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A Basic Study to Reduce Bacterial Contamination of the Hands of Nurses during Diaper Changes

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Abstract

This study examined finger contamination during diaper change by comparing bacterial counts with or without glove small holes. Natto with rapidly growing bacteria was used as simulated stool. As a result of dilution culture with three commercial natto products, one with measurable colonies was used. Simulated stool, prepared by mixing 45 g of natto in 100 mL of sterile distilled water, was applied to a diaper as watery stool in a model doll, and small holes (2 × 3 mm) were made from the outer side of the first fingers of double sterile gloves. Handling the doll while wearing the double sterile gloves with or without holes, diapers were changed and the outer gloves were removed, followed by inoculation of general bacterial agar medium with three samples each, taken from the right palm. As a result, colonies were detected in all three samples taken from palms while wearing gloves with holes, but not from those without holes. Thus, the holes in the double glove allow the watery stool to enter the inner gloves, thereby spreading infection.

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Introduction

Excretion care performed in nursing practice is a technique with the potential to spread infection via diapers, toilet bowls, urinals, and other utensils used by carriers, or environmental surfaces contaminated with pathogenic microorganisms [1]-[3]. In particular, there are concerns about the spread of infection through nurses' hands and clothes during diaper changes as part of excretion care, considering the presence of microorganisms with a strong propagation capacity in feces. These most frequently transmitted microorganisms, represented by *Clostridium difficile*, norovirus, rotavirus, and O-157, occasionally cause mass diarrhea, and the main routes of transmission of COVID-19 that has been raging since December 2019 are contact and droplets. Therefore, hand hygiene is important to prevent the spread of infection.

In Japan, the number of people with a care grade of 3 to 5 requiring assistance for excretion has been reported to be approximately 1.9 million in FY2009 and 2.3 million in FY2019 [4], suggesting that the number of those using disposable diapers on a daily basis is also increasing. The shortage of nurses and care workers who care for the elderly is an issue to be addressed, and there are also many elderly people receiving home care, the caregiving burden is likely to be growing in both facilities and homes. Among the care procedures, excretion care is a heavy burden on caregivers. They are instructed to change diapers in a minimum amount of time with consideration for care recipients' sense of shame. Thus, diaper changes are heavy work for caregivers and a care procedure they should quickly perform for care recipients, while perceiving an increased risk of infection.

As a hand hygiene approach to break down the route of infection, the Centers for Disease Control and Prevention (CDC) guidelines on hand hygiene in healthcare settings recommend washing hands with a detergent and running water when there is visible contamination, and disinfecting hands with a quick-drying alcohol sanitizer when there is no visible contamination. However, the guidelines do not specifically mention gloves or hand hygiene methods to prevent infection in care procedures where caregivers directly handle feces, such as diaper changes. Furthermore, although nursing books describe how to handle quilts, waterproof sheets, and changing clothes as a method for diaper changes, none specify methods for glove wearing/removal and hand hygiene based on evidence [5].

Some previous studies examined the degree of bacterial contamination of hands, focusing on diaper changes, and simply reported the current status, in which MRSA, Staphylococcus aureus, and E. coli were detected on the gloves of caregivers after diaper changes [6, 7]. The implementation of hand hygiene adopting the direct observation method during diaper changes was 3.5%, and the timing of hand hygiene was limited to before each diaper change [8]. Other studies bacteriologically addressing contamination of the hands of healthcare workers after care procedures revealed that their glove-removed hands were contaminated with multidrug-resistant bacteria [9,10]. These studies did not examine the timing of hand hygiene or glove wearing/removal during diaper changes. There have been no studies bacteriologically comparing the degree of contamination during diaper changes performed by nurses on a daily basis, adopting different glove use methods.

Evidence for diaper changes as an excretory care technique has been left insufficient due to the difficulty of conducting systematic studies on the timings of hand hygiene and glove change, as manual techniques vary among facilities and nurses and depend on the patients' defecation status. In order to advance and develop efficient and effective evidence-based care techniques, it is urgently necessary to establish evidence for blocking routes of infection.

