Effectiveness of clinical surface cleaning and disinfection: evaluation methods

Eficiência da limpeza e desinfecção de superfícies clínicas: métodos de avaliação

Eficiencia de la limpieza y desinfección de superficies clínicas: métodos de evaluación

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ABSTRACT

Objective: To discuss the methods employed to evaluate the effectiveness of clinical surface cleaning and disinfection (C&D). **Method:** This is a theoretical reflection based on scientific studies and the experience of the authors. Knowledge and current gaps, the need for further studies, and practical application of the methods were approached. **Results:** There are four main methods used to evaluate the effectiveness of clinical surface C&D: visual inspection, fluorescent markers, microbiological cultures, and adenosine triphosphate (ATP) bioluminescence. The first two are used to evaluate the process and to predict adherence to protocols by the staff, and the last two are employed to evaluate the results, therefore being the most relevant to assess the risk of infection. **Final considerations:** The ideal method was not found, because all of them showed limitations. There is a need for strategies to optimize the precision of these methods.
Descriptors: Cross Infection; Equipment Contamination; Housekeeping, Hospital; Disinfection; Process Assessment (Health Care).

RESUMO

Objetivo: Discutir os métodos empregados para avaliar a eficiência da limpeza e desinfecção (L&D) de superfícies clínicas. **Método:** Trata-se de uma reflexão teórica fundamentada em estudos científicos e experiência dos autores. Foram abordados o conhecimento e as lacunas atuais, a necessidade de futuras investigações e a prática na utilização dos métodos. **Resultados:** São quatro os principais métodos utilizados para avaliar a eficiência da L&D de superfícies clínicas: inspeção visual, marcadores fluorescentes, culturas microbiológicas e teste de adenosina trifosfato por bioluminescência. Os dois primeiros são utilizados para avaliar o processo e preveem a adesão aos protocolos pela equipe, enquanto os dois últimos são empregados para avaliar os resultados, portanto, mais relevantes na avaliação do risco de infecção. **Considerações finais:** Não foi encontrado um método ideal, pois todos apresentaram limitações. São necessárias estratégias que potencializem a precisão desses métodos.
Descritores: Infecção Hospitalar; Contaminação de Equipamentos; Serviço Hospitalar de Limpeza; Desinfecção; Avaliação de Processos (Cuidados de Saúde).

RESUMEN

Objetivo: Discutir los métodos utilizados para evaluar la eficiencia de la limpieza y desinfección (L&D) de superficies clínicas. **Método:** Reflexión teórica fundamentada en estudios científicos y en la experiencia de los autores. Fueron abordados el conocimiento y las carencias presentes, la necesidad de investigaciones futuras y la práctica en la aplicación de los métodos. **Resultados:** Los métodos más habitualmente aplicados para evaluar la eficiencia de la L&D de superficies clínicas son cuatro: inspección visual, marcadores fluorescentes, cultivos microbiológicos y test de adenosina trifosfato por bioluminiscencia. Los dos primeros son utilizados para evaluar el proceso. Prevén la adhesión a los protocolos por parte del equipo. Los dos últimos son aplicados para evaluar los resultados, por lo cual son más relevantes para descubrir riesgos de infección. **Consideraciones finales:** No se encontró el método ideal, dado que todos presentan limitaciones. Se necesitan estrategias que optimicen la precisión de estos métodos.
Descriptores: Infección Hospitalaria; Contaminación de Equipos; Servicio de Limpieza en Hospital; Desinfección; Evaluación de Proceso (Atención de Salud).

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INTRODUCTION

Over the past years, a step forward has been taken with discussions and studies by researchers, health institutions, and organizations regarding the role facilities play on the incidence of healthcare-associated infections (HAI)[1]. As a result of the growing body of evidence linking facilities with HAI transmission, greater attention has been given to sanitation and forms to improve the effectiveness of clinical surface cleaning and disinfection (C&D) practices, with an aim at reducing cross infection[2].

