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Major article

Is sterility essential for hand-drying products in surgical hand antisepsis? A controlled before-and-after study

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Key Words:
Clean paper towel
Sterile cloth towel
Sterile paper towel
Hand bacterial culture

Background: Using sterile hand-drying products for surgical hand antisepsis incurs high economic and labor costs.
Methods: In March 2024, a controlled study was conducted with 50 medical volunteers from the Second Affiliated Hospital of Chongqing Medical University. The study compared bacterial cultures on hands after drying with different products and using a rinse-free hand disinfectant, while also calculating the hand-drying cost per surgical procedure.
Results: Colony counts from hand bacterial cultures after drying with clean paper towels, sterile cloth towels, and sterile paper towels were 0.01 (0.00, 0.18) CFU/cm^2, 0.30 (0.05, 0.77) CFU/cm^2, and 0.01 (0.00, 0.08) CFU/cm^2, with a significant difference ($P < .001$). After using rinse-free hand disinfectant, counts were 0.00 CFU/cm^2 for all methods, with no significant difference ($P > .05$). Total bacterial colonies were below 5 CFU/cm^2, meeting surgical hand antisepsis standards. All products had a 100% qualification rate, with costs of CNY 0.20 RMB for clean paper towels, CNY 5.70 RMB for sterile cloth towels, and CNY 8.20 RMB for sterile paper towels.
Discussion: Clean paper towels, sterile cloth towels, and sterile paper towels all meet the hygiene requirements for hand-drying during surgical hand antisepsis. However, clean paper towels result in fewer residual bacteria on the hands compared to sterile cloth towels. Moreover, clean paper towels are more cost-effective and can significantly reduce operating room expenses.
Conclusions: Healthcare institutions may utilize clean paper towels as an alternative to sterile products for hand-drying during surgical hand antisepsis.

BACKGROUND

Surgical hand antisepsis is the process of thoroughly cleansing and disinfecting the hands and forearms up to the lower one-third of the upper arm using running water and an appropriate hand sanitizer. This procedure aims to eradicate transient bacteria and reduce resident bacteria on the skin prior to a surgical procedure.[1] Rigorous adherence to surgical hand antisepsis protocols is vital in preventing surgical site infections and represents the most effective and cost-effective method for reducing hospital-acquired infections.[2,3] Surgical hand antisepsis follows the principle of hand washing, followed by disinfection. After washing the hands, they should be thoroughly dried using hand-drying products, and then, a rinse-free hand disinfectant procedure should be carried out. World Health Organization guidelines on hand hygiene suggest that wet hands are more likely to harbor and transmit microbes. Therefore, hand drying is a crucial part before the application of rinse-free hand disinfectant and plays a significant role in the effectiveness of surgical hand antisepsis.[4]

In 2009, Specification of hand hygiene for health care workers[5] was published, which clearly stated that sterile towels should be used for hand drying following surgical hand antisepsis. Under this guidance, reusable sterile cloth towels were employed for hand drying in major hospitals across China. However, in clinical practice, these reusable sterile cloth towels are managed as clean items once the outer packaging is opened. This practice poses a risk of contamination if the user does not handle them properly. Additionally, the processes of recycling, cleaning, sterilizing, and aseptic storage of reusable hand

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towels after use can significantly increase both human resource costs and overall medical care expenses.[6] In the 2019 update of the specification of hand hygiene for health care workers,[1] the method for surgical hand antisepsis has been refined. However, it does not specify or recommend the type of hand-drying products before applying a rinse-free hand disinfectant, nor does it emphasize that the hand-drying products must be sterile. As the health care industry and technology have evolved, a variety of hand-drying products have emerged. The use of disposable paper towels for surgical hand antisepsis has become increasingly convenient and manageable. This opinion is endorsed by several health organizations, including the World Health Organization, which advocates that surgical hand washing should be followed by the use of paper towels or other hand-drying products that dry the hands quickly and effectively.[4] The American Association of Perioperative Registered Nurses, in its evidence-based guidelines for hand hygiene practices, specifically recommends the use of disposable paper towels to thoroughly dry hands following surgical hand antisepsis.[7] However, many hospitals still predominantly use sterile cloth towels in the operating room for drying hands after surgical hand washing due to concerns regarding the effectiveness of surgical hand antisepsis. Since chlorhexidine gluconate and ethanol in rinse-free hand disinfectant are effective in eliminating residual bacteria on the hands and provide a prolonged sanitizing effect[8,9], the need to extend the use of traditional sterile cloth towels for hand drying prior to the application of rinse-free hand disinfectant warrants further investigation.

