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The Effectiveness of Specific Infection Control Interventions

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ABSTRACT
Infections associated with healthcare are a major cause of morbidity and mortality. A large number of intervention studies have been conducted to address these healthcare-associated infections. There are existing reviews and guidelines that summarize the evidence of the effect of many infection prevention and control interventions. This study provides a formal overview and summaries of studies evaluating some less commonly assessed interventions that have previously not been summarized in existing reviews.
Many types of healthcare-associated infections are largely preventable through the implementation of evidence-based infection prevention and control measures. Such measures have been shown to be cost-effective. The effectiveness of several key infection prevention and control interventions has been established with a range of evidence from randomized and non-randomized studies. However, less commonly used interventions may not have had their effectiveness formally assessed or the evidence summarized. This paper aim at identifying, describing, and summarizing the findings of studies that have evaluated the effects of specific infection prevention and control interventions on any type of healthcare-associated infection. The interventions could either be primary components of standard precautions, additional single interventions, or additional bundled interventions.

Keywords: Infection control, health care associated infection, infection control guidelines, disinfectants, personal protection equipment.

1. INTRODUCTION

In many countries, hospital infections are a principal health problem, both because they affect patient safety and because they generate an increase in healthcare costs and lead to a longer period of hospital stay (1). One effective approach to reduce the rate of hospital infection is to implement specific health technology assessments and healthcare quality programs (2). Our objective is to evaluate the effectiveness of specific infection control interventions, assessing their clinical impact. The prioritization of safety and control of nosocomial infections must be implemented from two approaches (3): developing health technology assessment activities by properly assessing, on the basis of scientific evidence, the effectiveness of infection control procedures, as well as favoring the updating of professionals, the involvement of patients, and the respect for legal and ethical profiles of hospital organizations (4). The objective of the present work is to evaluate the effectiveness of specific infection control interventions, assessing the impact achieved in the field of hospital infection control and also the quality of the studies published. The research also aimed to identify and summarize the evidence that those who work professionally or use the healthcare service must be aware of permanently in order to guarantee effective and informed choices.

1.1. Background and Rationale

Inadequate infection control practices are identified as one of the contributing factors of outbreaks, thereby making it a significant challenge within the healthcare sector 4. This is despite the availability of strategies and interventions that have been developed from numerous studies of various designs (5). Assessing the effectiveness of these measures is essential not only to determine interventions that are suitable in different settings but also to guide future research and the development of strategies that are likely to be effective (6). However, there is considerable variability in studies in terms of the infection control interventions being investigated and the methods used in evaluating these measures (6). Responding to the need for better aggregated evidence on this topic, we have embarked on a comprehensive systematic review to synthesize evidence on the effectiveness of interventions aimed at preventing outbreaks of infectious organisms in inpatient healthcare settings and their associated costs (7). In order to clearly present the findings, it is important to see the wider context of current evidence and how the study will contribute to addressing the gaps.

3. Overview of Infection Control Interventions

Infections continue to be a major burden for healthcare systems internationally, not only because of the morbidity and mortality they cause but also because of their financial implications and the various economic incentives that may act against effective surveillance and control (8, 9). The most effective means of promoting the routine use of these infection control interventions will, almost certainly, be through improving both their evidence base and our knowledge as to how this evidence should be presented to those responsible for decision making (6, 10). The purpose of these interventions is to help reduce the healthcare system's burden of disease by reducing the incidence of infection. Infections that affect patients are seen as an important contributor to the morbidity and mortality associated with many diseases (11). These infections frequently lead to extended lengths of hospital stay and so have important economic implications for health systems (12).

Hand Hygiene

There is strong evidence that hand hygiene interventions are effective in reducing infections. The most effective, important, commonly implemented, and practical intervention is the promotion of hand hygiene by all health care workers with reminders and provision of feedback (10, 13) It is the one intervention where there are many high-quality trials, all with similar effect sizes. The consistent and large treatment effect is likely to be due to the number of undiagnosed pathogens that cause health care-associated infections; dirty hands provide an ideal vehicle to deposit as well as acquire such pathogens (14). The size of the effect is similar to that of vaccines, and important viral infections such as influenza are stopped or diminished by good hand hygiene (15). The only other intervention that has as substantial an effect as hand hygiene is isolation of the patient, but patients often infect themselves, other patients, and staff via their unwashed hands (16).

