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# Evidence-Based Plan for Environmental Cleaning of Operating Room: Impact on High-Frequency Contact Surfaces

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**Abstract:** *Objective:* To develop an evidence-based plan for cleaning operating room and evaluate the impact on high-frequency contact surfaces. *Method:* The evidence application model of the JBI Evidence-Based Nursing Center was utilized to create a strategy, which was implemented in a tertiary-level hospital in Yunnan Province. The adenosine triphosphate (ATP) biological biofluorescence detection method was used to assess the quality of cleaning before and after the intervention. *Results:* A total of 17 quality review indicators were established in this study. Following the application of evidence, the implementation rate for 16 quality review indicators increased significantly, from a range of 0–65.8% to 81.5–100%. Moreover, the pass rate of ATP bioluminescence detection on high-frequency contact surfaces increased from 14.07% to 47.19%, with significant difference ($p < 0.05$). *Conclusion:* The evidence-based environmental cleaning program proved to enhance the overall cleanliness of operating room and reduce the risk of surgical infections. This strategy holds promise for effective cleaning of operating room.

**Keywords:** Environmental cleaning scheme; High frequency contact table; Operating room; Evidence-based practice; Management

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## 1. Introduction

Operation room environmental cleanliness is an important measure in preventing surgical site infections [1]. The level of cleanliness in the operating room is directly linked to perioperative incisional site infection (SSI) and hospital-associated infection (HAI), which are often associated with health care-associated infections [2,3]. Surgical patients are exposed to various infection risks upon entering operating room environment, with studies confirming

that contaminated surfaces such as building structures, equipment and tables contribute to the spread of pathogenic bacteria due to frequent contact by medical staff [2,4,5]. This type of environmental surface, which is commonly touched, is referred to as a high-touch surface [4,6,7]. These high-touch surfaces play a significant role in increasing the risk of surgical site infections. A notable percentage of HAIs are linked to the transmission of pathogens from contaminated hands of healthcare workers to environmental surfaces within the hospitals [8]. Therefore, monitoring the contamination of high-touch surfaces is crucial for evaluating the cleanliness of medical facilities and improving infection control measures [9,10].

Standardized environmental cleaning measures are essential and effective in reducing the risk of infection in medical settings and achieving high-quality cleaning outcomes. However, there is lack of specific regulatory requirements and guideline recommendations for environmental cleaning in China. Therefore, in this study we aimed to developed an evidence-based cleaning protocol for operating room. By utilizing the ATP biofluorescence detection method, we monitored the 'high-frequency contact surface' area in operating room before and after implementing the protocol. The evaluation results were satisfactory, confirming that this evidence-based cleaning strategy can significantly enhance the cleaning quality of operating room in clinical practice.

## 2. Methods

### 2.1. Establishment of operating room cleaning program

#### 2.1.1. Establish an evidence-based practice group

The operating room cleaning plan was formulated by a team consisted of 10 members. The team included a head nurse specializing in evidence-based nursing who supervised this study, 3 graduate students with master's degree who collected and analyzed the data, 2 experienced nurses with title of nurse in charge and training in evidence-based methodology who monitored the evidence application process, a nursing team leader responsible for coordination and communication, resource mobilization and assignments, and 3 key operating room nurses in charge of applying the evidence.

#### 2.1.2. Clinical questions

Clinical questions were formulated using the PIPOST tool from the JBI Evidence-Based Nursing Cooperative Center of Fudan University in Shanghai, China [11]. The structured questions focused on the high-frequency contact surfaces in operating room (P), interventions involving environmental cleaning measures (I), practitioners such as operating room nurses and cleaning staff who apply the evidence (P), outcomes related to the environmental cleaning effectiveness of high-frequency contact surfaces (O), evidence application scenario in operating room of a Grade III Class A general hospital in Yunnan Province (S), and types of evidence including best practices, evidence summaries, guidelines, systematic reviews, and original research relevant to the study topic (T).