There are differences in the glove use method for diaper changes performed by nurses daily. In some cases, single-gloving is used for each diaper change, and new gloves are put on when the first gloves become contaminated. In other cases, double gloving is used from the beginning, where the outer gloves are removed when they become contaminated, and inner gloves are used. However, caregivers' hands may become contaminated through care, as some gloves have

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leakage through pinholes, and damage that is difficult to see with the naked eye. A previous study noted the risk of contamination of inner gloves resulting from outer glove removal in the case of double gloving. The JIS standard for medical gloves in Japan stipulates that the acceptable pinhole rate is 2.5% for inspection and medical examination gloves, and gloves that meet this standard are used in healthcare settings. Among all types of personal protective equipment, gloves have the highest contamination and microorganism retention rates, as manual techniques for care procedures involve the hands. During diaper changes where caregivers directly handle feces, the presence of pinholes in gloves as a route of infection may cause the transmission of highly dangerous infection.

Methods

Definition of terms

Simulated feces

We created simulated feces to be used for diaper changes in this study from easily available food.

Pinholes in gloves

Pinholes are damage to new gloves. The JIS standard for medical gloves in Japan stipulates that the acceptable pinhole rate is 2.5% for inspection and medical examination gloves, and gloves that meet this standard are used in healthcare settings.

Diaper changes performed by nurses using double gloving

This method is used by nurses when performing diaper changes daily in nursing practice. They wear 2 gloves before a diaper change, and if they find the second (outer) glove contaminated after the diaper change, they remove the contaminated glove, and use the first (inner) glove.

Study design

This study was conducted with a quasi-experimental design.

Study period

March 31, 2022, after the approval of the Research Ethics Committee of the affiliated institution.

Experimental methods

Creation of simulated feces

Selection of materials for simulated feces

We selected commercially available natto (fermented soybeans) to create the simulated feces to be used in this study, as bacteria stably grew in yogurt and natto in previous studies [12] [13]. To select the most appropriate type of natto, we conducted a preliminary experiment.

We first selected 3 types of natto from a large number of commercially available natto products, which were similar in weight and nutritional composition and made by different manufacturers. Their types and characteristics are shown in Table 1. A (Okame Natto®; Takanofoods Co., Ltd.) is made from whole soybeans, rice flour, and Bacillus subtilis var. natto (B. natto); B (Natto Ichi®; Mizkan Holdings) is made from soybeans and B. natto; and C (Tansei®; Mizkan Holdings) is made from soybeans and B. natto. These 3 types of natto are manufactured by adding the nutrients found in natto to the raw materials. We stirred each type of natto with a mixer disinfected with rubbing alcohol cotton swabs (ethanol-impregnated cotton containing 83 mL of Japanese Pharmacopoeia ethanol in 100 mL of ingredients; Sanicot® Design; alcohol cotton), collected 0.01 mL (1 loopful) of milky white matter with strong viscosity, and smeared it on an agar plate with a Conradi stick. However, due to fusion, the number of bacterial colonies was unmeasurable in any agar plates of A-C. Therefore, to accurately measure the number of bacterial colonies, we prepared 10-fold dilutions, and compared these with the original solutions of A-C. We prepared each undiluted solution by stirring natto with a mixer, collected a sample of 0.01 mL, and dissolved it in 5 mL of saline. Then, we took a 0.5 mL of the undiluted solution, and dissolved it in 4.5 mL of saline to prepare a 10-fold dilution. We collected 0.1 mL of both the undiluted and 10-fold diluted solutions, and smeared them on agar plates. After 72 hours, the number of bacterial colonies was unmeasurable again due to colony fusion in both the undiluted and 10-fold diluted solutions of A and C after 72 hours, whereas 171 cfu/plate and 44 cfu/plate colonies were measured in the undiluted and 10-fold diluted solutions of B, respectively. Based on this, we selected B, in which the number of bacterial colonies was measurable, to create simulated feces for this study.