Even with proper hand hygiene, C&D measures have shown some flaws. As professionals touch contaminated surfaces near patients, the hygiene effect may be invalidated by transferring pathogens from one patient to the next, which leads to the occurrence of HAI, thus increasing morbidity-mortality rates, hospital stay, and additional costs with material and human resources.

Studies have demonstrated that there is greater risk of HAI when patients use beds that were previously occupied by patients who were colonized or infected by healthcare-associated pathogens, such as methicillin-resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile*, Vancomycin-resistant *Enterococcus* (VRE), and multidrug-resistant Gram-negative (MDRGN) agents. These agents often contaminate clinical surfaces near patients and may lead to the transmission of pathogens, representing a primary source of contamination for health professionals' hands and/or gloves[3-4].

Currently, there are many unanswered, controversial or conflicting questions about C&D regarding strategies for HAI control compared to other actions, such as patient monitoring, use of isolation, hand hygiene, and antimicrobial regimen. The evidence is still incipient and lacks qualitative and quantitative improvements. The consensus is that the C&D process is subject to discussion on its rules, rates and, most importantly, procedures, equipment, and benchmark related to quantitative monitoring methods for surface C&D[5].

Healthcare facilities are often evaluated only by visual inspection, which may meet the aesthetic parameters, but cannot avoid risk of infection for patients. Therefore, the Centers for Disease Control and Prevention (CDC)[6] and the Brazilian Health Regulatory Agency (ANVISA, as per its acronym in Portuguese)[7] started to recommend that hospitals assure proper procedures for surface C&D and carry out continuous monitoring to guarantee the quality of their procedures. However, it is not clear which methods are ideal for the monitoring, and there was no specification on how this is supposed to be achieved[2-3,8].

OBJECTIVE

To discuss the methods employed to evaluate the effectiveness of clinical surface C&D.

METHOD

This theoretical and reflective study was based on scientific articles published in journals indexed in the Virtual Health Library (VHL), the US National Library of Medicine (PubMed), Scopus, and the Web of Science databases. The basic database form was used for the following search strategy: "Method*" AND (Evaluate* OR Assessment) AND (Clean* OR Disinfecti*) AND (Environment* OR Clinical surfaces). Titles and abstracts of the resulting articles were read to select the most relevant, in which 10 were elected by consensus among three researchers for critical analysis, reflection, and text design.

The analysis showed four main methods used to evaluate the effectiveness of C&D in healthcare institutions: visual inspection, fluorescent markers, microbiological cultures, and ATP bioluminescence[1-2,5,9-15]. A synoptic chart was created to extract the following aspects for reflection: principles, indications, operation, benchmark (cut-off point), effectiveness, and advantages and disadvantages of the methods. Based on the synoptic chart, the reflective text was designed.

RESULTS

There are currently four main methods used to evaluate the effectiveness of clinical surface C&D: visual inspection, fluorescent markers, microbiological cultures, and ATP bioluminescence. The first two are used to evaluate the process and to predict adherence to protocols by the staff, whereas the last are employed to evaluate the results, therefore being the most relevant to assess the risk of infection

DISCUSSION

Visual inspection

The visual inspection of healthcare facilities is the most commonly used method worldwide to evaluate the effectiveness of C&D.[2,4,10,12] It detects gross practice flaws, such as visible dirt, dust, waste, stains – including from patches – cracks on surfaces, and humidity.[2,10,12] Therefore, it helps to evaluate individual performance of the janitorial staff. Nevertheless, it has been well documented that visual assessment is a poor indicator because of the subjective characteristics from each evaluator related to what is cleaned or dirty[2,12]. In addition, the professional that performs the inspection often tends to concentrate in some areas, such as floors and walls, which have limited relevance in the transmission of pathogens[2,10].

