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Progress in the application and management of medical cleaning brushes for lumen instruments

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ABSTRACT: Objective To systematically review the current practices regarding the use and management of medical cleaning brushes for lumen instrument reprocessing in the Central Sterile Supply Department (CSSD), identify how brush-associated deficiencies contribute to instrument cleaning failure, and generate evidence to improve lumen instrument cleaning efficacy and ensure reprocessing safety. **Methods** Domestic and international literature was retrieved and synthesized. Operational practices, brushing protocols, and reprocessing workflows for reusable cleaning brushes were analyzed. **Results** Operators generally underestimate the importance of cleaning brushes and perform brushing in a non-standardized manner. No consensus exists regarding brushing strokes, angles, or combined operational sequences. Reprocessing protocols for reusable brushes are largely lacking, creating an occult reservoir for cross-infection. These interconnected, reciprocal issues hinder sustained improvement in lumen instrument cleaning efficacy. **Conclusion** Future efforts should establish evidence-based criteria for one-to-one matching between brush types and lumen instruments, develop standardized full-workflow operating protocols, and integrate the cleanliness of cleaning brushes into routine quality control surveillance. Concurrent advances in automated brushing systems should be pursued to strengthen the safety of instrument reprocessing and safeguard patient well-being.

KEY WORDS: medical cleaning brushes; Central Sterile Supply Department; lumen instruments; cleaning quality; management factors

Medical cleaning brushes (hereinafter referred to as "cleaning brushes") are fundamental specialized tools used in central sterile supply departments for manual cleaning of lumen instruments. At present, most lumen instruments still require manual cleaning[1], and the selection and suitability of cleaning brushes are among the key factors affecting cleaning efficacy[2]. Chen et al.[3] conducted a survey using a convenience sampling method on the occurrence of adverse events in a tertiary hospital, reporting a total of 101 adverse events, among which those caused by substandard cleaning quality accounted for as high as 33.66%. Garcia et al[4] conducted a survey from July 2021 to January 2022 across 34 endoscopy centers in 12 Brazilian cities and found that cleaning brushes were commonly reused in violation of regulations, continued to be used despite aging and damage, and lacked standardized disposal and maintenance protocols; not a single institution had established a cleaning and disinfection procedure for brushes between uses. Consequently, a brush that had just cleaned a heavily contaminated gastroscope could, without any processing, be used to clean the next colonoscope, making the risk of cross-contamination clearly evident. This finding directly demonstrates that the very tool in our hands that is supposed to remove contamination is itself a source of contamination. Given the importance of cleaning brushes, this article reviews the literature, analyzes and summarizes the current research status domestically and internationally, and examines the types of cleaning brushes, operational behaviors in their use and management, brushing protocols, and reprocessing procedures for reusable brushes.

1 Specifications, Types, and Selection of Cleaning Brushes

1.1 Specifications and Types

According to the literature, cleaning brushes mainly comprise two major categories: general lumen instrument cleaning brushes and specialized cleaning brushes for flexible endoscopes. The total length of reusable cleaning brushes for general surgical lumen instruments is mostly 30~60 cm. The working channels of flexible endoscopes are narrow and elongated, and the total length of specialized endoscope cleaning brushes can reach 120~240 cm, with a flexible and bendable brush body to adapt to the long, narrow working channels of endoscopes. The brush shaft is mostly made of stainless-steel wire or polypropylene plastic, which can withstand cleaning and thermal disinfection. The bristles are composed of nylon monofilament threads (bristle filaments), which have stable physicochemical properties and high-temperature resistance[5]. At present, domestic CSSD industry standards have not yet established unified grading specifications for the bristle hardness of cleaning brushes. Based on the brush parameters provided by manufacturers and with reference to the classification standards for oral cleaning toothbrushes[6], cleaning brushes are classified according to bristle filament diameter into soft brushes (0.08 mm), medium brushes (0.12 mm), and hard brushes (0.18 mm). This hardness grading is only for reference, and there is currently no official grading standard specifically for cleaning brushes.

1.2 Selection Principles

The correct selection of model and specifications is premised on ensuring cleaning efficacy and protecting instruments. The core principle is to select a brush with an appropriate diameter to scrub the inner wall of the lumen[7], ensuring that the brush head can pass smoothly through the lumen while enabling the bristles to generate effective friction against the lumen wall. If the brush is too thick, the brush head may become stuck or even damage the inner wall of the lumen; if it is too thin, effective friction cannot be generated, resulting in incomplete cleaning. For instruments with valves or joints, attention should also be paid to whether the brush head can pass through the valve openings and joint gaps.

2 Current Status of Cleaning Brush Use

2.1 Inappropriate Selection of Cleaning Brushes

Both nurses and technical workers in CSSDs lack sufficient familiarity with the specifications and models of cleaning brushes, leading to inappropriate selection. When cleaning lumen instruments, staff mostly rely on experience for selection, and brush diameter selection is based solely on visual observation, lacking objective references.