Creation of simulated feces and preparation of diapers

Adults have a typical daily normal stool weight of 100-250 g. In general, stools with high water content make it more difficult to

	Product names	Weight(g)/(pack)	Ingredient	Nutritional composition (Natto only)
A	Okame Natto®	45g	Whole soybeans (segregated production and distribution controlled), rice powder, Bacillous natto	Energy: 83 Kcal, protein: 7.0g, carbohydrates: 5.6g, salt: 0.001g, sugar: 2.5g, fiber: 3.1 g
B	Natto Ichi®	45g	Soybeans (segregated production and distribution controlled), Bacillus natto	Energy: 177 Kcal, carbohydrates: 12.0g, protein: 15.4g, Na: 3mg, fat: 9.1g, salt: 0.0g
C	Kume Natto Tansei®	40g	Soybeans (non-genetically modified), Bacillus natto	Energy: 178 Kcal, carbohydrates: 12.5g, protein: 16.2g, Na: 5mg, fat: 8.5g, salt: 0.0g

Table 1: Name and characteristics of each type of natto.

change diapers than normal stools, and are thought to increase the risk of transmission of infection. For this reason, we made simulated feces correspond to Type 6 or 7 based on the Bristol Stool Scale.

We used 3 packs of natto, added 20 mL of sterile distilled water, and stirred them with a hand mixer to create simulated feces. We put diapers contaminated with the created simulated feces on a model doll, made pinholes in sterile gloves by puncturing them with an 18G needle, and performed diaper changes. After removing the gloves, we incubated the bacteria from our hands, but no colonies were measured.

As a higher water content promotes bacterial development, we adjusted the amount of sterile distilled water added to natto, as well as the shape and amount of natto, when creating simulated feces. We first mixed 1 (45 g), 2 (90 g), and 3 packs (135 g) of natto with 100 mL of sterile distilled water, and compared the 3 conditions (Table 2). Consequently, we decided to use 1 pack (45 g) of natto B stirred for 1 minute with 100 mL of sterile distilled water as simulated feces, as the number of bacterial colonies was measurable without fusion.

Subsequently, we calculated the mean number of bacterial colonies in the simulated feces. We incubated the undiluted solution of simulated feces on an agar plate, but the number of bacterial colonies was not measurable due to their fusion. As a solution, we first diluted the undiluted solution to the 8th power of 10 to calculate the mean number of bacterial colonies in simulated feces. As colonies were fused and unmeasurable in the agar plates for solutions diluted to 10 to the 3rd power of 10, we adopted solutions diluted to the 4th to 8th power of 10. To calculate mean values more accurately, we prepared 3 packs of natto B, and smeared 3 samples from the solutions diluted to the 4th to 8th power of 10 on agar plates. After an approximately 20-hour incubation in an incubator at 37°C, the number of bacterial colonies (mean±standard deviation) in the simulated feces was $4.4\pm1.8\times10^8$ cfu/mL.

After applying simulated feces to a urine absorbent pad in an area of 20 cm (length) x 10 cm (width), we placed that pad on top of a tape diaper, and put the diaper on a model doll (Patient Simulator Model Sakura; Kyoto Kagaku Co., Ltd.).

Experimental devices

Among the experimental devices shown in Table 3, we disinfected the model doll, mixer, and bowl used in the experiment with alcohol cotton immediately before it. After disinfection, we placed a urine absorbent pad coated with simulated feces on top of a tape diaper, and put this diaper on the model doll. To make the experimental conditions more realistic, we selected a full-bodied adult model doll.

Method of diaper changes

Diaper changes were performed by 2 persons: a practitioner wearing sterile gloves (A) and an assistant wearing contaminated plastic gloves (B). The same persons performed all diaper changes to ensure uniformity of technique. A and B performed hand hygiene using a quick-drying alcohol hand sanitizer, and wore a mask before starting each diaper change.