#### 2.1.3. Obtaining evidence

A systematic search was conducted for all literatures up to April 30, 2023. A total of 9 relevant sources were included, comprising 3 guidelines, 2 experimental studies, 2 national industry norms, and 2 evidence summaries [1–3,6, 12–16]. The quality of the retrieved literature was assessed to gather pertinent evidence, which was then evaluated based on the feasibility, appropriateness, clinical significance, and effectiveness. The best evidence summary regarding environmental cleaning measures in operating room (OR) was presented in **Table 1**. A table for evidence data

extraction was designed, and evidence content was extracted in accordance with the theme of this study. In cases of conflicting data from different sources, the priority was given to evidence-based evidence, high-quality evidence, and recent publications. Additionally, the JBI evidence grading and recommendation Level system (2014 edition) was utilized to grade and recommend the included evidence, which was categorized into levels 1 to 5 based on the study design.

Database search was conducted following the '6S' pyramid evidence model [16]. The search included databases such as BMJ Best Practice, Up to Date, JBI Centre for Evidence-based Health Care, US Index Network, UK National Institute for Health and Clinical Excellence Guidelines Network, Scottish Guidelines Network, Cochrane Library, PubMed, EMbase, CNKI, Wanfang Database, and China Biomedical Literature Database.

Retrieval strategy for searching evidence-based questions was based on a combination of free words and subject words. Search terms such as 'Environmental management', 'environmental disinfection', and 'environmental cleaning' can be paired with terms such as 'hospital infection', 'environmental infection', and 'Nosocomial infection'. Additionally, keywords such as 'operating room' and 'Prevention/management' can be included to refine the search.

**Table 1.** Summary of best evidence for OR cleaning protocols

| Evidence subject | Evidence content | Evidence level | Recommendation level |
|---|---|---|---|
| *Selection and Use of Disinfectants* | 1.Do not use high-grade disinfectants or liquid chemical disinfectants to clean and disinfect environmental surfaces or equipment[17]. | Level 3 | B |
| | 2.Alcohol should not be used to clean large areas of environmental surfaces[16]. | Level 2 | A |
| | 3.If sodium hypochlorite solution is selected, the EPA-registered sodium hypochlorite product is preferred, and 1:100 dilution can be used for routine disinfection. If large quantities (e.g. >10 mL) of blood or contaminants are involved, use a 1:10 diluted hypochlorite solution for disinfection[17]. | Level 3 | A |
| | 4.Instructions for the correct use of disinfection (or detergent) products, and the use dilution, material compatibility, storage, and shelf life of each disinfectant[16]. | Level 2 | A |
| | 5.The choice of disinfectant should be environmentally friendly, and the disinfectant solution should be prepared daily[17]. | Level 3 | A |
| | 6.Infected areas (HIV or hepatitis B virus) should be disinfected with freshly diluted hypochlorite solution[17]. | Level 3 | B |
| *Cleaning methods* | 7.If the surgical area contains a large amount of blood or body fluids, it is recommended to clean and adsorb contaminants such as blood with disposable absorbent materials, and dispose of contaminated materials in appropriate, labeled containers[18]. | Level 4 | A |
| | 8.Non-porous surfaces, such as mattress covers, pressure tourniquet cuffs, blood pressure cuffs, and other patient equipment, should be cleaned and disinfected with an EPA-registered hospital disinfectant during patient use[16]. | Level 2 | B |
| | 9.Contaminated clothing should be placed in leak-proof containers or bags and properly labeled where used to avoid contaminating air, surfaces and people[18]. | Level 4 | A |
| | 10.Consult the manufacturer's cleaning recommendations before cleaning computer keyboards, monitor screens, telephones, and other electronic equipment[16]. | Level 2 | A |
| | 11.Purchase keyboard covers and install them on each computer keyboard for cleaning and disinfecting between uses[2]. | Level 2 | B |
| | 12.Single-use items contaminated with blood and/or tissue must be placed in sealable, leak-proof containers or bags that are color-coded, labelled or easily identifiable as biohazard waste[16]. | Level 2 | A |
| | 13.Cleaning and disinfection methods that produce mist, aerosols or dust (such as spray bottles containing disinfectants, dry mopping, etc.) should not be used when cleaning[16]. | Level 2 | A |