Therefore, clean paper towels, sterile cloth towels, and sterile paper towels were selected for comparison in this study. The aim was to investigate whether the use of different hand-drying products prior to the rinse-free hand disinfectant session affects the disinfection efficacy of surgical hands. Additionally, the study aimed to conduct an economic evaluation of hand-drying products made from various materials and to provide guidance for the clinical selection of safe, comfortable, and cost-effective hand-drying products.

METHODS

Study design and participants

In this study, a before-and-after control design was employed. Fifty medical volunteers from the operating room of hospital in March 2024 were selected to participate in the study. Inclusion criteria: (1) working in the operating room; (2) having received surgical hand antisepsis training and passed the examination; (3) removing hand jewelry and refraining from wearing artificial nails, decorative nails, etc; and (4) trimming nails to the tips of the fingers. Exclusion criteria: (1) recent viral infection, and (2) obvious wounds or ulcers on the hands. All subjects voluntarily participated in this study and signed an informed consent form. This study was reviewed and approved by the Ethics Committee of the hospital, with Ethics Approval Number: 2024 research ethics review No. (11).

To prevent delayed effects and sample contamination, the study was conducted over 3 days. On the first day, 50 volunteers used clean paper towels for hand drying (group A). On the second day, they used sterile cloth towels (group B), and on the third day, they used sterile paper towels (group C). This design ensured an adequate washout period for each instance of surgical hand antisepsis among the study subjects.

Sample size

The results of the preliminary experiments indicated that the average number of bacterial colonies cultured by hand after using clean paper towels, sterile cloth towels, and sterile paper towels were 0.30 CFU/cm², 0.06 CFU/cm², and 0.43 CFU/cm², respectively. The corresponding standard deviations were 0.16 CFU/cm², 0.41 CFU/cm², and 0.30 CFU/cm². With the inspection level set at $\alpha = 0.05$ and the inspection power at $1\text{-}\beta = 0.9$, calculations performed using the PASS 2021 software determined that the minimum sample size required for each group was 38 cases. Accounting for a 20% attrition rate, at least 48 study subjects needed to be included in each group. Consequently, a total of 50 volunteers were ultimately enrolled in this study.

Instruments

Hand washing and sanitizing products: (1) Antibacterial hand sanitizer: RETOUCH hand sanitizer is a water-based hand hygiene product containing 0.20% ± 0.02% trichlorohydroxydiphenyl ether as the main active ingredient. The batch number is 230703. (2) Rinse-free hand disinfectant gel: the brand of RETOUCH uses chlorhexidine gluconate and ethanol as the main effective components, with chlorhexidine gluconate content of 1.0% ± 0.1%, and the ethanol content is 60.00% ± 6.00%, which conforms to GB/T27951-2021[10]. The batch number is 230903.

Hand-drying products: (1) Clean paper towels: The brand of Mind Act Upon Mind, a product of Fujian Hengan Group Co, Ltd, which meets the national standard of GB/T 24455-2022 Toilet paper.[11] The batch number is CS005. (2) Sterile cloth towels: Produced by the Disinfection Supply Center, these towels adhere to the stringent sterilization efficacy standards as outlined in the Hygienic Standard for Hospital Disinfection. The batch number is 3275271. (3) Sterile paper towels: The paper towels of the Mind Act Upon Mind brand (batch number: CS005) were sent to the disinfection and supply center for disinfection and sterilization. The disinfection process must comply with the Hygienic Standards for Hospital Disinfection.[12]

Detection tools: (1) Sterile cotton swab: Produced by Henan Yadu Industrial Co, Ltd. The batch number is 2308IC9947. (2) Disposable culture medium: Produced by Jiangsu Kangjian Medical Products Co, Ltd and sterile by ethylene oxide. The implementation standard was Q/321284CBB09. (3) Cryogenic incubator: Manufacturer is Thermo Fisher Scientific and product serial number is J3XT250C014. (4) About 2-mL sterile saline. (5) Alcohol lamp.