When performing a diaper change, B took the tape off the diaper attached to the model doll lying in a supine position, placed the doll in

Equipment	Product information, number of uses
Beds	3-crank gagged bed, Paramount bed, (1) Wagons for treatment (3)
Modell doll	Patient care simulator (Universial training model Sakura), Kyoto Kagaku, (1)
Simulated feces (Bristol stool scale type 6-7)	Natto Ichi®, 45g Sterile distilled water (AS ONE corporation, Refined water for research 20L), 100 mL Mixer (Hitachi Mixer V A-W-10L), (1) Bowl, (2) Silicone rubber spatulas, (1)
Diapers for adults	Refer, Easy tape-fastening type fastening type to prevent side leakage when sleeping on the side of the body, Size M, 1 sheet/time.
Urine absorbent pads	Refer, Soft and snugfitting pad for pants, regular, 1 sheet/time.
Fast-drying hand sanitizer	Hibiscol®SH
Alcohol-impregnated cotton	Sanicot®dezin, Marusan Industry Co., ltd., Mixer, Bowl, Disinfections of genital area using care simulator training model, 5-10 pieces/times, Training 1 piece/time
Palm check	Hand contamination inspection device (soybean-casein digest agar with lecithin & polysorbate)
Sterile gloves	AS ONE corporation, Latex long sterile gloves (ProtegrityTM, CP), 7, 2 sets/time
Non-Sterile gloves	Navi Roll glove (Latex powder free), size S, 2 pieces/time
Butt wipes (Sterile condition)	Sterile gauze (Sterile rectangular gauze blister 30 cm × 30 cm), 4 folds, 2 sheets, Hasegawa Menko Co., Ltd, 2 pieces/times Sterile cup (Sterile cotton balls Neo-Pearl R/ Neo-Pearl JE EB Series), Osaki Medical Corp., 1 pieces/time, cottons balls are removed, and cups only are used. Sterile distilled water (AS ONE corporation, Refined water for research, 20L), 100 mL/time
Needle creating pinholes	Terumo needle 18G, 1 needle/time
Disposal bags	Ecology packs 45L, Showa-shokai Co. Ltd

Table 2: Equipment.

Bacterial count for each sample (cfu/plate)							
Time	Simple number	Comparision based on the needle gauze					
		18G	21G	22G	24G	25G	26G
24	No. 1	-*	1	-	-	-	-
	No. 2	-	-	-	-	-	-
	No. 3	-	-	-	-	-	-
48	No. 1	-	1	-	-	-	-
	No. 2	-	-	-	-	-	-
	No. 3	1	-	1	-	-	-
72	No. 1	-	1	-	1	-	-
	No. 2	-	-	-	-	-	-
	No. 3	-	1	-	-	1	-

"-" indicates zero bacteria.
Note 1) Test environment: room temperature 25.2±0.3°C, humidity 58.5±5.5%
Note 2) Incubation environment: room temperature 20.4±1.7°C, humidity 52.0±7.8%
Table 3: Comparison of the bacterial count based on the size of pinholes.

a left lateral recumbent position, and maintained this position. Then, A wiped the doll from the urethral opening to anal area with 1 piece of sterile gauze, and outwards from the pubic area toward the buttocks with another piece of sterile gauze to remove the simulated feces; in the latter, A folded the piece of sterile gauze to completely wipe off fecal matter without leaving any residue on the buttocks with its clean surface. B confirmed that the simulated feces were completely wiped off, and removed the contaminated diaper while rolling it up.

Size and location of pinholes

Confirmation of the presence and size of pinholes

Concerning plastic gloves generally used in healthcare settings, the JIS standard for medical gloves in Japan stipulates that the acceptable pinhole rate is 2.5% for inspection and medical examination gloves, and gloves that meet this standard are used in such settings. Considering this, we confirmed the presence of pinholes in 200 plastic gloves (Plastic Disposable Gloves E Powder-free®) generally used in healthcare settings by injecting 100 mL of tap water into each glove from the part where the hand is inserted. Two of the 200 plastic gloves had pinholes: one had a pinhole with a diameter of 0.1 mm in the area between the second and third fingers, and the other had a pinhole with a diameter of 2×3 mm in the palm area.