Studies have reported that subjective (visual inspection) and objective (ATP bioluminescence, aerobic culture, fluorescent markers) analyses – when carried out prior and after a routine cleaning protocol – are capable of demonstrating a significant increase in the proportion of surfaces that are considered cleaned, after the protocol implementation[3,12]. However, there is evidence that visual inspection, when performed separately, increases significantly the proportion of surfaces considered cleaned, even after terminal cleaning[1,4,9,11]. A study that assessed 124 articles identified that 17 to 93% more surfaces were considered "cleaned" by visual inspection compared to other evaluation methods[8].

This finding may be explained by the high sensitivity (95%) and very low specificity (9%) of visual inspection, when compared to aerobic culture as a "reference"[3,12]. In short, visual inspection alone can be a poor indicator of C&D quality, because more contaminated surfaces may be classified as cleaned[10-11]. The

use of other methods, such as fluorescent markers or ATP biolu-minescence, provides a slight increase in specificity, but with a decrease in sensitivity[10]. Therefore, visual evaluation of surfaces proved to be less reliable for monitoring surface C&D, when the comparison to quantitative methods to document the results of this practice becomes relevant[11].

Fluorescent markers

In recent years, fluorescent gels, powders, and lotions were developed to mark objects submitted to cleaning. As a result of severe limitations in the last two years related to scattering (powders) and removal (lotion, when submitted to dry air), there are few or no experience published on the application of these methods as monitoring strategies for sanitation practices in hospital settings[10].

In contrast, fluorescent gels have been widely used to evaluate the quality of cleaning. This method involves the application of an invisible gel, which quickly dries in contact with the surface and is resistant to dry friction, but can be easily removed with friction if wet. The gel is visible only through ultraviolet (UV) light, thus, cleaning precision is assessed by applying UV light on the areas where the gel was applied before cleaning[6]. Studies carried out with this method reported recurrent practice flaws during surface C&D[11,13].

In short, the fluorescent gel is used to indicate the physical removal of a given substance applied. Additionally, when it is inspected by UV light, the lack of stains indicates that sufficient friction was applied to the cleaning[4], but this does not guaran-tee that the surface is microbiologically safe, since the method is unable to detect microorganisms. Therefore, the results must be interpreted with caution, because surfaces that are effectively disinfected, but less effectively cleaned, may be labeled as dirty and vice-versa[6]; thus, its use during outbreaks must be adjuvant.

Microbiological cultures

Microbial culture methods have been widely used to evaluate the contamination of hospital facilities in different studies[2,6,8-13]. In modern hospitals, samples of target surfaces (mattresses, stethoscopes, toys, etc.) have been studied applying culture techniques. The method consists of obtaining samples potentially impregnated by microorganisms submitted to culture medium with favorable conditions for their growth (substrate, pH, oxy-genation, water)[3,10,12].

Culture results are expressed as colony forming units (CFU) of total aerobics[2,12] or specific microorganisms, such as *S. aureus*[10] and *C. difficile*[4,11]. This kind of investigation is generally recom-mended only as part of an epidemiological investigation, with ongoing outbreaks, as a research study, or as part of the evaluation process or policy[12], since the time needed to count the colonies and to identify the pathogens may take at least two days, apart from being expensive[11,13].

Cultures provide the most precise indication for risk of infec-tion, because they are able to detect and quantify a wide range of viable microorganisms. Microbiological methods can produce results with high specificity, sampling techniques provide varied

sensitivity, and often underestimate the bioburden on a surface, which hinders a precise evaluation of surface contamination in terms of comparability[2,6]. However, it is a user-friendly method applied by several institutions, including the food industry and, most recently, hospitals.

The most frequently cut-off point used in the studies for surface approval is <2.5 UFC/cm^2 for aerobic colony count[2,4,6,11-13] and <1 UFC/cm^2 for hospital pathogens (MRSA, VRE, *C. difficile*, etc.)[5]. However, there is not yet a universally accepted benchmark, given that the studies use other benchmarks, such as5 UFC/cm^2, and methodologies vary considerably[9-13].