**Table 1 (Continued)**

| Evidence subject | Evidence content | Evidence level | Recommendation level |
|---|---|---|---|
| *Cleaning tools* | 14.When choosing a rag, choose a clean, lint free cloth that is moistened with an Environmental Protection Agency (EPA) -registered hospital detergent/disinfectant to avoid dust[16]. | Level 2 | A |
| | 15.Disposable microfiber mop heads can be used (microfiber particles are positively charged and can attract negatively charged particles, dust, blood, etc., reducing the risk of chemical spatter) and cleaning cloths, which should be replaced immediately after each use. Used mops or rags should not be returned to the cleaning solution container[18]. | Level 4 | A |
| | 16.After each operation or invasive procedure, operating room should be cleaned using a lint-free or microfiber cloth, soaked with detergent/disinfectant and water[2]. | Level 3 | A |
| | 17.Use a wet vacuum cleaner or disposable mop and disinfectant to thoroughly clean the floor during terminal disinfection[18]. | Level 4 | A |
| *Terminal disinfection treatment* | 18.In addition to routine cleaning, all high-contact objects should be cleaned and disinfected after the patient leaves the operating room as part of an enhanced environmental cleaning procedure[18]. | Level 4 | A |
| | 19.During terminal disinfection, all exposed surfaces, including wheels and casters of all items, should be cleaned and disinfected[18]. | Level 4 | B |
| | 20.All containers (e.g. bins, buckets, buckets), countertops, and tables are cleaned and disinfected after the procedure[16]. | Level 2 | A |
| *Cleaning and disinfection procedures* | 21.When cleaning and disinfecting floors, disinfect them from the outside in. That is, the floor surface in the center of the room is disinfected first around the room (the floor area under the operating room bed and mobile equipment should also be disinfected)[18]. | Level 4 | A |
| | 22.Wipe all surfaces (operating table, head, arm and leg rest stands, lighting and anesthesia equipment) with detergent and disinfectant solution, from clean to dirty, from top to bottom, in a uniform clockwise or counterclockwise cleaning sequence. Special attention should be paid to cleaning keyboards, video towers, and anesthesia equipment[18]. | Level 4 | A |
| | 23.After each use of the operating table, apply detergent solution to clean and wipe, including the mattress and surfaces[2]. All surfaces with contact with the patient or the patient's body fluids must be cleaned and disinfected in accordance with protocol using appropriate disinfectant. | Level 3 | A |
| | 24.All horizontal surfaces in the operating room (e.g. furniture, operating lights, booms, equipment) should be removed from damp dust prior to the first operation of the day. Plasma and display screens should be cleaned according to manufacturer's instructions[16]. | Level 2 | B |
| | 25.A comprehensive cleaning procedure should be performed at the end of each day. All areas within the operating room, scrub pools, scrub or common areas, corridors and equipment should be thoroughly cleaned regardless of whether they have been used in the past 24 hours[18]. | Level 4 | B |
| | 26.Replace fresh solutions as often as necessary, with a frequency of not less than 60 minutes[18]. | Level 4 | A |
| *Staff management* | 27. Limit the spread of microorganisms by all personnel in their daily environmental cleaning and disinfection activities[16] | Level 2 | A |
| | 28.Cleaning personnel should receive initial education, training and competency verification on proper environmental cleaning and disinfection methods, selection of agents and safety precautions. When procedures or supplies and equipment change, additional training should be provided to employees[2]. | Level 3 | A |

**Table 1 (Continued)**

| Evidence subject | Evidence content | Evidence level | Recommendation level |
|---|---|---|---|
| *Cleaning and Disinfection system management* | 29.Managers should develop an operating room environmental cleaning policy and establish quality management procedures to evaluate the process and results of environmental cleaning and disinfection procedures[18]. | Level 4 | A |
| | 30.Establish an interdisciplinary team[2]to determine the cleaning procedure and frequency (e.g. disinfection frequency for high contact areas and non-contact areas) according to the type of operating room surface and the task to be performed. | Level 3 | A |
| | 31.Cleaners should always wear gloves made of natural rubber latex, nitrile, neoprene blend or butyl rubber when cleaning and sanitizing[16] and reduce the use of vinyl gloves. | Level 2 | B |
| | 32.After each operation, the patient must be cleaned and disinfected after leaving operation room[2]. | Level 3 | A |
| | 33.Develop a cleaning checklist for operating room[2]and record cleaning activities on the checklist. Managers use cleaning checklists to assess compliance and visually check surface cleanliness. | Level 3 | A |
| | 34.The covering should be changed and washed each time the patient uses it[2]. | Level 3 | B |
| | 35.All areas and equipment in the surgical practice environment should be cleaned according to an established schedule[2]. | Level 3 | A |
| | 36.Ventilation ducts should be cleaned and filters replaced regularly[18]. | Level 3 | A |
| | 37.A daily, weekly or monthly cleaning schedule for areas and equipment should be established. This schedule should be developed by a multidisciplinary team to determine the appropriate frequency of cleaning, disinfection, and maintenance[16]. | Level 2 | A |