We created pinholes for our experiment using 6 types of needles: 18G, 21G, 22G, 24G, 25G, and 26G. After washing our hands with a scrub-type hand sanitizer for surgery (Hexizac® Scrub), we disinfected them with a fast-drying hand sanitizer (Hibiscol ®SH), wore a sterile glove on our right hand, and artificially created a pinhole on the tip of its second finger. After removing that sterile glove, we calculated the bacterial count on the hand, and compared it among gloves. We used the previously mentioned undiluted solution (0.01 mL of natto stirred and mixed with 5 mL of sterile distilled water) as the simulated feces. As the amount of water should be enough to immerse a hand in, we used 20 mL of the undiluted solution. As the number of bacterial colonies was the highest when puncturing gloves with an 18G needle, we selected this type of needle to create all pinholes (Table 2). On the other hand, the sizes of the pinholes found in unsterilized plastic gloves were 0.1 mm and 2.0×3.0 mm. We adopted size 2.0×3.0 mm for all pinholes to be used in the present experiment in consideration of its potential to increase the risk of bacterial infiltration through pinholes and number of bacterial colonies measured.

Location of pinholes

Previous studies reported that there were pinholes in the first, third, and fourth fingers of unused inspection gloves, and that pinholes occur at the highest rate during surgery in the first and second fingers. It should also be noted that damage to gloves may occur during diaper changes as a procedure to be efficiently performed in a short time, involving forceful movements. Based on these findings, among the fingers that are expected to be most exposed to feces during diaper changes, we selected the following 4 points to create pinholes: the first, second, third, and between the second and third fingers. We first wore 2 sterile gloves, created a pinhole in the outer glove with an 18G needle, and changed a diaper contaminated with simulated feces. Subsequently, we removed the outer glove, placed the hand wearing the inner glove on an agar plate for inoculation, and compared the bacterial count among the 4 points after incubation. The number of bacterial colonies was measurable only on the first finger after 48 and 72 hours (Table 5). Therefore, we decided to create a pinhole in the first finger in expectation of an increased risk of hand contamination during diaper changes (Figure 1).

Bacterial count for each sample (cfu/plate)					
Time	Sample number	Amount of natto (number of packs)			
		First finger	Second finger	Third finger	Between the seond and third finger
24	No. 1	-*	-	-	-
	No. 2	-	-	-	-
	No. 3	-	-	-	-
48	No. 1	-	-	-	-
	No. 2	1	-	-	-
	No. 3	1	-	-	-
72	No. 1	-	-	-	-
	No. 2	11	-	-	-
	No. 3	4	-	-	-

"-" indicates zero bacteria.
Note 1) Test environment: room temperature 21.7±0.1°C, humidity 26.4±0.4%
Note 2) Incubation environment: room temperature 24.2±1.6°C, humidity 40.3±0.9%
Table 4: Comparison of the bacterial count based on the location of pinholes.

Time	Sample number	Bacterial count for each sample (cfu/plate) Amount of natto (number of packs)		
		1	2	3
24	No. 1	-*	-	-
	No. 2	2	-	-
	No. 3	1	3	-
48	No. 1	2	-	10
	No. 2	2	1	26
	No. 3	-	4	1
72	No. 1	2	25	7
	No. 2	27	25	14
	No. 3	35	51	1

"-" indicates zero bacteria.
Note 1) Test environment: room temperature 21.7±0.1°C, humidity 26.4±0.4%
Note 2) Incubation environment: room temperature 24.2±1.6°C, humidity 40.3±0.9%

Table 5: Comparison of the bacterial count based on the concentration of natto.

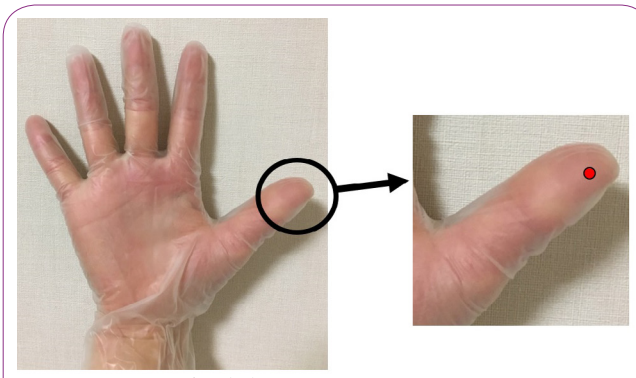

Figure 1: Location of pinholes.