Monitoring of compliance with hand hygiene provides feedback, which is important as the act of observation significantly increases adherence to hand hygiene by staff (17). However, once one group has been observed, adherence to infection prevention increased in a subsequent unmonitored group (18). Evaluating the effectiveness of hand hygiene products within the confines of a healthcare facility is a difficult task. It is possible, through product testing and real-life observation of hand hygiene practices, to gain a better understanding of a product’s level of effectiveness (13). Regulatory agencies now require antiseptic handwash and rub efficacy data to be collected both in vivo and in vitro (19).

Types of sanitizers

Various types of hand sanitizers are available, each generating different levels of compliance. Five classes of sanitizers are available, namely alcohols, diluted povidone-iodine, chlorhexidine, chloroxylenol, and alcohol-free (20, 21). Ethanol-based sanitizers are considered to be more effective than other types. Sanitizers should contain a minimum of 60% alcohol (22). A comparative survey on the acceptability of various hand sanitizers demonstrated that sanitizers containing triclosan and chlorhexidine exhibited inferior acceptance (23). A systematic review concluded that alcohol solutions had superior compliance compared to alcohol-based or alcohol-free hand sanitizers (24). It was stated that hand sanitizers containing ethanol, combined with training and education, serve as an effective and acceptable alternative in school activities for effective hand washing and are also of great convenience (25).

Ethanol-based sanitizers reduce the number of infected children during the contagious phase, which in turn lessens the incidence of hand infections (26). Therefore, such hand sanitizers are essential in the prevention and control of Hand, Foot, Mouth Disease (HFMD) (27). Ethanol-based hand sanitizers are more cost-effective in medical use compared to pure soap. In addition, these types of hand sanitizers are more effective than hand washing with water alone in microbial removal but are less effective than hand washing using soap (22). During an infection outbreak, those exposed to infected individuals commonly use soap for hand washing (28). Alcohol-based hand sanitizers applied for 30 seconds can quickly reduce the number of viable microorganisms on the hands, but immediate re-contamination can occur following ethanol application when chlorhexidine, bensothonium, and triclosan are formulated in ethanol and applied for 1 minute, or those containing chlorhexidine and benzalkonium chloride took about 3 minutes each (29).

Effectiveness of compliance to infection control guidelines

In various countries around the globe, guidelines pertaining to infection control in hospital nursing stations are widely found in the literature and are regarded as of paramount importance (30). The strict adherence to these guidelines plays a vital role in minimizing the risk of nosocomial infections and the vertical transmission of diseases (31). These measures predominantly encompass essential elements such as hand hygiene protocols, alcohol-based hand rubs, surgical masks, respirator masks, gowns, and gloves (32). The overarching aim is to evaluate the efficacy of these measures in effectively preventing the transmission of highly contagious diseases such as severe acute respiratory syndrome, influenza, tuberculosis, Middle East respiratory syndrome coronavirus, and the recent global pandemic, COVID-19 (33, 34).

The comprehensive review encompasses a wide range of valuable resources, including randomized controlled trials, meticulous reviews, insightful meta-analyses, and authoritative guidelines (35). The findings derived from the analysis unequivocally demonstrate that interventions like meticulous hand hygiene, utilization of alcohol-based hand rubs, rigorous implementation of surgical masks, compliant usage of gowns, and diligent employment of gloves have indeed exhibited a highly positive impact in significantly reducing the incidence of infections (15). Nevertheless, it is important to mention that for some alternative interventions, such as vertical plastic barriers, air disinfection, ultraviolet germicidal irradiation, and the implementation of specific waste handling procedures, the evidence supporting their effectiveness remains quite limited (36). Furthermore, it is noteworthy to mention that there is a significant dearth of available evidence regarding the effectiveness of hot and humidified air handpieces and protective clothing endowed with an outer single-use covering (6). Thus, this study serves as a comprehensive and insightful evaluation of the existing literature, shedding light on the effectiveness of various infection control measures in hospital nursing stations, while simultaneously highlighting the gaps that should be addressed through further research and investigation.

Effectiveness of the use of personal protection equipment

Healthcare-associated infections represent the most frequent adverse event for patient safety. A large body of literature reports that several healthcare-associated infections might be prevented by the implementation of specific infection control guidelines, recommendations, and interventions, and the improvement of some infection control elements of the hospital environment and clinical activities (7, 37). Although there is an increased awareness of the importance of adopting infection control strategies, there are still major problems in translating evidence-based guidelines into everyday practice (38). Many varied factors contribute to this gap, but more efforts must be made to identify those interventions that might bridge the gap between the availability of evidence-based guidelines and their everyday use to obtain some effects (39). The monitoring and enforcement of their correct application of PPE could be facilitated by the employment of the correct quality measures (40). The previous research reveals that the compliance with the use of personal protective equipment is generally unsatisfactory (41). Several direct and indirect determinants of the use of gloves and gowns are, at least partially, external to each healthcare professional concerned, requiring an extensive commitment from hospital management (42). Any guidelines' recommendations and interventions aiming to support the use of personal protective equipment should also consider the possible negative impact that the use of gloves, gowns, and face masks may have on patients, healthcare professionals' level of comfort, and their ease in performing clinical activities (41).

