ORIGINAL ARTICLE

Evaluation of efficacy and clinical utility of potassium peroxymonosulfate-based disinfectants

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ABSTRACT

Background: Environmental cleaning is an important aspect of infection control, especially for organisms such as rotavirus that are transmitted through direct and indirect contact.

Methods: We evaluated an intervention to prevent rotavirus infection in a pediatric ward by using wipes impregnated with a potassium peroxymonosulfate-based environmental disinfectant (PPD) for environmental cleaning. Prevalence rate (%) and incidence density rate (‰) for rotavirus were measured before and after the intervention. To estimate the efficacy of environmental cleaning, we evaluated the persistent bactericidal activities of commercially available antimicrobial products containing PPD.

Results: Prevalence rate (%) and incidence density rate (‰) for rotavirus were 5.54 and 2.85 before intervention (Apr-Jun, 2012), incidence density rate after intervention (Apr-Jun, 2013) was decreased to 1.48 despite the higher prevalence rate 8.62. PPD demonstrated persistent bactericidal activity against methicillin-resistant *Staphylococcus aureus* and *Pseudomonas aeruginosa* for up to 24 hours after application on experimental surfaces.

Conclusions: This study showed that intervention to promote the use of PPD was useful in preventing secondary infection of RV in pediatric ward. PPD was also considered to be useful from the viewpoint of persistent antimicrobial action, convenience, and safety.

KEY WORDS

Rotavirus, potassium peroxymonosulfate, environmental cleaning

INTRODUCTION

Healthcare environments are well known as propagation paths for pathogenic microorganisms. Disinfecting the hands of medical personnel as well as the medical environment, with a focus on frequently touched surfaces, is useful in infection control (1,2). As rotavirus (RV) is resistant to alcohol, the use of 200–1,000 ppm Sodium hypochlorite (NaClO) in disinfecting environments contaminated with RV is recommended (3). NaClO is a disinfectant with a broad antimicrobial spectrum. However, it is problematic for reasons such as corrosion of metal and other equipment surfaces, generation of irritating chlorine gas, and complicated management of concentrations (4). On the other hand, disinfectants and cleaning agents formulated with potassium peroxymonosulfate that are improvement over chlorine-based disinfectants and cleaning agents have been reported to be efficacious against many infectious microorganisms such as viruses and bacteria (5-9), and they have been used in a manner similar to that of NaClO in the hygiene management of healthcare environments (10,11). In addition, it has been reported that with hypochlorous acid as the active substance, there is little metal corrosion and no chlorine odor, and this agent is highly efficacious against many infectious organisms. Furthermore, the United States Environmental Protection Agency (EPA) states that potassium peroxymonosulfate-based disinfectants (PPD) are widely effective against such organisms such as norovirus, methicillin-resistant *Staphylococcus aureus* (MRSA), hepatitis B virus, and hepatitis C virus (12). The Centers for Disease Control and Prevention (CDC) guidelines recommend selection of a disinfectant or cleaning/disinfectant registered with the EPA for use in environmental maintenance (1). In addition, the Japanese dialysis guidelines recommend the use of potassium peroxymonosulfate in the cleaning and disinfection of environmental surfaces (13). However, reports regarding the clinical usefulness and sustainability of the effects of PPD are scarce.

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In this study, we aimed to evaluate the usefulness of PPD from an actual clinical intervention and through the use of questionnaires. We also examined the persistence of the disinfection effect of PPD from a microbiological perspective.

METHODS

Clinical intervention

The infection control team (ICT) of our hospital conducted a review of the work manual in environmental improvement; in January 2013, the daily environmental cleaning practices in this hospital's pediatric ward was changed from cleaning once a day with cloths impregnated with a neutral diluted household detergent solution, to cleaning once a day with disposable wipes impregnated with 1% w/v potassium peroxymonosulfate-blended disinfecting and cleaning agent, a type of PPD (Rubysta®: Kyorin Pharmaceutical Co., Ltd.). In addition, we switched from cloths impregnated with 0.1% w/v NaClO (Yoshida® 0.1% NaClO solution, Yoshida Pharmaceutical Co., Ltd.), which were prepared in the ward, to the use of PPD wipes for environmental disinfection in the vicinity of patients infected with RV. We also provided training to medical staff and patients' families on the conscientious use of disposable gloves and meticulous hand hygiene during the treatment of contaminants of RV patients and the processing of these contaminants. Following the changes, we regularly conducted ICT rounds. Following the changes, we regularly conducted ICT rounds. Next, we retrospectively investigated the number of patients hospitalized for RV enteritis and the number of patients diagnosed with RV enteritis due to nosocomial transmission during the pre- and post-intervention periods (January-June 2012 and January-June 2013, respectively) from electronic medical records; data collected was used to calculate the prevalence and incidence density rate.