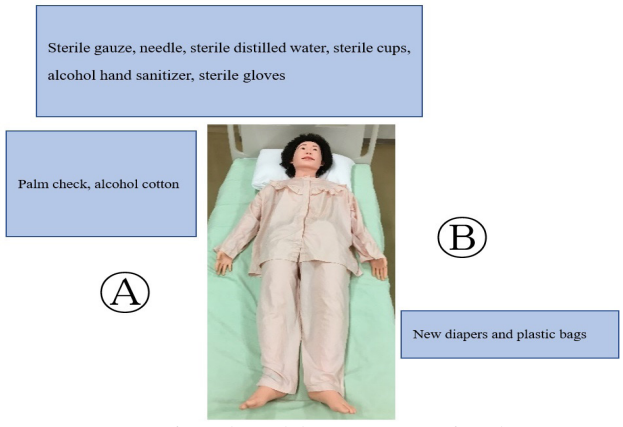

Figure 2: Positions of A and B and the arrangement of goods.

Procedures and data collection

We disinfected the model doll lying on a bed with alcohol cotton from the buttocks to the anus and vulva, and put a diaper contaminated with simulated feces on it.

In this experimental procedure, A disinfected her hands with a fast-drying alcohol hand sanitizer (Hibiscol ®SH), wore the inner sterile glove (glove), and the outer glove over it for both hands. Then, B created a pinhole in the first finger of the outer glove worn by A on her right hand, using an 18G needle and the aseptic technique. We did not perform this procedure for gloves without pinholes as controls. A and B performed each diaper change and fecal disposal in 3 minutes using the aseptic technique. To prevent hand contamination when A removed her outer glove, B disinfected the wrist area of A's right glove from the outside with alcohol cotton in advance. A picked up the wrist area of her right outer glove with her left hand, removed it from her right hand, and pressed her dominant right hand still wearing the inner glove into an agar plate with 2 kg pressure for 5 seconds for inoculation. The duration of the entire process was 5 minutes (Figure 3). We set the time required for the entire process at 5 minutes based on the results of our preliminary experiment, in which the mean time±standard deviation needed to change a diaper for the model doll was 4 minutes 47 seconds±1 minute 3 seconds. We newly created simulated feces, and performed 3 diaper changes while wearing gloves with and without pinholes. Assuming that the number of bacterial colonies is higher when wearing gloves with pinholes, we collected 3 samples as the minimum number of samples required for analysis.

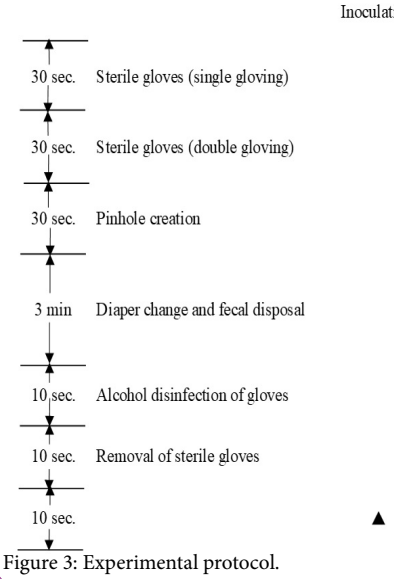

Figure 3: Experimental protocol.

Data Analysis

We analyzed the data by observing colonies on the agar plates for palm printing at 24, 48, and 72 hours, and measuring the number of bacterial colonies that developed after incubation. Bacterial counts are shown as Colony Forming Units (cfu).

Ethical Considerations

Using a model doll, the consent process was unnecessary. The period of data storage after the publication of this paper is 5 years. The study was conducted with the approval of the Research Ethics Committee of the Kagawa Prefectural University of Health Sciences (No. 324).