### 2.1.4. Develop evidence-based practice programs

The team for operating room evidence-based specialist was provided with training for operating room cleaning staff in seven key aspects, including the selection and use of disinfectants, cleaning methods, cleaning tools, terminal disinfection treatment, procedures, staff management, and system management. The team will then integrate and construct an evidence-based implementation plan for environment cleaning of operating room.

## 3. Application and effect evaluation of evidence-based practice programs

### 3.1. Practice place

The study on evidence-based practice was carried out in four 100-level laminar flow operating rooms at a tertiary-level general hospital in Yunnan Province. These operating rooms are similar in terms of building structure, layout area, equipment, facilities, and types of surgeries. The cleaning plan was standardized during implementation with no apparent bias.

### 3.2. Implementing evidence-based practice programs

#### 3.2.1. Baseline review

The standard procedure for the evidence-based clinical Evidence Practice application system was assessed in May 2023, involving four grade 100 operating rooms. Following this assessment, the project team members evaluated the evidence's feasibility, suitability, clinical significance, and validity based on the FAME principle [19]. They developed a total of 17 quality review indicators, including:

(1) Establish a multidisciplinary team, cleaning procedures, and select appropriate cleaning materials and equipment;

(2) Designate trained personnel for cleaning responsibilities;
(3) Avoid using high-grade disinfectants or liquid chemicals on environmental surfaces;
(4) Refrain from using alcohol on large surfaces;
(5) Establish cleaning frequency for high-touch objects;
(6) Determine when enhanced cleaning is needed;
(7) Use microfiber or low-pile cotton materials;
(8) Inspect the operating room for cleanliness before bringing in supplies;
(9) Wipe down all horizontal surfaces before the first surgery of the day;
(10) Dust removal should start from the top and work downwards;
(11) Do not reuse cleaning materials or use spray bottles for chemicals;
(12) Promptly clean and disinfect surfaces contaminated with blood or body fluids, using a diluted solution of sodium hypochlorite for large spills;
(13) Follow manufacturer instructions for cleaning and disinfection, ensuring proper contact time for effective disinfection;
(14) Clean and disinfect all reusable patient surfaces such as mattress covers, pneumatic tourniquet cuffs, and blood pressure cuffs;
(15) Wait until the patient has left the operating room before starting to clean the environment, which includes removing litter and contaminated surgical gowns.
(16) Thoroughly clean the floor using a wet vacuum cleaner or disposable mop with disinfectant, starting from the top and working towards the bottom, from the center outwards, and from the cleanest areas to the dirtiest.
(17) For terminal disinfection, ensure all exposed surfaces are thoroughly cleaned and disinfected, including wheels and casters. Regularly clean ventilation ducts, vents, and grilles, and replace filters according to the scheduled maintenance plan.

### 3.2.2. Evidence-based practice transformation

From May to August 2023, the practice transformation stage was successfully completed with the support of the department director and head nurse. Considering the obstacles and current situation in operating room, the following strategies have been developed to implement the evidence-based practice plan.

The first obstacle is a lack of knowledge among operating room nurses and cleaning staff regarding the implementation processes and methods of evidence-based strategies for cleaning and disinfection. To address this, a comprehensive 4-week training program will be conducted both online and offline. The training will cover topics such as evidence-based nursing practices, management standards for high-touch areas, best practices for environmental cleaning, and infection prevention. A knowledge assessment will follow the training, with a required correct rate of above 90% for qualification.