Research procedure

Before the trial commenced, all volunteers received training and qualification from the research team following the “Specification of hand hygiene for healthcare workers” (WS/T313-2019).[1] They were trained in surgical hand antisepsis and successfully passed the examination. Before testing 3 different hand-drying products, a brand-new antibacterial hand sanitizer and a rinse-free hand disinfectant gel were opened. The subjects washed their hands in strict accordance with the surgical hand antisepsis protocol.[1] The process was supervised by a designated individual, and the hand washing duration was controlled to be between 3 and 5 minutes.

Specimens were gathered from hand-drying products, tissue device boxes, jars of sterile towels, hand sanitizers, rinse-free surgical hand sanitizing gels, and sterile cotton swabs. Sampling took place at the point of opening (0 hours) and at intervals of 2, 4, 6, and 24 hours thereafter, leading to a total of 5 collections. After washing and drying their hands, volunteers immediately performed hand bacterial sampling. An appropriate amount of rinse-free hand sanitizer was applied to both hands, forearms, and upper arms and rubbed carefully until the sanitizer dried. Hand bacterial sampling was then conducted again. During the sampling process, the samplers adhered to the Hospital Sanitization Hygiene Standards and employed the smear culture method. They utilized sterile cotton swabs soaked in sterile saline to thoroughly smear the surfaces of the fingers on both hands of the study subjects, from the base to the tip of each finger, performing this procedure twice. The area covered on both hands was approximately

60 cm². Subsequently, place the cotton swab into a test tube containing 2 mL of sterile saline solution. Next, use an alcohol lamp to sterilize the portion of the cotton swab that has come into contact with the individual conducting the test. After that, seal the test tube with a cap that has also been sterilized by burning it with an alcohol lamp. Label the samples sequentially, ensuring that all sample numbers are assigned by a single individual. The remaining personnel should remain unaware of the significance of the numbers.

After the samples were thoroughly shaken in the sampling tubes, 2 mL of each sample was inoculated onto the surface of ordinary agar plates. The samples were evenly spread using sterile cotton swabs and then incubated in a constant temperature chamber at 36 °C ± 1 °C for 48 hours to count the number of colonies and to detect the presence or absence of pathogenic bacteria. This step was performed by the microbiology laboratory personnel, who were not involved in the study design or sample collection. Additionally, the microbiology personnel were blinded to the sample grouping and source of the samples.

Outcomes

Primary outcomes: (1) The total number of bacterial colonies (CFU/cm²) on hands after hand drying and hand disinfection is calculated using the formula: average dilution factor per dish × colonies/sampling area (cm²). (2) The pass rate for the total number of bacterial colonies on the hands of medical volunteers after surgical hand antisepsis is determined by the qualification standard outlined in the "Specification of hand hygiene for healthcare workers" (WS/T313-2019)[1]. According to this standard, the total number of bacterial colonies on the hands of medical staff after surgical hand antisepsis must be ≤5 CFU/cm² to be considered qualified.

Secondary outcomes: (1) Results of bacterial culture identification following hand drying and hand sanitization. (2) The cost of hand-drying products used in each operation.

Statistical analysis

All data were recorded in the 2016 version of Microsoft Excel, and statistical analyses were conducted using SPSS version 27.0. Measurement data that did not conform to a normal distribution were expressed as quartiles, while those that did conform were presented as mean ± standard deviation ($\bar{x} \pm s$). Comparisons between groups were performed using the nonparametric test for correlated samples, and comparisons among multiple paired samples were conducted using Friedman's test. For paired samples, Wilcoxon's signed-rank test was employed. Categorical data were expressed as percentages (%), with comparisons between groups made using Cochran's Q test for multiple groups and the McNemar test for paired samples. The significance level was set at $\alpha = 0.05$, indicating that a P value less than .05 was considered statistically significant.

RESULTS

General information

A total of 50 medical volunteers were included in the study, with the age of (26.28 ± 4.50) years, working experience of (3.94 ± 4.27) years, 44 females and 6 males, and hand washing time of (3.91 ± 0.61) minutes. The bacterial culture results for all substances tested in the 3 hand-drying products were 0 CFU/cm².

