *average percent* of the marks removed as “clean” (>75%), “partially clean” (26%–74%), or poorly cleaned (<25%) (Fig. 2). We arbitrarily used the percentages to help define the thoroughness of the areas being cleaned. We felt this was a better representation than “all or nothing.” This process was repeated randomly 12 times. The data collected in this study will be utilized to help improve the thoroughness of cleaning by instituting a monitoring and feedback program. This has been done successfully in the OR and other areas of the hospital in previous studies [11,12].

## Statistical analysis

Proportions to compare thoroughness of cleaning were calculated and analyzed using Fischer’s exact test. Statistical analysis was performed using Minitab v. 18.1 (Minitab, State College, PA).

## Results

Overall, 12 different OR terminal cleanings were performed. A total of 936 marks were analyzed from the 16 high-touch surfaces. There was a significant difference in the number of marks completely clean (29.1%, 272/936) vs marks that were not touched (ie, 0% of the marks removed; 40.8%, 382/936,  $P < .001$ ). Results showed that the mean overall thoroughness of cleaning (ie, expressed as a percentage of objects evaluated) was 37.5% (standard deviation, 32.9; confidence interval, 18.9–56.2) (Table 2). Only the OR back table (75%) had an average rating of clean. Partially clean areas included Mayfield table (72%), overhead lights (70.8%), infusion pump (61.1%), clock reset button (58.3%), table remote control (50%), tourniquet machine (50%), and the OR table (33.3%). Poorly cleaned surfaces included anesthesia medication cart

**Table 1**  
High-touch surfaces.

High-touch surfaces	Marking location
1. Operating room table	Area on top (facing ceiling) of middle of the bed, end of the bed, and area in the middle 3 spots in a line down (as viewed from the foot of the bed).
2. Operating room table control	Two spots, 1 on each of the ends in the middle on the control panel.
3. Back table	Area on top (facing ceiling), 5 markings, 1 at each end and 3 in the middle. Area on the bottom, 1 mark in the middle.
4. Mayfield table	Area on top (facing ceiling), 3 markings, 1 at each end and 1 in the middle. Area on the bottom, 1 mark on the left leg (closest leg to the bed).
5. Electrocautery control unit	All 3 areas of the control unit and 3 markings on the top.
6. Intravenous pump	Middle buttons on the side of the display monitor, to the left and right. Buttons on control unit below monitor.
7. Anesthesia machine (including machine knobs and screen)	Area on the top monitor, 3 spots along the bottom of the touch screen, area to the right and the left of the computer monitor, area on the handle of the keyboard used to adjust the keyboard, area in the middle of both lower drawers, 2 spots on the middle monitor 1 in the middle of the bottom row of buttons and 1 in the middle of the right side of buttons, all 4 knobs below this same monitor. Three spots on the working surface facing the ceiling attached to the anesthesia machine across the middle.
8. Supply cabinet doors	Area on the 3 center top cabinets doors, 1 marking on each handle and another on the middle bottom surface of each door.
9. Medication cart	All drawers in the middle, the monitor, on the touch to start here button, and the surface facing the ceiling in the middle of the cart.
10. Clock reset/start button	One mark on the stop/start button.
11. Nurses’ documentation station (including telephone, mouse, monitors, keyboard, and scanner)	One mark on the bottom middle of the main computer screen, 1 mark on the telephone handle, 1 mark on both mouse, 1 mark on both keyboards on the space bar, and surface on the far left, far right, and middle of the desk. One mark on each side of the far-left computer screen on the adjustable station, 1 mark on the keyboard handle that moves the workstation in the middle. One mark on the trigger button of the scanner.
12. Door handles (×2)	In the middle of each handle, 1 marking
13. Overhead light	1 Marking on bottom handle and in the center of the light above the handle.
14. Turnover call telephone	1 Marking in the middle of the telephone handle.
15. Tourniquet machine	One mark on the far-left button and another mark on to the left of the screen in the middle.
16. Foot pedal pressurizer	One mark on the tubing just above the foot pedal device.



**Figure 1.** Example of marked surfaces on the OR back table.

(21.9%), door handles (20.8%), phone (16.7%), electrocautery unit (16.7%), foot pedal (16.7%), anesthesia cart (16.2%), nurses' station (14.1%), and supply cabinet doors (6.9%).