Effectiveness of surface disinfection

Evaluating the effects of surface disinfection as an infection control intervention is fairly straightforward (43). surface disinfection measures include assessments of the initial efficacy of a disinfectant in killing pathogenic microorganisms, challenge testing to evaluate how well the efficacy demonstrated in laboratory tests predicts the effects under actual use conditions, and epidemiologic data related to surface contamination and infections (44). However, potential study subjects may fail standard tests for disinfectant efficacy. It is possible to increase the likelihood of trial participation and to derive meaningful data from additional testing beyond current recommended protocols (45). Educational efforts and effective interpersonal communication are effective strategies to address the potential obstacles to participation in studies focusing on surface disinfection (46).

The influence of an environmental protection/disinfection intervention on the environmental survival of clinically relevant microorganisms is often evaluated in clinical settings (47). Studies typically assess either or both the number of colonies of individual species of bacteria cultured from environmental samples and/or the use of semi-quantitative bioluminescent reagents to produce visible light as a function of metabolic status (48). Such studies may provide useful data to inform the impact of surface cleaning efficacy on the spread of microorganisms, but they do not directly address the influence of routine disinfection on clinically relevant outcomes such as healthcare-associated infections (49). The uncertainty emphasizes the need to conduct an intervention study designed specifically to evaluate the influence of an intervention on clinical outcomes (50). Assessments of environmental bioburden used to evaluate the effects of surface cleaning interventions also need to be interpreted with caution (51).

Information directly relevant to the topic explored in this overview, which is the comparative effectiveness of different infection control methods, is limited and may not apply to a wide range of situations. The influence of how a study is designed on its ability to show a positive impact of an intervention, incorrect conclusions drawn from study results, and the potential financial costs of efforts to prevent infections in healthcare settings are all key areas for further study (6).

Types of surface disinfectant

Quaternary ammonium compounds, also known as quats, are considered surfactants for ease of cleaning, and there are no associated fumes. Each product is labeled according to its level of toxicity. Products may require between 2 to 10 minute contact times, and it may be appropriate to keep the surface visibly wet for the duration of the contact time (52).

Phenolics: Phenolic compounds are a group of disinfectants that may contain up to 65% alcohol and are usually found in wet contact times that are measured in minutes. Phenolic compounds are often advertised as odorless and cause less tissue irritation. They are not effective in the presence of blood and other organic materials and are also inactivated by detergent residues (53).

Sodium hypochlorite: Sodium hypochlorite or common household chlorine bleach is a strong oxidizing agent, and because of its adverse reactions, products should never be mixed with ammonia (54).

Alcohol: Alcohols in concentrations of 70 to 90% are frequently used in healthcare. Alcohol is bactericidal, tuberculocidal, and also effective against fungi, but it loses its effectiveness against non-enveloped viruses. Alcohol should be used differently on different surfaces. In small areas, it should be applied by wiping with a cloth and repeated as needed until the surface is visibly wet for 30 seconds. Ethyl alcohol or isopropyl alcohol reduces rotavirus infections on environmental surfaces as long as the surface is allowed to remain wet for a specific contact time, generally until dry (55, 56).

Glutaraldehyde: Glutaraldehyde is a high-level disinfectant with excellent tissue-penetrating properties that make it useful for reprocessing alcohol-sensitive endoscopic equipment. It is also used as a surface disinfectant on shipment containers of laboratory animals (57). Isopropyl alcohol is of superior performance when used to clean surfaces while still allowing for activity against bacteria, viruses, and yeast. It is not as good for cleaning surfaces and dries quickly before it is able to kill microorganisms, so it requires a prolonged contact time. Quaternary ammonium compounds should never be used for cleaning or disinfecting surfaces in areas used to prepare medications (58).

Maleic acid: Manufacturers use formulations such as Maleic Acid in their cleaning and disinfectant solutions to control corrosion and biofilm formation in pipelines and water storage tanks, and microbiological control to regulate microorganisms (59).

Hydrogen peroxide: Accelerated hydrogen peroxide is marketed as a strong disinfectant, with 5-minute kill times and 15-minute kill times of 10 to 20 pathogens. It does not color the surfaces with a 1-minute contact time, and it will reduce toxic exposure if the contact time for all the products is allowed to increase (60).