Total number of colonies and qualified rate of bacterial culture on hand surface after hand drying

The total number of bacterial colonies cultured on the hand surface after hand washing and drying with 3 different hand-drying products was less than 5 CFU/cm². The qualified rate was 100%. After conducting the Shapiro-Wilk test for normality on small samples, the total number of colonies from hand surface bacterial cultures following hand drying in all 3 groups did not conform to a normal distribution ($P < .05$). Therefore, the Friedman M test was used to compare the differences in colony counts among the 3 groups, and the results showed that there were significant differences in colony counts among the 3 groups ($P < .05$) (Table 1). The Wilcoxon test was employed to compare the differences between the 2 groups. The results indicated that the differences between group A and group B, as well as between group B and group C, were statistically significant ($P < .05$) (Table 2). The number of positive ranks of B-A was more than the number of negative ranks and bound values, that is, the total number of bacterial colonies in group B was more than that in group A. The number of negative ranks of C-B was more than the number of positive ranks and bound values, that is, the total number of bacterial colonies in group B was more than that in group C. The difference in bacterial colony counts between hand drying with clean paper towels and sterile cloth towels was not significant. However, the bacterial colony counts on the surface of the hands after using both hand-drying products were lower than those observed after hand drying with sterile cloth towels.

Table 1
Comparison of the total number of colonies cultured on the surface of the hands after hand drying

Group	N	M (P_{25}, P_{75})	Rank average	χ^2	P
A	50	0.01 (0.00, 0.18)	1.81	23.602	< .001
B	50	0.30 (0.05, 0.77)	2.52		
C	50	0.01 (0.00, 0.08)	1.67		

Bacterial colony counts and qualified rates of hand surface bacterial cultures following rinse-free hand disinfectant

The total colony counts of bacteria on hand surfaces cultured after rinse-free hand disinfectant using 3 different hand-drying products, were all less than 5 CFU/cm². The qualified rate was 100%. Following the Shapiro-Wilk test for normality, the total number of bacterial colonies on the surface of hands after rinse-free hand disinfectant in all 3 groups did not conform to a normal distribution ($P < .05$). A comparison of the differences in colony counts among the 3 groups, conducted using the Friedman M test, revealed that the differences were not statistically significant ($\chi^2 = 2.567$, $P = .277$).

Identification of strains of bacterial cultures on the hand surface

The strains of bacteria cultured in each group were classified into 4 main categories: 65 cases of *Staphylococcus warneri*, 88 cases of *Staphylococcus epidermidis*, 4 cases of *Staphylococcus haemolyticus*, and 1 case of *Staphylococcus hominis*. Cochran's Q test revealed a significant difference in the bacterial strains cultured from the hand surfaces sampled after hand drying in groups A, B, and C ($P = .048$) (Table 3). Further comparisons using McNemar's test indicated that

Table 2
Pairwise comparison of the total number of colonies cultured on the surface of the hand after hand drying

	N			Z	P
	Negative rank	Positive rank	Binding value		
B-A	11	34	5	−3.93*	< .001
C-A	21	17	12	−1.23†	.220
C-B	37	8	5	−4.19†	< .001

*Based on negative rank.
†Based on positive rank.

Table 3
Comparison of bacterial cultures on the surface of the hands after hand washing and rinse-free hand disinfectant

Group	N	Non-Sterile (n, %)	Sterile (n, %)	Cochran's Q Test	*P*
A*	50	28 (56)	22 (44)	6.059	.048
B*	50	39 (78)	11 (22)		
C*	50	30 (60)	20 (40)		
A†	50	28 (56)	22 (44)	4.188	.123
B†	50	26 (52)	24 (48)		
C†	50	35 (70)	15 (30)		

*Sample after hand drying; sample after hand sanitization without rinsing.
†Sample after rinse-free hand disinfectant.

Table 4
Pairwise comparison of bacterial cultures on the surface of the hands after hand drying

	A-B	A-C	B-C
N	50	50	50
P	.043	.832	.078

the differences between groups A and C, as well as B and C, were not statistically significant ($P > .05$), while the difference between groups A and B was statistically significant ($P = .043$) (Table 4). Additionally, the difference in bacterial cultures from the hand surfaces sampled after rinse-free hand disinfectant was not statistically significant among the 3 groups ($P = .123$) (Table 3).