2.2 Non-standard Operational Practices

Huang et al.[8] found in interviews that CSSD staff were relatively arbitrary in brushing methods and brushing frequency, resulting in unqualified cleaning or instrument damage. Cleaning brushes are important tools for manual cleaning of lumen instruments. Correct use of medical cleaning brushes can effectively clean hard-to-reach areas of lumen instruments, thoroughly remove contaminants, ensure the cleaning quality of instruments, reduce the breeding and transmission of microorganisms, and lower the risk of hospital-acquired infections[9-10].

2.3 Quality Issues of Cleaning Brushes

In a study by Ofstead et al.[11], trained personnel inspected endoscopes by inserting clean lumen instruments and performing visual inspections from the distal end to the proximal end. The results showed that residual matter of varying degrees was found inside the lumens of all examined instruments, among which fibrous lint that was completely invisible to the naked eye and bristle fragments shed from cleaning brushes were the most common. There are certain differences in the quality of cleaning brush products on the market. During the brushing process, bristles may shed, and the brush shaft is prone to bending and deformation; with repeated use, bristles become flattened. These issues pose potential risks to the cleaning quality of lumen instruments and instrument safety.

2.4 Disposal and Discard Management of Cleaning Brushes

In terms of cleaning brush disposal manage-

ment, in actual practice, there exist situations such as failure to dispose of brushes promptly after brushing, incomplete cleaning and disinfection, and storage without adequate drying. Meanwhile, there is a lack of unified criteria for judging the wear status of cleaning brushes, and replacement mostly relies on the subjective experience of staff. A literature search of foreign guidelines and studies shows that for cleaning brushes reused daily, thorough cleaning and disinfection should be performed according to the instructions for use[12-13]. Currently, in China, there are no unified standards, guidelines, or expert consensus regarding the use of cleaning brushes in lumen instruments and their post-use disposal.

3 Factors Influencing the Effectiveness of Cleaning Brush Use

3.1 Material Factors: Material and Structural Design of Cleaning Brushes

The material and structure of the brush itself determine its cleaning capacity and brushing effectiveness. The hardness trend of bristle materials is as follows: microfiber < polyolefin < nylon fiber < DuPont fiber. Compared with other materials, DuPont fiber bristles exhibit higher hardness, resulting in greater friction against the inner wall of the lumen channel during use of DuPont fiber brushes, while causing less damage to instruments. Therefore, the cleaning effectiveness of this type of brush is the highest among the four types[14]. Regarding innovative designs, Shen et al. experimentally confirmed that a double-headed disposable brush can multiply the contact area with instruments and significantly improve cleaning efficiency[15]. Sun Zhihui et al. [16] improved a novel lumen instrument cleaning brush by replacing traditional bristles with nanosponges that have strong decontamination ability; the brush shaft has an adjustable diameter, and the nanosponge is detachable from the brush shaft, allowing the brush shaft to be reused and saving costs. Nanosponges are easily damaged but inexpensive. To avoid secondary contamination and residual debris, they should be cleaned promptly after use and replaced promptly once damaged.

3.2 Method Factors: Incorrect Operational Methods

Even with a good brush, if the operational method is incorrect, the cleaning effectiveness fluctuates markedly. After four brushing cycles, the contaminant removal efficiency reaches a plateau; further increasing the brushing frequency shows no statistically significant difference in cleaning effectiveness, but instead increases the risk of bristle shedding and lumen wall scratching[14]. The standard brushing method involves inserting the brush head from one end of the lumen and allowing it to emerge from the other end, ensuring that the entire inner wall of the lumen is subjected to the mechanical friction of the bristles, followed by rinsing with a pressurized water gun to thoroughly flush away loosened and detached contaminants. According to standard requirements, manual cleaning of lumen instruments should adopt a through-and-through brushing method, with no fewer than 3 brushing cycles. This method has been widely accepted as the standard operation for manual cleaning of lumen instruments.

3.3 Human Factors: Lack of Awareness and Operational Inertia

Failure to meet instrument cleaning quality standards cannot be attributed solely to the cleaning brush itself; the operational behavior of users is often the key variable. A study by Huang et al.[8] showed that only 8.33% of staff consistently used one specification of cleaning brush, while 56.67% frequently switched among three different specifications within the same shift, with the reason being “whatever is at hand is what I use.” An additional 41.67% of staff had insufficient awareness of the importance of rational cleaning brush selection, subjectively considering it unimportant. This directly led to arbitrary operations and non-standard disposal behaviors. Insufficient personnel training is an important influencing factor in cleaning quality, and staff should receive systematic training in both theory and practice. After incorporating cleaning brush use knowledge into pre-job training and annual assessments, the compliance rate of surgical instrument cleaning significantly improved[17-21]. Standard Operating Procedures (SOP) cleaning methods can significantly im-

prove cleaning quality, with remarkable instrument cleaning outcomes[22]. This indicates that optimizing and constructing institutional systems is an effective approach to addressing personnel shortcomings.