The second obstacle is the inability to carry out evidence-based practice due to insufficient materials and equipment. The strategy includes creating a flowchart for environmental cleaning and disinfection based on best evidence, incorporating cleaning and disinfection responsibilities into job descriptions, establishing nursing quality indicators and standards, conducting daily quality control checks, and procuring necessary materials such as dedicated disinfection vehicles, cleaning agents, color-coded cloths, and floor towels from the Materials Department.

## 3.3. Effect evaluation

By utilizing the same database, this study developed various search strategies, reviewed pertinent literature,

assessed and summarized literature quality, and ultimately gathered evidence-based data to outline the summary of evidence aligning with the high-frequency contact table within our surgical facility. A concise overview is presented in **Table 2**, with the team creating a customized checklist following deliberation. The environmental cleaning quality of the high-frequency contact table in the operating room was assessed at three specific junctures:

(1) Prior to the initial operation on the same day,

(2) Before subsequent operations, and

(3) After the final operation of the day.

Three graduate students employed ATP bioluminescence detection technology to collect data on the cleaning quality of the high-frequency contact table at the three time points, aiming to evaluate the efficacy of cleaning and disinfection protocols in operating room.

**Table 2.** Summary of evidence on the surface range of high-frequency contact objects in OR

| Evidence subject classification | Specific project |
|---|---|
| Anesthesia high contact area | Anesthetic machine display, rotary button, drawer handle, drawer inner surface and bottom;<br>Operation unit connected with anesthesia machine<br>Anesthesia table surface, computer display screen, keyboard, mouse, medical record clip<br>Narcotics cabinet surface, drawer |
| Itinerant nurse high-contact area | Operation table, treatment table<br>Computer monitor, keyboard, mouse, scanner<br>Phone handle |
| Surgeon high-contact area | Foot pedals and buttons of electrosurgical equipment<br>Surgical footstool, surgical lamp handle<br>C/G arm imaging system |
| Patient high-contact area | Operating bed, thermal blanket/pipe<br>Tourniquet, blood pressure cuff, oximeter<br>Restraint strap, position pad, position retainer, both ends and bottom of Mayfield head frame |

## 3.4. Evaluation indicator

The implementation rate of review indicators is calculated by converting evidence suitable for clinical situations into measurable and easily assessed quality review indicators [20]. The implementation rate is denoted by a check mark (√) for implementation and a cross mark (×) for non-implementation. The implementation rate is calculated as follows: (number of cases performed/total number of cases) × 100%. Additionally, the cleaning effect is monitored using ATP bioluminescence values and data from a self-made checklist. The review method for review indicators included questionnaire surveys and clinical observation.

## 3.5. Statistical methods

SPSS 26.0 statistical software was used for statistical analysis, and $p < 0.05$ was considered statistically significant.

Baseline review data were collected from May to June 2023, while post-application data were collected from July to August 2023. The nursing team leader monitored the implementation of the review indicators in operating room and accurately recorded their observations. Two researchers extracted the data by examining the record sheet and querying the ATP detection information system, and documented them in Excel spreadsheet.

# 4. Results

## 4.1. The rate of implementation of the indicators

The comparison of the implementation of 17 review indicators between the two groups is shown in **Table 3**.

**Table 3.** Comparison of the implementation of the review indicators

| Indicator | Baseline review group (n = 462) | | | Evidence use group (n = 481) | | |
|---|---|---|---|---|---|---|
| | Execute (Y) | Non-execute (N) | Execution rate (%) | Execute (Y) | Non-execute (N) | Execution rate (%) |
| **1** | **0** | **462** | **0** | **481** | **0** | 100 |
| 2 | 0 | 462 | 0 | 481 | 0 | 100 |
| 3 | 118 | 344 | 25.5 | 481 | 0 | 100 |
| 4 | 256 | 206 | 55.4 | 481 | 0 | 100 |
| 5 | 174 | 288 | 37.7 | 481 | 0 | 100 |
| 6 | 304 | 158 | 65.8 | 481 | 0 | 100 |
| 7 | 0 | 462 | 0 | 481 | 0 | 100 |
| 8 | 0 | 462 | 0 | 481 | 0 | 100 |
| 9 | 144 | 318 | 31.2 | 481 | 0 | 100 |
| 10 | 287 | 175 | 62.1 | 481 | 0 | 100 |
| 11 | 0 | 462 | 0 | 481 | 0 | 100 |
| 12 | 68 | 394 | 14.7 | 481 | 0 | 100 |
| 13 | 33 | 429 | 7.1 | 481 | 0 | 100 |
| 14 | 221 | 241 | 47.8 | 481 | 0 | 100 |
| 15 | 267 | 195 | 57.8 | 481 | 0 | 100 |
| 16 | 189 | 273 | 40.9 | 481 | 0 | 100 |
| 17 | 122 | 340 | 26.4 | 392 | 89 | 81.5 |