Results

We wore 2 gloves, created a pinhole in the outer glove, and performed diaper change to compare the bacterial count with and without pinholes. After each diaper change, we removed the outer glove, and incubated bacteria by pressing our hand still wearing the inner glove onto an agar plate to visually measure the number of bacterial colonies after 24, 48, and 72 hours. The results are shown

in Table 6. No colonies were measured from the 3 samples without pinholes at any point. In contrast, with pinholes, colonies were measured from 2 samples after 24 hours and from 3 samples after 72 hours of incubation.

		Bacterial count from each sample (cfu/plate)		
No.	With/without pinholes	Sample number		
		No. 1	No. 2	No. 3
24	With	-*	10	3
	without	-	-	-
48	With	-	14	8
	without	-	-	-
72	With	7	14	10
	without	-	-	-

"-" indicates zero bacteria.
Note 1) Test environment: room temperature 19.5±0.5°C, humidity 55.0±1.7%
Note 2) Incubation environment: room temperature 19.4±1.6°C, humidity 63.3±6.8%
Table 6: Bacterial counts with and without pinholes during diaper changes.

Discussion

To compare the degree of hand contamination when changing diapers with and without pinholes in outer gloves, we put diapers contaminated with simulated feces on a model doll, changed these diapers wearing 2 gloves, and measured bacterial counts from the inner gloves. There were no bacteria from gloves without pinholes, whereas gloves with pinholes were found to be contaminated, as colonies were measured on their agar plates, indicating that liquid from the stimulated feces penetrated into the inner gloves through pinholes in the outer gloves.

Based on the results, this section discusses the risk of infection caused by pinholes in gloves, as well as the necessity of appropriate glove wearing/removal and thorough hand disinfection when changing diapers from the perspective of infection prevention.

Risk of infection caused by pinholes in gloves

To conduct this experiment under a more practical condition, we made simulated feces correspond to Type 6 or 7 based on the Bristol Stool Scale; thus, it was liquid stool, which makes diaper changes difficult. The number of bacterial colonies in simulated feces per plate (mean±standard deviation) was $4.4\pm1.8\times10^8$ cfu/mL. With pinholes in gloves, colonies were measured in 2 samples after 24 hours and 3 samples after 72 hours of incubation, revealing a stable increase over time. Based on this value, $4.4\pm1.8\times10^8$ cfu/mL, it is estimated that there were an uncountable number of bacterial colonies in a 145-mL undiluted solution of simulated feces. In fact, the intestinal microflora exist at 1011 cells/g or more in the large intestine. The number of bacterial colonies contained in the simulated feces we created was $4.4\pm1.8\times10^8$ cfu/mL, but the bacterial count in actual feces is more than 1,000 times this value. As is the case of noroviruses that are long present in the environment and establish infection with relatively a small number of viruses (10 to less than 100), a small number of bacteria or viruses may become a source of infection in some cases. In the present study, 7 to 14 colonies were measured after 72 hours of incubation with pinholes, suggesting that the presence of pinholes in gloves also contributes to the establishment of infection during diaper changes.

In general, the size of most bacteria is in the range of 1-5 μm, and that of viruses is 1 μm or smaller. When immersing gloves with a pinhole with a pore diameter of 10 μm in 1-cm H_2O body fluid or similar solutions for 1 minute, 7 to 8 microorganisms are transferred into the gloves. Furthermore, a previous study compared the amount of bacteria passing through gloves with pinholes with different pore diameters, and reported that there was a more than 1,000-fold difference in the amount between pore diameters of 10 μm and 5 times that, 50 μm [14]- [16]. Based on this, it is likely that microorganisms pass through pinholes even if their size is so small, 10 μm, that is invisible to the naked eye, and the larger the pinhole, the greater the amount of bacteria passing through it.