## Discussion

Despite the use of trained perioperative service personnel and policies at our institution, we found many areas of improvement needed in the terminal OR disinfection process. Of the high-touch surfaces we investigated, only the OR back table had an average rating of “clean”. This inconsistency of cleaning and environmental contamination is similar to previous reports in the literature [11,12,18–21]. These studies have clearly shown that visual inspection alone is not adequate in the terminal disinfection process. As such, most of these studies have recommended an enhanced cleaning protocol (ie, staff education, UV light) to supplement this process.

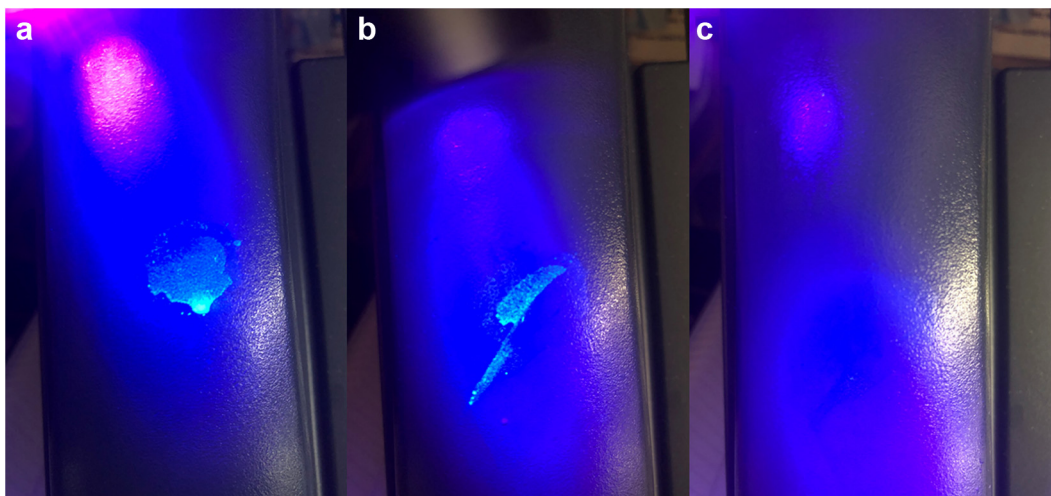
It is clear that the OR environment can become contaminated with pathogens and may lead to an increase risk of PJI [8–10,14–17,21]. This may be secondary to suboptimal cleaning practices. The original standard for determining cleanliness within the hospital environment was visual inspection until this was proven to be inferior to more quantitative methods [22–25]. Visual inspection is subjective and less sensitive than other evaluation

methods such as the use of the gel solution in this study [20–26]. Our data show that there may be a need for more stringent cleaning and disinfection of the OR environment as an adjuvant to standard infection control protocols used for arthroplasty procedures.

Improvements in cleaning procedures within the hospital and OR can be and have been done with success [1,8,9,11,12,20,21,23–25,27]. The use of microbiologic analysis of surface hygiene, the use of fluorescent markers or adenosine triphosphate assays to assess the thoroughness of cleaning, gives the opportunity for providing feedback of cleaning performance. Educational campaigns and awareness have been shown to be effective techniques to improve the cleaning process and thus reduce contamination of surfaces [1,8,9,11,12,19–21,24]. Based on the data from this study, we plan to implement these techniques in our standard practice.

No-touch room decontamination systems such as UV light for terminal disinfection of ORs have been shown to help reduce and eliminate residual pathogens on surfaces [1,2,28–39]. These systems when implemented appropriately eliminate the “human error” portion of the cleaning process. While the manual terminal clean is still utilized, this adjunct certainly may be warranted to decrease contamination. One limitation of this technology is the practicality of its use since, in general, these systems are recommended for unoccupied times in the OR. This typically requires a hospital employee to move these machines from room to room after the operative day and clean them completely. Newer technology may allow for in-room use to decrease environmental contamination; however, further research is needed in this area to assess the efficacy and safety [40]. This would potentially allow for the terminal clean and adjunct UV-light disinfection to occur simultaneously.