## 4.2. Comparison of outcome indicators

The comparison of the qualified rate of high-frequency contact surface cleaning before and after the application of evidence is shown in **Table 4**.

**Table 4.** Comparison of the qualified rate of high-frequency contact surface cleaning before and after the application of evidence

| Groups | Samples | Qualified number | Pass rate (%) | ATP monitored value (RLU) | $\chi^2$ value | *p* value |
|---|---|---|---|---|---|---|
| Baseline review | 462 | 65 | 14.07 | 299257 | 120.955 | < 0.01 |
| Evidence use | 481 | 227 | 47.19 | 71352 | | |

# 5. Discussion

This study demonstrated that the implementation rate of 17 indicators significantly improved from 0-65.8% to 81.5–100% following the adoption of evidence-based practice, indicating successful integration of evidence into

clinical practice. By providing clear guidance on nursing tasks and activities, evidence-based nursing can greatly enhance the implementation rate of hygiene protocols and promote the advancement of nursing practices.

In this study we utilized the '6S' search model to systematically gather evidence on environmental cleaning, disinfection, infection prevention, and management. The retrieved evidence underwent thorough evaluation for quality, feasibility, clinical significance, and effectiveness in operating room settings. This process led to the identification of high-frequency contact areas in operating room and the development of cleaning and disinfection protocols. Clinical review indicators based on the best evidence were established, and baseline investigations were conducted. The Evidence Application Group facilitated the implementation of best practices by analyzing survey results, addressing the barriers to evidence implementation, and developing effective strategies. The evidence application team monitored the transformation of evidence into the practice of cleaning and disinfecting high-frequency contact areas in operating room, leading to improved clinical quality, enhanced nurse cognition and behavior, and better patient outcomes. This evidence-based approach was both sound and practical.

The application of evidence-based practice can enhance the cleaning effectiveness of high-frequency contact surfaces and improve clinical outcomes [4,21]. Various studies have highlighted the connection between contaminated surfaces and equipment in patient areas and the increased risk of infections in operating room [15]. It has been shown that thorough environmental surface cleaning and disinfection can significantly reduce the incidence of infections by multidrug-resistant bacteria [22]. However, there are inconsistencies in cleaning and disinfection methods, disinfectant selection, and environmental monitoring standards across different studies [23]. By implementing evidence-based practices, such as training staff, establishing clear procedures, and ensuring the use of appropriate equipment, healthcare facilities can improve environmental cleaning and disinfection practices. Overall, this study highlights the importance of translating evidence into clinical practice to enhance infection control measures in healthcare settings.

Quality review is an effective tool for promoting quality improvement. Training plays a crucial role in facilitating the development of evidence-based nursing practice. The initial baseline review revealed a lack of knowledge among operating room cleaning staff regarding environmental cleaning and disinfection. The evidence application team conducted two rounds of comprehensive training for the staff, which included knowledge assessments, practical training and ethical education, to enhance their understanding of theoretical concepts related to environmental cleaning and disinfection. Our study emphasizes that improving knowledge is essential to proper environmental cleaning and disinfection practices for operating room cleaning staff.

## 6. Conclusion

In conclusion, this study systematically reviewed evidence on environmental cleaning and disinfection programs in operating room, focusing on aspects such as staff management, cleaning tools, processes, optimization measures, and surface monitoring. By integrating evidence with clinical practice and addressing implementation challenges, this study successfully facilitated the translation of evidence into practice, enhanced theoretical knowledge and practical skills of operating room nurses, and served as a guide for future development of evidence-based nursing practice.

## Disclosure statement

The authors declare no conflict of interest.

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