Economic cost

Taking the operating room where this study was conducted as a reference, with an average of 5 individuals (1 instrumentation nurse and 4 surgeons) requiring surgical hand disinfection per surgery, the cost of hand drying for surgical hand disinfection per surgery is presented in Table 5. Sterile cloth towels can be reused after washing, disinfecting, and sterilizing. Therefore, the purchase cost was calculated based on the assumption that each towel could be used up to 20 times.

DISCUSSION

Clean paper towels are effective as hand-drying products in surgical hand antisepsis. Specification of hand hygiene for health care workers was issued in 2009.[5] It explicitly mandates the use of towels for hand drying after hand washing during surgical hand antisepsis. Consequently, the hand-drying products utilized in surgical hand antisepsis across various health care institutions over the past decade are required to undergo sterilization processes. In the updated 2019 hand hygiene code for medical personnel,[1] the method of surgical hand antisepsis has been refined. However, there is no requirement for the separate disinfection or sterilization of hand-drying products. High-quality research in the area of selection of hand-drying products for surgical hand antisepsis is still scarce. The experimental results of this study showed that the bacterial colony counts on the hands of 3 different hand-drying products after surgical hand disinfection met the monitoring standards for effectiveness (total colony counts of bacterial cultures on hands ≤ 5 CFU/cm^2). But the sampling results after the use of the 3 hand-drying products showed a statistically significant difference in the results of the hand bacterial culture, which was mainly reflected in the sterile cloth towel. Although the test results following hand drying with sterile cloth towels met the national standards for surgical hand antisepsis effectiveness, the number of bacterial colonies on the hands remained higher than that observed with clean and sterile paper towels. This conclusion is further supported by findings from another study.[13] The reason for this may be that hand towels are mainly made of cotton, which is a very different material from disposable products. The characteristics of cotton are more conducive to the survival and spread of pathogens.[14] Due to repeated cleaning, use, and disinfection, the fiber structure of hand towels is deformed, which affects their interaction with water molecules and friction properties and reduces their water absorption.[15] At the same time, the porous surface of the towel increases in size, providing more space and shelter for bacterial growth. This facilitates the attachment and multiplication of pathogens on the surface, significantly elevating the risk of infection.[16] In this study, after the volunteers applied the rinse-free hand sanitizer, the hand bacteria were retested. The culture results of the sampled bacteria met hygienic standards, and the differences among the 3 groups were not statistically significant. This further confirms that a clean paper towel can serve as an effective surgical hand antisepsis and drying product, potentially replacing traditional sterile hand-drying products.

Clean paper towels are feasible as hand-drying products for surgical hand antisepsis. Studies have demonstrated that surgical hands are the primary means of bacterial transmission during surgical procedures and that pathogenic bacteria carried by health care workers are significant risk factors for surgical site infections.[17,18] In this study, we identified the major species of bacteria present on hands after washing, drying, and applying rinse-free hand sanitizers. Notably, common causative organisms associated with surgical site infections, such as *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Streptococcus hemolyticus*, were not detected.[19] The predominant bacteria identified were *Staphylococcus epidermidis* and *Staphylococcus warneri*, which together accounted for 96.8% of the strains identified. Both species are part of the normal skin flora and are typically nonpathogenic under normal circumstances. The bacterial species testing revealed that the detection rate of bacteria on hands dried with sterile cloth towels was higher than that on clean paper towels and sterile paper towels, which also indicated that the number of bacteria remaining on the hands after drying with sterile cloth towels was greater. In addition, the method of hand drying significantly influences the effectiveness of rinse-free sanitizers.[20] Appropriate hand-drying products can prevent secondary contamination after hand washing; they should be unbreakable, made of fibers that do not easily adhere to the skin, and should be soft, comfortable, and highly absorbent. Research has demonstrated that paper towels are the most effective means of quickly drying hands by absorbing moisture, making them the preferred hand-drying option in the health care industry.[21] Studies indicate that drying

Table 5
Cost comparison of 3 types of hand-drying products

Products	Procurement cost (CNY/sheet)	Cleaning cost (CNY/sheet)	Sterilization cost (CNY/sheet)	Dosage per surgery (sheet)	Hand-drying cost per surgery* (CNY)
Clean paper towel	0.02	0.00	0.00	10.00	0.20
Sterile cloth towel	0.14	0.20	0.80	5.00	5.70
Sterile paper towel	0.02	0.00	0.80	10.00	8.20