"Incidence rate" indicates the risk of newly developed morbidity over a certain period of time, while "incidence density rate" is the incidence rate for the total patient population over a period of time. In other words, "incidence density rate" is the risk of patients acquiring rotavirus after hospitalization. (14,15)

Note: Prevalence rate (%) = (Number of hospitalized patients due to rotavirus enteritis + Number of hospitalized patients with secondary rotavirus infections)/ (Total number of hospitalized patients) *100

Incidence density rate (‰) = (Number of hospitalized patients with secondary rotavirus infections)/ (Total inpatient days) *1000

Questionnaire survey

In September 2013, approximately 10 months after the change in procedures, we surveyed the pediatric ward nurses for their evaluation of the disinfectants used for environmental improvement.

Sustainable bactericidal action

To evaluate the effectiveness of environmental disinfectants against bacteria, we examined the sustained bactericidal action of PPD and various disinfectants. In this study, as an alternative to RV, we evaluated three strains each of MRSA and *Pseudomonas aeruginosa*. We used disinfectants diluted with sterile purified water to obtain the specified concentrations. The disinfectants used were 1% w/v PPD, 0.1% w/v alkyldiaminoethylglycine hydrochloride ("amphoteric surfactant"), TEGO 51 Disinfectant Solution 10%®: Alfresa Pharma Corporation), ethanol for disinfection ([EtOH], Metal®: Nakakita Co., Ltd.), 0.1% w/v NaClO, and physiological saline solution [control], OTSUKA NORMAL SALINE®: Otsuka Pharmaceutical Factory Inc.). The SCDLP culture medium (Eiken Chemical Co., Ltd.) was used as a neutralizing medium, following confirmation that it demonstrated a neutralizing action against each disinfectant.

2 mL of each disinfectant was added dropwise to a sterilized disposable dish (As One Co., Ltd., diameter: 90 mm), and the solution was spread over the entire dish and dried at room temperature on a clean bench. 200 μL of bacterial solution (MRSA/*Pseudomonas aeruginosa*) adjusted to 10^6 cfu/mL was brought into contact for 5 minutes immediately after the dropwise addition, as well as at 30 minutes, 1 hour, 3 hours, 6 hours, 12 hours, and 24 hours after.

Thereafter, the bacterial solution on the petri dish was recovered using a neutralizing medium and incubated at 35 °C for 24 hours in sheep blood agar medium (Eiken Chemical Co., Ltd.) to observe whether or not bacterial growth occurred. A case without bacterial growth was judged as effective.

Ethical considerations

The present study was approved by the Institutional Review Board of Ogaki Municipal Hospital (approval number: 20160128-12).

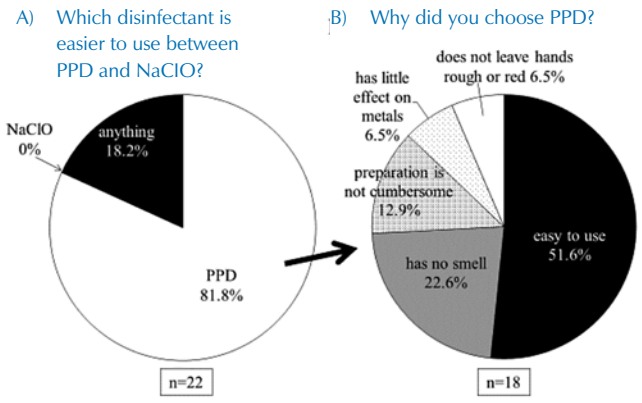
TABLE 1. Evaluation of rotavirus infection before and after intervention

	Before intervention (Apr-Jun, 2012)	After intervention (Apr-Jun, 2013)
Total number of hospitalized patients	1300	1276
Total inpatient days	7023	6752
Number of hospitalized patients due to rotavirus enteritis	52	100
Number of hospitalized patients with secondary rotavirus infections	20	10
Prevalence rate (%) [a)]	5.54	8.62
Incidence density rate (‰) [b)]	2.85	1.48

a) Prevalence rate (%) = (Number of hospitalized patients due to rotavirus enteritis+ Number of hospitalized patients with secondary rotavirus infections)/ (Total number of hospitalized patients) *100

b) Incidence density rate (‰) = (Number of hospitalized patients with secondary rotavirus infections)/ (Total inpatient days) *1000

FIGURE 1: Evaluation of disinfectants by pediatric ward nurses



A) Pie chart displaying the responses of pediatric ward nurses regarding which environmental disinfectant is easier to use, the 1% w/v potassium peroxymonosulfate-based (PPD) environmental disinfectant cleaner or the0.1% sodium hypochlorite (NaClO). No nurses chose NaClO.

B) Pie chart displaying the reasons for choosing PPD (responses from 18 nurses).

RESULTS

Clinical intervention

The Prevalence rate (%) and incidence density rate (‰) for rotavirus were 5.54 and 2.85 before intervention (Apr-Jun, 2012), incidence density rate after intervention (Apr-Jun, 2013) was decreased to 1.48 despite the higher prevalence rate 8.62 (Table 1).

Questionnaire-based survey

Of the 22 pediatric ward nurses surveyed, 18 nurses (81.8%) were more likely to use PPD compared to NaClO, the agent that had been used previously (Figure 1). The reasons indicated were 51.6% for "easy to use," 22.6% for "no smell," 12.9% for "preparation is not cumbersome," 6.5% for "little influence on metals," and 6.5% for "hands-free."