The most reliable indicator of environmental hygiene for health-care facilities is the presence of coagulase-positive Staphylococ-cus, since it survives for months on hospital surfaces.[10] Studies that investigate the application of microbiological guidelines in healthcare units have used both *S. aureus* and MRSA to help monitoring the C&D[5,10].

Adenosine triphosphate bioluminescence

Adenosine triphosphate is the main energy carrier of all hu-man beings. Its presence in the cells is a strong indicator of living organisms[4,14]. ATP bioluminescence is a method that measures the quantity of organic ATP present in a sample. Using a specific swab, the organic matter present on the surface is collected and transferred to a detection device that is made up of an enzyme substrate compound (luciferin-luciferase). The reaction formed by contact of the sample with this compound releases a type of light, similar to what happens with a firefly, and its intensity is measured by portable luminometers that show the result in relative light units (RLU). The quantity of RLU is proportional to the quantity of ATP, which in its turn is proportional to the density of the organic matter[1,4].

This method has become popular, but there are still contro-versial issues[2,11,13] and limitations (Table 1), which require robust investigations. Depending on the luminometer brand or model and setting to be monitored, the benchmark of ATP bioluminescence systems may vary considerably. In healthcare units, reference levels vary considerably from 25 to 500 RLU per 10 to 100 cm^2 of surface[5]. This variation is due to the wide range of commercial-ized devices, systems, and reagents[6]. The benchmarking must be specific, according to local characteristics related to room temperature, humidity, nature of the surface, type and level of association with the organic matter, risk of infection in the unit, local pathogenic epidemiology, and presence of outbreaks[4].

It is important to measure ATP 10 minutes after cleaning with detergent or disinfectant. This procedure allows complete surface drying, and prevents alterations in RLU readings due to the contact between sanitizing and reagents. Even so, the correlation between ATP levels and microbial contamination is unknown[2,10,12-13]. Additional investigations are necessary to determine the threshold for the ideal ATP value, in order to define whether a given surface is properly cleaned[15], and with the challenge of correlating the value with a decrease in infec-tions. The sensitivity and specificity of the luminometers or trial systems may differ significantly, such as chemical reactions, light detection systems, among others[11].

Similar to the fluorescent gel, and due to the great amount of microbial ATP of unknown origin on surfaces, ATP readings on surfaces that are properly disinfected, but less properly cleaned, may be more frequently disapproved when compared to culture techniques[6]. Regardless of whether a considerable variation may occur between readings and the sensitivity of the systems commercially available, very low readings are typically associated with low aerobic colony counts on surfaces[10]. Currently, there are systems already available that measure ATP of microbial origin only.

ATP reading may be jeopardized by several factors, such as the presence of residual detergents or disinfectants, such as sodium hypochlorite, which is contraindicated for ATP measuring, including corroded surfaces, plasticizers found in microfiber cloths or ammonium compounds found in laundry products[5,8]. The attempt to correlate RLU with the amount of microorganisms on surfaces has been widely discussed among researchers to try to standardize the ATP bioluminescence method as a replacement to other methods. However, this issue is controversial, because the presence of ATP is conditioned to the amount of animal or vegetal organic matter and not necessarily of microorganisms. Therefore, the lack of a correlation or a poor correlation between RLU and the presence of microorganisms may be due to several factors, such as variations on the size and type of microbial cells and in their development stage[14]. The main advantages and disadvantages of the four methods used to evaluate surface C&D practices are summarized in Chart 1.

Study limitations

There are few or no studies correlating quantitative and qualitative data from methods of evaluation of the effectiveness of clinical surface C&D with results for health care, including infection-association health care. Therefore, this study provides resources for choosing methods and strategies for monitoring the quality of surface C&D. Clinical trials must be carried out to determine the best indications (outbreak, routine, research, etc.) for these methods, as well as their cost-benefit, and respective impacts on healthcare indicators.