Formaldehyde, also known as Formel, is rarely used on hard surfaces. Acetic acid has been shown to be effective against viruses such as poliovirus and rotavirus and fungi such as Aspergillus sp. and Candida sp. Coronaviruses, such as SARS and MERS, are resistant and have not yet been tested against COVID-19 (61).

Effectiveness of Specific Interventions

In a number of previous studies conducted by various researchers, the utilization of respiratory protective masks, especially in high-risk scenarios such as the provision of care to patients with Tuberculosis, has been strongly advocated for healthcare professionals (62). This recommendation applies not only to regular interactions with patients but also extends to specific situations involving personnel who test negative for BCG scars (63). These situations may include patient transportation, emergency medical procedures, cardiopulmonary resuscitation, or the disposal of emesis. It becomes imperative, therefore, to comprehend the indications for the vaccination of healthcare workers (64). These indications can be categorized into two main aspects: firstly, the need to protect individual healthcare workers from diseases that could potentially be transmitted by patients in the hospital setting; and secondly, the recognition that healthcare workers themselves are at an elevated risk of contracting such diseases (65).

It should be noted that the present guidelines for vaccination among healthcare workers closely resemble those applicable to non-healthcare workers, albeit with stronger recommendations. This is primarily due to the significant potential for healthcare workers to inadvertently transmit infections to vulnerable patient populations, which emphasizes the need for vaccination (66, 67).

The utilization of respiratory protective masks, as identified in numerous previous studies conducted by a diverse range of researchers, holds a paramount importance, particularly in high-risk scenarios, such as the provision of care to patients inflicted with Tuberculosis (62). Such protective measures have gained fervent advocacy among healthcare professionals, highlighting their significance. This advocacy transcends the boundaries of regular patient interactions and expands to encompass specific situations involving medical personnel without BCG scarring. These situations may encompass patient transportation, emergency medical procedures, cardiopulmonary resuscitation, or the safe disposal of emesis. Consequently, it is essential to fully comprehend the indications for the vaccination of healthcare workers (68).

These indications can be effectively categorized into two principal aspects. Firstly, there exists an imperative need to safeguard individual healthcare workers from diseases that possess the potential to be transmitted by patients within the hospital setting (69).

This crucial aspect strives to ensure the utmost well-being and security of healthcare professionals. Secondly, it is crucial to recognize that healthcare workers themselves are at an escalated risk of contracting such diseases (70). The physically demanding and often intricate nature of their work exposes them to a heightened vulnerability. Therefore, it becomes evident that healthcare workers require elevated protection against infectious diseases (71).

It is noteworthy to mention that the present guidelines pertaining to vaccination among healthcare workers bear striking similarities to those applicable to non-healthcare workers, albeit with intensified recommendations. This parallelism primarily arises due to the significantly greater potential for healthcare workers to unintentionally transmit infections to vulnerable patient populations. This highlighting of the aforementioned potential accentuates the paramount importance of vaccination (72).

Role of technology in infection control and its effectiveness

Technology has made the world a much smaller place, in the sense that people are able to travel over large distances in a relatively short space of time (73). This ability to travel has, in turn, placed the world at greater risk of emerging infectious diseases and their rapid spread. It has also led to increasing public concern and fear of such diseases, and to considerable media interest in disease outbreaks (74). The risk of introduction of an infectious disease and its subsequent spread can never be reduced to zero, and the perceived benefits of globalization and mass travel are such that few would wish to see a return to the days of lengthy and uncomfortable boat journeys as the only means of crossing the oceans (75). However, the enormous increase in trade, travel, and tourism in recent decades means that more people than ever before are on the move, and are therefore potentially exposed to infections for which they may have no immunity (76). For some diseases, a lack of immunity can be disastrous on an individual level, or the disease may have the potential to cause widespread epidemics (77).

Technology has also had a positive effect on infection control and outbreak management. The development of new diagnostic techniques and treatments in the field of infection has led to improved patient outcomes (78). For example, the development of gene amplification techniques has greatly improved diagnostic capability by allowing the detection of minute quantities of viral nucleic acid in a variety of clinical and environmental samples (79). This has led to earlier and more accurate diagnoses of a number of viral infections and allowed appropriate infection control measures to be implemented more quickly (80). Such techniques have also proven invaluable in outbreak situations, not only in diagnosing individual cases but also in investigating the likely source and mode of transmission of the infection (81).