The implementation of cleaning and processing of cleaning brushes should also not be overlooked. Reusable medical instruments are often contaminated during use by patients' blood, body fluids, secretions, and excretions, which may carry large numbers of pathogenic microorganisms. During the repeated brushing of instruments with cleaning brushes, microorganisms can easily remain in the brushes. If cleaning and disinfection are not strictly performed, the brushes are highly likely to become vehicles for disease transmission[23]. In 2016, the National Health and Family Planning Commission of China issued the "Regulation for Cleaning and Disinfection Management of Environmental Surface in Healthcare" WS/T 512—2016, which states that reusable cleaning tools that have been used or contaminated should promptly undergo cleaning, thermal disinfection, and mechanical drying procedures[24]. Using fully automatic washer-disinfectors for the reprocessing of cleaning brushes can effectively ensure the cleaning quality, disinfection, and drying effectiveness of cleaning brushes, thereby ensuring medical quality and safety[25].

3.4 Compatibility Factors Between Cleaning Brushes and Instruments: Specialized Selection

The degree of specialization of cleaning brushes and their compatibility with instruments cannot be ignored. Fine lumen instruments have special structures, with narrow and elongated lumens and numerous grooves, making cleaning relatively difficult[26]. The practice of using a single universal brush for all applications should be abandoned. A study by Jiang et al.[27] showed that using specialized cleaning brushes for cleaning fine lumen instruments can reduce the occurrence of infections after the use of lumen instruments and avoid nosocomial cross-infection. As the most commonly used power tools in surgery, shaver power tools have a unique negative-pressure suction system that can rapidly suction away excised tissue. A domestically developed hydrodynamic cleaning brush has solved the cleaning challenge of the spiral grooves of shaver handles[28]. Specialized cleaning brushes maintain the patency of fine lumen instruments through through-and-through cleaning, greatly reducing the risk of obstruction during use, thereby improving clinical satisfaction.

3.5 Management and Supervision Factors: Incomplete Quality Control Mechanisms

At present, the supervision mechanism covering the entire process of medical cleaning brush use remains incomplete. A survey showed that only 25% of CSSD departments had infection control departments, nursing departments, or their own departments conduct relevant supervision, and the supervision content was limited to checking the degree of bristle damage, without standardized supervision of operational procedures and disposal methods[8]. The actual application of cleaning brushes in lumen instrument cleaning varies considerably, and standards need to be developed as soon as possible to improve the cleaning qualification rate.

4 Future Prospects

4.1 Establishing a Standardized Matching System Between Cleaning Brushes and Lumen Instruments

Currently, clinical selection of cleaning brushes mostly relies on experience and lacks unified standards. In the future, based on parameters such as lumen diameter, length, curvature angle, inner wall material, and typical contaminant types, a "one category, one brush" matching database should be established, so that each category of lumen instrument corresponds to a clinically validated optimal cleaning brush, thereby ensuring cleaning efficacy from the source and reducing the risk of instrument damage.

4.2 Promoting Informatization and Intelligent Management of Cleaning Brushes

With the help of the Internet of Things (IoT) and sensing technology, a unique digital identity can be assigned to each reusable cleaning brush to achieve the following functions: real-time monitoring of use frequency and wear degree, recording parameters such as brushing cycles and bristle deformation through sensors; lifespan warning and automatic re-

minders, whereby the system automatically issues warnings and prompts for replacement when a brush approaches its preset lifespan limit, technically preventing extended service beyond the designated period; and binding with instrument information, whereby cleaning data are synchronously uploaded to a quality management platform to form a traceable system of "one category, one brush, one record."

4.3 Improving Standardized Disposal Specifications for Reusable Cleaning Brushes

On the basis of the existing WS 310.2—2016, the entire process standards for the collection, cleaning, disinfection, drying, storage, and discard of reusable cleaning brushes should be further refined, clarifying operational requirements and quality control indicators for each step to reduce the risk of secondary contamination caused by improper storage.

4.4 Strengthening Personnel Training and Supervision Mechanisms

Standardized use of cleaning brushes should be incorporated into the routine training and assessment system for CSSD personnel. Meanwhile, a three-level supervision mechanism involving the infection control department, nursing department, and clinical departments should be established, with supervision content expanded from "checking the degree of bristle damage" to full-process monitoring and management, including correct selection, standardized operational procedures and disposal methods, and frequency and duration of use.

5 Conclusion

Taken together, the difficulties associated with cleaning brushes in CSSD are the result of the interlocking of four factors: staff underestimation, inappropriate selection of specifications and models, arbitrary disposal methods, and absent management. Although it is a small tool, its management involves multiple links, including selection, operation, disposal, training, and supervision, and the absence of any one link may lead to cleaning failure. The cleanliness of the cleaning brush itself should be incorporated into routine quality control, use records and mandatory discard standards should be established, and standardized disposal methods such as processing with fully automatic washer-disinfectors should be promoted. Research and development of novel cleaning brush devices should be encouraged to ensure the reprocessing quality of lumen instruments.

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