Contributions of this reflective paper for the nursing area

Since clinical surface C&D is assigned to the nursing staff in most healthcare facilities in Brazil and worldwide, and its evaluation is mostly carried out by visual inspection, this study helps to define and analyze the methods and breakthrough technologies currently available to evaluate the impact these practices have on the microbiological safety of clinical surfaces. Although it is not a panacea, it serves as a resource (i) to stimulate formal teaching of this underrated practice in healthcare facilities, (ii) to boost the management of material (planning, decision-making, method selection, and technologies) and human (ongoing education) resources, (iii) to stimulate the development of robust clinical research, and (iv) to promote guidance for the healthcare practice. Finally, this study contributes to the understanding that

Chart 1 - Summary of the main advantages and disadvantages of the methods used to evaluate cleaning and disinfection practices in healthcare facilities

Method	Advantages	Disadvantages
Visual inspection	- Simple[8,16] - Cheap[8,16] - User-friendly for large areas (wards, rooms)[8] - May be implemented with minimum training[8] - Possible benchmarking[8]	- Unreliable measure for C&D* quality[16] - Subjective[8] - Does not evaluate bioburden[8] - Does not correlate with bioburden[8] - May be mistaken with disorder and odors[8]
Fluorescents markers	- Quick, objective, and cheap[8] - Minimum training required[8] - Minimum equipment required[16] - Provide immediate feedback[8] - May improve the quality of the practices[16] - Possible benchmarking[8]	- Tricky, since there is a need to mark the surfaces blindly before cleaning, without the staff knowing the defined areas, and to check them after cleaning with UV light[8,16] - Do not evaluate bioburden[8] - Emphasis on easily visible surfaces and not heavily touched[8]
Microbiological cultures	- Objective[8] - Relatively simple[16] - Provide quantitative data[8] - High sensitivity and specificity[8] - Identify traced pathogens[8,14] - May suggest or confirm environmental reservoirs and/or sources of outbreak[8]	- Expensive[8,16-17] - Require, at least, 24-48h to provide results[8,16-17] - Tricky[17] and require a microbiology lab[16] - Require accessible lab resources and specialized personnel to interpret the results[8] - Routine use unadvisable in local and international guidelines[8] - Risk of infection depends on standardized benchmarking[8] - Sample of small surface area only[8]
Adenosine triphosphate bioluminescence	- Quick[8,16] - Objective[8] - Minimum training required[8] - Provides quantitative measurement of the C&D*[16] - Provides immediate feedback[8] - May improve the practices[16]	- Expensive[8,16] - Requires luminometers and swabs[16] - Propensity to false-positive results of given systems[8] - Low sensitivity and specificity[8,18] - Trials currently non-standardized[8,18] - Variable cut-off point[8,18] - Technology under development[8,18] - Does not identify pathogen[17]

*Note: *C&D: cleaning and disinfection.*

surface C&D goes much further than meeting mere aesthetic obligations, considering that it is an important variable related to patient safety.

FINAL CONSIDERATIONS

The ideal C&D method should be able to determine whether a surface was cleaned, taking into account the levels of organic matter and microorganisms present, the risk of infection, the presence of MDR pathogens, as well as being cost-effective, replicable, user-friendly, and quick. Therefore, the development of new technologies and innovations is strongly recommended, such as the improvement of monitoring methods for surface C&D in healthcare services.

The prevention of pathogen transmission is unquestionably one of the major challenges of this new millennium. One to the main strategies to overcome this challenge is the maintenance of the surfaces of facilities in proper sanitary conditions to limit the spread of pathogens and/or the acquisition of antimicrobial resistance. There is still a lot to improve, but at least there are alternative methods to visual inspection already available to evaluate the effectiveness of C&D.

FUNDING

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