Biosensors

When assessing infection, an ever-increasing number of techniques, ranging from cell culture to standard blood testing, are being used (82). Frequently, these biomarkers are disease-specific, while others can be attributed to a cocktail of infection parameters for the given disease (83). Biosensors are capable of detecting a single specific analyte and have, in addition to the above-mentioned techniques, a number of specific advantages (84). Biosensors are self-contained integrated devices that can provide specific analytical information. The biorecognition element is in direct contact with a transduction mechanism that can convert a biological response into a quantifiable signal, and conveniently, the output can be displayed within minutes, close to real-time (85). This is particularly useful in infection detection, as it may predominantly affect a patient quickly in a critical condition. In addition, biosensors allow for simple, fast, and reliable detection of various analytes and have the potential to be either entirely portable, hand-held devices or at least be used at the point of care (86).

Potentially, biosensors can use several different types of biorecognition elements. In particular, biochemical sensing is commonly implemented with glucose and enzyme-based sensors (87). Electrochemical sensor systems are relatively simple, and both potentiometric and amperometric measurements can be performed using glucose oxidase or other enzymes (88). Optical-based sensors utilize fluorescence, chemiluminescence, or absorbance and have the potential to be highly sensitive, using more sophisticated or novel fluorophores, chromophores, or particle-based labels (89). Impedance sensors do not require labeling of the analyte, and with the appropriate surface modification, can be highly specific (90). Calibration-free biosensors induce unique analyte-substrate interactions, capable of generating a signal that can be directly related to the concentration of the analyte (91). Due to the variety of designs, there are a number of ways that could be implemented for a given biosensor design (84).

Role of AI in infection control and its effectiveness

During the last twenty years, many mathematical AI approaches have been utilized to effectively address various elements of infection control (92). These AI infection control applications include, among others, automated tools for the identification and tracking of relevant infectious disease agents, monitoring and control of nosocomial infections, development and assessment of infection control policies, interpretation of infection-related clinical data, and real-time outbreak prediction and management (93).

Apart from the outbreak prediction approaches, which are practically implemented in specific geographical areas, the rest of the developed AI tools can be incorporated either into specialized infection control consulting companies or into hospital IT companies developing broader hospital systems, including infection control modules (94). For hospitals, one of the important infection control tasks is to continuously monitor and control nosocomial infections. Many efforts have been conducted in this area, developing tools that could identify clusters of similar infections and outbreaks (95). Statistical temporal and spatial cluster identification methods have been applied extensively for this purpose, and AI techniques like data mining and epidemic intelligence have also been employed (96).

The latter utilizes adaptive fuzzy cognitive maps in order to perform situation assessment and decision-making while it continuously learns from the changing external and internal conditions (97). The hybrid infectious disease intelligence system utilizes data mining identification and epidemic intelligence verification of alerts, with the two components being dynamically linked (98). It uses latent semantic analysis for recognizing infectious disease patterns and case-based reasoning for verifying the identified patterns (99). Two AI technologies, fuzzy temporal rules and adaptive network-based fuzzy inference systems, have been extended to define fuzzy rules for recognizing short-term outbreak patterns (100). Many of the developed signal detection algorithms could be used to recognize outbreaks, but they may have a high false positive rate (101). To eventually reduce the false signaling rate, multiple hybrid approaches have been developed by integrating statistical methods with data mining, AI epidemic intelligence, and machine learning (102).

Conclusion and Future Directions

In conclusion, considerable Health Associated Infections (HAI) prevention effectiveness evidence was found for hand hygiene, aseptic insertion of central venous lines, chlorhexidine bathing, alcohol-containing rubs, and oral decontamination with chlorhexidine for subjects receiving mechanical ventilation or extensive oral care. Only one essay appraised antibacterial clothing, and only single trials appraised selective digestive decontamination, written care plans, preoperative bathing, chlorhexidine use for peripheral venous catheters, or service delivery change. Generalizability of all interventions, dose-response evidence, and duration of intervention impact evidence would be invaluable for HAI prevention. Longer follow-up of trials would elucidate impact sustainability. Combined barriers for prevention complexity should be addressed pragmatically for safe care. Future directions include rigorously designed clinical and public health research studies, culturally acceptable, low-cost, yet effective techniques demonstrated through field trials and observational studies, and effective interventions for settings in every development context established. Circular trial evidence on contamination chronology and target etiological pathogen microbiology would advance evidence-supported intervention guideline development. Optimally, well-designed rigorous trial outcomes, split by pathogen, would elucidate specific infection control intervention impact to address entrenched barriers of practical knowledge gaps. In addition, policymakers, professionals, consumers, and foundations should invest in proven HAI control to protect patients.

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