This study is not without limitations. Our data were limited to the terminal cleaning process and did not account for between-case cleanings. The cleaning between the cases may have left more environmental contamination since there is typically a “rush” to turn the rooms over in our busy arthroplasty practice. We were unable to do this secondary to the flow of our OR and the blinding of this study to the perioperative staff. We did not obtain cultures from the surfaces. While this would have been ideal, our hospital system does not allow cultures for environmental purposes. Nevertheless, the intent of this study was to identify areas that may not get thorough cleaning, not to evaluate for cultures. We intend to implement further treatments to the high-touch surfaces with UV light treatment and perioperative cleaning education in our future studies. Cultures of these surfaces may be considered for further



**Figure 2.** Markings seen with a florescent light as “poorly cleaned” (a), “partially cleaned” (b), and “clean” (c).

**Table 2**  
High-touch surfaces mean proportion cleaned.

Object	Mean proportion cleaned (%)	Lowest proportion cleaned (%)	Highest proportion cleaned (%)	Standard deviation	95% CI
Back table	75.0	16.7	100.0	34.5	55.5 to 94.5
Mayfield table	72.2	0.0	100.0	34.3	52.8 to 91.6
Overhead light	70.8	0.0	100.0	33.4	51.9 to 89.7
Intravenous pump	61.1	0.0	100.0	37.2	40.1 to 82.1
Clock reset/start	58.3	0.0	100.0	51.5	29.2 to 87.5
Operative room table control	50.0	0.0	100.0	52.2	20.5 to 79.5
Tourniquet machine	50.0	0.0	100.0	42.6	25.9 to 74.1
Operative room table	33.3	0.0	80.0	31.1	15.7 to 51.0
Medication cart	21.9	0.0	62.5	21.4	9.8 to 34.0
Door handle	20.8	0.0	100.0	39.6	–1.6 to 43.3
Electrocautery unit	16.7	0.0	100.0	30.2	–0.4 to 33.7
Foot pedal	16.7	0.0	100.0	38.9	–5.4 to 38.7
Turnover phone	16.7	0.0	100.0	38.9	–5.4 to 38.7
Anesthesia cart table	16.2	0.0	35.3	12.6	9.1 to 23.3
Nurses station	14.1	0.0	38.5	11.8	7.5 to 20.8
Supply cabinet doors	6.9	0.0	50.0	16.6	–2.4 to 16.3
Mean	37.5	1.0	85.4	32.9	18.9 to 56.2

data and treatment options moving forward. We concede that only certain areas were marked and that other areas of the high-touch surfaces may have been neglected during the cleaning process. It is not possible to cover the entire surface, and the technique we utilized has been done in previous studies. Additionally, we selected high-touch surfaces from other studies, but certainly there may be other surfaces in arthroplasty surgery worth exploring such as computer/robot and fluoroscopy machines. This already has been shown in surgical helmets used during TJA [41]. Lastly, we did all attempts to blind this study, but our perioperative cleaning staff may have been aware. We do not think that this was the case, but if it was, I would argue they likely would have been more thorough in their cleaning efforts.

Effectiveness of manual terminal cleaning varied greatly across surfaces. In general, surfaces further from the operative field were less likely to have markings removed. An adjunct to cleaning (ie, UV light) and perioperative education may be warranted, and future studies are needed to determine the best method to decrease environmental contamination.

### Conflicts of interest

Dr. Dennis receives royalties from DePuy, a Johnson & Johnson Company; gave paid presentations for Corin U.S.A. and DePuy, a Johnson & Johnson Company; is a paid consultant for Corin U.S.A. and DePuy, a Johnson & Johnson Company; has stock or stock options in Corin U.S.A. and Joint Vue; receives research support as a principal investigator for DePuy, a Johnson & Johnson Company, Corin U.S.A., and Porter Adventist Hospital; receives financial or material support from publishers like Wolters Kluwer Health–Lippincott Williams & Wilkins; and is in the editorial or governing board of *Clinical Orthopaedics and Related Research*, *Journal of Arthroplasty*, *Journal of Bone and Joint Surgery–American*, and *Orthopedics Today*. Dr. Jennings is a paid consultant for Total Joint Orthopedics and Xenex and receives research support as a principal investigator for DePuy, a Johnson & Johnson Company, Corin U.S.A., and Porter Adventist Hospital. All other authors declare no potential conflicts of interest.

For full disclosure statements refer to <https://doi.org/10.1016/j.artd.2022.07.002>.

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