Sustained bactericidal action

EtOH showed bactericidal action only immediately after dropwise addition, and had no bactericidal action after 30 minutes. NaClO showed bactericidal action against MRSA up to 30 minutes after the coating, and for *Pseudomonas aeruginosa* until one hour after the coating, but did not show bactericidal action after that. In contrast, PPD and amphoteric surfactant showed sustained bactericidal action against MRSA and *Pseudomonas aeruginosa* even 24 hours after the application (Table 2).

DISCUSSION

In the hospital environment, it is necessary to pay attention to transmission of infection by various pathogenic microorganisms, and RV is one of the viruses that can be transmitted via environmental surfaces, especially in children's areas (1). Like norovirus, RV is one of the viral causes of infectious gastroenteritis that causes repeated epidemics annually. A compact, non-enveloped spherical virus, RV is stable in the environment, and its infectivity is so strong because ID_{50} is only 10 to 100 viruses (16, 17). Nosocomial infection with RV has been reported to increase hospitalization periods in Europe (3). Every year in Ogaki Municipal Hospital

TABLE 2: Sustainable effects of environmental disinfectants against bacteria

		Processing [b]					
Bacteria	**Disinfectant [a]**	**immediately afterwards**	**30 min**	**1 hr**	**6 hr**	**12 hr**	**24 hr**
MRSA	Control	+	+	+	+	+	+
	PPD	–	–	–	–	–	–
	Amphoteric surfactant	–	–	–	–	–	–
	EtOH	–	+	+	+	+	+
	NaClO	–	–	+	+	+	+
Pseudomonas aeruginosa	Control	+	+	+	+	+	+
	PPD	–	–	–	–	–	–
	Amphoteric surfactant	–	–	–	–	–	–
	EtOH	–	+	+	+	+	+
	NaClO	–	–	–	+	+	+

a) PPD: 1%w/v potassium peroxymonosulfate-based environmental disinfectant cleaner; amphoteric surfactant: 0.1% w/v alkyldiaminoethylglycine hydrochloride; EtOH: ethanol for disinfection; NaClO: 0.1% sodium hypochlorite; control: physiological saline solution

b) Bacterial growth was evaluated when the bacterial solution was brought into contact for 5 minutes with a petri dish surface on which each disinfectant had been dropped and dried for a certain period of time. +: growth, –: no growth.

(our hospital), there have been cases of secondary infection in the hospital causing prolonged hospitalization of infected patients. One propagation pathway of this secondary infection is care of other patients while the hands of the healthcare workers who touched the infected patient's vomit or excretions are contaminated, and another route of propagation is by healthcare workers touching environment surfaces contaminated with RV.

Therefore, to prevent in-hospital transmission of RV, we changed our environmental cleaning wipes from those impregnated with amphoteric surfactant to those with PPD, and evaluated the clinical usefulness of PPD from the actual intervention. As a result, though the prevalence of RV was higher in 2013 after intervention than it was in 2012, a decrease in incidence density rate was observed. The decrease of incidence density rate suggested that changing the environmental wiping cloth to a PPD wipe, while reviewing the timing and method of hand hygiene, and ensuring proper guidance, education, and compliance in the ward, may have contributed to the prevention of secondary propagation of RV infections. Moreover, in the questionnaire survey, it was shown that PPD is easier to use for reasons such as "there is no irritating smell," "preparation is not troublesome," etc. compared with NaClO used conventionally. PPD is less corrosive to metals and resins and is useful in environment improvement. Since it is a weighed individually package, it is a formulation featuring comparatively easy concentration control (18). PPD is an improvement on chlorine-based disinfectants and cleaning agents. PPD shows a pale red color when dissolved. Since the color tone changes in proportion to the decrease in the effective concentration of the disinfectant, this color change can be useful for estimating the effective concentration without measuring actually it (19). In this questionnaire survey, the usefulness and utility of PPD at the clinical site ware evaluated. In addition, it was revealed that PPD shows a persistent bactericidal effect for 24 hours for bacteria such as MRSA and *Pseudomonas aeruginosa*, similar to amphoteric surfactants. Low-level disinfectants such as amphoteric surfactants, chlorhexidine, and quaternary ammonium compounds have been reported to exhibit persistent bactericidal effects (20). However, there is no report on the sustainability of chlorinated disinfectants such as NaClO; the results of this study are therefore very interesting. The mechanism of action of PPD is through a production of hypochlorous acid in aqueous solution when potassium peroxymonosulfate oxidizes sodium chloride as a blending component (19). In this study, it was inferred that the bactericidal effect of the component of PPD that remained dry on the surface of the petri dish reacted with the moisture in the bacterial liquid, again producing hypochlorous acid as the active ingredient. NaClO undergoes natural decomposition even at room temperature (21), and it was thought that the persistence of the bactericidal effect disappeared because the remaining ingredients had decomposed by 60 minutes after application. In further investigations, it will be necessary to examine the sustainability of the effects of PPD on viruses.

CONCLUSION

This study showed that intervention to promote the use of PPD was useful in preventing secondary infection of RV in pediatric ward. PPD was also considered to be useful from the viewpoint of persistent antimicrobial action, convenience, and safety.

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