*Hand-drying cost per surgery = (procurement cost + cleaning cost + sterilization cost) × the amount of each surgery.

hands with paper towels after washing results in lower microbial deposition, which substantially reduces the spread of microorganisms.[22,23] This study further examined the effects of hand-drying products made from paper materials in both sterile and clean conditions. Unfortunately, this study did not conduct quantitative tests on the physical properties of the paper towels following sterilization. However, previous research has demonstrated that the methods of disinfection and sterilization, as well as the material composition and structure of the paper itself, can significantly influence the strength, absorbency, and fiber structure of the paper after disinfection. Nevertheless, employing appropriate disinfection methods and dosages does not adversely affect the physical characteristics of the paper. Consequently, disposable paper towels exhibit good stability in their physical properties, and whether in a clean or sterile state, they possess the excellent qualities required for effective hand-drying products. In the operating room, cleaning disposable hand towels are managed as clean items and are stored in tissue device boxes, which have a very low risk of contamination during use. In this study, no bacterial growth was observed within 24 hours after the paper towel device box was opened and utilized. The data analysis results indicate that the clean paper towel possesses the necessary characteristics for hand drying in surgical hand antisepsis. Furthermore, it effectively reduces the number of bacteria on hands and enhances the quality of surgical hand antisepsis, demonstrating good clinical applicability and safety. Therefore, it can be concluded that when clean paper towels are used for hand drying, their disinfection efficacy meets hygienic standards and can more effectively prevent surgical site infections.

Clean paper towels are generalizable as hand-drying products in surgical hand antisepsis. Sterile cloth towels, traditionally employed in surgical hand antisepsis and drying, must be strictly sterile and stored by regulations. Improper use of these towels poses a significant risk of secondary contamination, which complicates the storage and management of sterile items. Additionally, the cleaning, sterilization, storage, and transportation of these items require designated personnel, thereby consuming more human resources. In contrast, clean hand towels do not necessitate special sterilization procedures, storage, or transportation. Clean paper towels do not necessitate special sterilization procedures and are easier to store and manage. This not only reduces the risk of contamination of supplies but also enhances the optimization of human resource allocation in the operating room, thereby improving overall operational efficiency.[24] In addition, health care costs have consistently been a significant concern for the entire health care system and organizations at all levels. Hand-drying products, as part of the hygiene consumables used in the operating room, are directly linked to the operating room costs, while the increase in the operating room consumables costs will be directly related to the hospital's costs.[25] Therefore, the selection of hand-drying products for surgical hand antisepsis must also consider economic costs.[18] This study conducted an economic evaluation of 3 different types of hand-drying products. The cost of using sterile cloth towels or sterile paper towels for each operation is significantly higher than that of clean paper towels. Additionally, the use of sterile cloth towels and sterile paper towels incurs expenses related to detergent, water, and energy, as well as the operation of sterilization and drying equipment during the sterilization and disinfection processes. Consequently, the actual clinical cost difference between clean paper towels and sterile options is likely greater than estimated in this study. A comprehensive analysis indicates that promoting the use of clean paper towels as drying products in surgical hand antisepsis can substantially reduce operating room costs and enhance the economic benefits for hospitals. It is important to note that, while the results of this study suggest that cleaning paper towels are safe and effective when used correctly, there is often a risk of contamination in clinical settings due to improper paper extraction practices. Therefore, operating room managers should carefully select the location and design of paper towel dispensers, provide training on proper paper extraction techniques, opt for enclosed, touch-free paper towel dispensers, and regularly clean and disinfect the dispenser outlets.[26,27] These measures will help further reduce the potential for contamination and ensure the applicability of the study's conclusions in real clinical scenarios.

CONCLUSIONS

This study demonstrates that clean paper towels used for surgical hand antisepsis not only meet hygienic standards but also reduce hand bacteria more effectively than sterile cloth towels. They are user-friendly and dry hands quickly. Additionally, they are cost-effective, which reduces operating room expenses while ensuring effective disinfection. This approach improves surgical quality and provides social and economic advantages to hospitals, thus endorsing clean paper towels as a recommended practice.

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