The results of the present study revealed that pinholes in gloves during diaper changes may become a source of infection. A previous study also noted the possibility of bacteria being wiped off and transferred from contaminated hands after changing diapers to patient/bedclothes during the process of putting on new diapers or adjusting these clothes. Indeed, not only the surroundings of infected persons, but also environments around non-infected persons, such as their beds, toilet bowls, and the floors of their rooms, are also contaminated [17]. It has been confirmed that E. coli can live on clothes for 21 hours, and *Clostridium difficile* can live on environmental surfaces for 5 months [18]. For an example of diseases caused by these pathogenic microorganisms, E. coli bacteria normally live in the intestinal tract, but there are diarrheagenic strains, and enterohemorrhagic E. coli that causes hemolytic anemia, acute renal failure involving thrombocytopenia, and many deaths in some cases is a dangerous pathogen [18]. *Clostridium difficile* is one of the bacteria normally found in the large intestine, but forming spores and being resistant to dryness and disinfectants such as ethanol, it can also live in the environment for a relatively long period. It is also a pathogen of antibiotic-associated diarrhea, causing diarrhea and pseudomembranous enteritis. Furthermore, being continuously present in the environment, such as in beds and toilets, it is easily transmitted. Therefore, preventing transmission of infection by this bacterium is important not to increase the number of carriers [18], and it can be inferred that the risk of spreading infection by the numerous bacteria and viruses found in feces through gloves and hands contaminated due to pinholes in the former is high during diaper changes.

Based on these findings, pinholes in gloves during diaper changes may become a source of infection. In order to prevent the transmission of infection, it is indispensable to change gloves whenever detecting pinholes in them before each procedure, such as changing a diaper.

Necessity of appropriate glove wearing/removal and thorough hand disinfection

In the present experiment, colonies were observed with pinholes, demonstrating that pinholes in gloves during diaper changes are a source of infection. In contrast, without pinholes, no colonies were measured from inner gloves after removing outer gloves when double gloving. As the purpose of the present study was to compare the degree of hand contamination with and without pinholes in gloves, we did not examine hand contamination when removing gloves for experimental operations. A previous study reported that double gloving can reduce the risk of viral contamination of the hands of healthcare workers when removing contaminated personal protective equipment [16]. However, when double gloving, the inner glove may be contaminated if the outer glove has a pinhole. The inner glove

may also become contaminated through touch when removing the outer contaminated glove. Some studies compared the degree of contamination among different glove use methods, and showed that the degree of contamination is higher with a wider distribution when wearing 2 gloves and removing the outer glove than when wearing 1 glove and replacing it with a new glove [19]. In this case, there is the option to disinfect the inner glove, but disinfection over gloves leads to a higher positive microbial culture rate than disinfection after glove removal [20]. Therefore, even when double gloving, it is important to promptly remove gloves whenever they become contaminated, and wear new gloves after hand disinfection, taking the possibility of double gloving increasing the risk of contamination of inner gloves through pinholes in outer gloves and touch when removing outer gloves into account.

In these regards, we believe that bacterial contamination of hands wearing gloves without pinholes during diaper changes is preventable by eliminating contamination due to inappropriate glove removal. However, as pinholes exist in 2.5 of 100 gloves, it is necessary to consider the presence of pinholes when double gloving for a diaper change and removing the outer glove after it. The results of the present study suggest the necessity of removing both inner and outer gloves and wearing new gloves after disposing of feces in consideration of the possible presence of pinholes when double gloving for diaper changes in nursing practice. Further studies are necessary to establish evidence for contamination due to double gloving for diaper changes, including when there are pinholes in both inner and outer gloves.

Conclusion

In this study, we put diapers contaminated with simulated feces on a model doll, and changed these diapers wearing 2 gloves with and without an artificially created pinhole in the outer glove to compare the bacterial count on the inner glove. Bacterial colonies were measured from inner gloves with pinholes, but not from those without pinholes.

The results indicate that inner gloves may become a source of infection by being contaminated through pinholes in outer gloves during diaper changes. When double gloving, it is necessary to consider the possibility of inner gloves being contaminated through pinholes in outer gloves or touch when removing outer gloves.

Competing Interests

The author declares that she has no competing interest.

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