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# Analysis of Factors Influencing the Cleaning Quality of Reusable Instruments in the Central Sterile Supply Department

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**Abstract:** Cleaning is the first and most critical step in the reprocessing of medical devices. Its quality directly determines the effectiveness of subsequent disinfection and sterilization, thereby affecting patient safety and the level of hospital infection prevention and control. As the core department responsible for ensuring the supply of sterile items in hospitals, the Central Sterile Supply Department (CSSD) plays a decisive role in the cleaning quality of reusable instruments. This paper systematically reviews relevant studies and practice guidelines published between 2020 and 2025, both domestically and internationally. Based on the six-dimensional "Man–Machine–Material–Method–Environment–Measurement" (6M) model, it provides an in-depth analysis of the key factors influencing the cleaning quality of reusable instruments in CSSD. The findings indicate that insufficient professional competence of personnel, improper equipment maintenance, non-standard selection and use of detergents, lack of standardized operating procedures, complex instrument structures, and imperfect quality management systems are the main causes of cleaning failure. Accordingly, this paper proposes the establishment of an integrated quality control system based on the "Man–Machine–Material–Method–Environment–Measurement" framework, emphasizing the importance of multidisciplinary collaboration, information technology empowerment, and continuous quality improvement. The aim is to provide theoretical references and practical pathways for improving the cleaning quality of CSSD in medical institutions in China.

**Keywords:** Central Sterile Supply Department (CSSD); reusable instruments; cleaning quality; influencing factors; continuous quality improvement; multidisciplinary collaboration

## Introduction

With the development of modern medical technology, reusable medical instruments are widely used in clinical diagnosis and treatment. After use, instruments are often contaminated with organic matter. Inadequate cleaning may lead to the formation of biofilms, which hinder effective disinfection and sterilization, becoming an

important source of hospital-acquired infections. The World Health Organization (WHO) and infection control guidelines from various countries emphasize that cleaning is the most fundamental and critical step in the reprocessing of medical devices. If cleaning is insufficient, instruments may still pose potential risks to patients even after sterilization. The Central Sterile Supply Department (CSSD) is responsible for the cleaning, disinfection, and sterilization of reusable instruments throughout the hospital, and the quality of its work is directly related to medical safety. However, in actual practice, the cleaning process in CSSD is often affected by multiple factors, resulting in unstable cleaning quality and frequent non-conformance events. Systematically identifying and analyzing the key factors influencing the cleaning quality of instruments in CSSD is of great significance for establishing a robust cleaning quality assurance system and reducing the risk of hospital-acquired infections[1]. Based on a comprehensive review of literature, industry standards, and clinical experience from 2020 to 2025, this paper analyzes multidimensional influencing factors and proposes optimization strategies, aiming to provide references for enhancing the professional level and infection control capacity of CSSD.

## 1. Key Factors Influencing the Cleaning Quality of Reusable Instruments in CSSD

### 1.1 Personnel Factors

(1) Insufficient professional knowledge and skills training:

Some CSSD staff lack an in-depth understanding of the cleaning principles for instruments made of different materials and with varying structures, the characteristics of contaminants, and the mechanisms of action of detergents. This knowledge gap may lead to deviations during pretreatment, classification, loading, and parameter setting. For example, failure to perform timely point-of-use pretreatment allows contaminants to dry and adhere firmly, significantly increasing cleaning difficulty[2]. In addition, unfamiliarity with the reprocessing procedures for special instruments—such as precision devices and powered instruments—results in a higher rate of operational errors.

(2) Poor compliance with operating procedures:

Even when standard operating procedures (SOPs) are in place, some staff may simplify steps due to heavy workloads, time pressure, or habitual practices. Such behaviors include shortening cleaning time, reducing the frequency of manual brushing, or preparing detergents at improper concentrations, all of which directly compromise cleaning effectiveness.

(3) Occupational burnout and lack of responsibility:

The CSSD working environment is relatively enclosed, with high labor intensity and repetitive tasks, which may contribute to occupational burnout among staff. This condition can negatively affect concentration and meticulousness at work, leading to perfunctory performance in critical steps such as visual inspection, thereby increasing the risk of inadequate cleaning.

### 1.2 Equipment and Facility Factors

(1) Improper selection and configuration of cleaning equipment:

Cleaning devices may not be appropriately matched to the types, quantities, and complexity of hospital instruments. For example, the absence of ultrasonic cleaners or spray washer-disinfectors suitable for lumened instruments, or insufficient spray arm pressure and water coverage in fully automated washer-disinfectors (WDs), can make it difficult to effectively clean instruments with complex lumens and structures.

(2) Inadequate equipment maintenance:

Cleaning equipment, especially WDs, requires regular physical monitoring (e.g., temperature, cycle time, pressure), chemical monitoring (e.g., cleaning efficacy tests), and preventive maintenance. Issues such as clogged filters, impaired spray arm rotation, insufficient pump pressure, or excessive water conductivity, if not detected and addressed promptly, can directly lead to cleaning failures.

(3) Water quality issues:

The hardness, conductivity, and microbial content of cleaning water are critical. High water hardness can form scale on instrument surfaces, reducing detergent activity and causing corrosion; excessive chlorine levels accelerate rusting. CSSD must be equipped with qualified water treatment systems and perform routine water quality monitoring.

### 1.3 Consumable Factors

(1) Inappropriate selection of detergents:

Detergents must be chosen based on the type of contaminants (e.g., blood, fat, starch) and instrument materials (e.g., stainless steel, aluminum, plastic).

Using a generic detergent may fail to effectively break down specific contaminants, resulting in incomplete cleaning.

(2) Improper use of detergents:

Errors in concentration (too high wastes resources and may damage instruments; too low is ineffective), inappropriate water temperature (e.g., multi-enzyme detergents usually require 30–45 °C), and insufficient soaking time can all reduce cleaning efficacy.

(3) Substandard consumables:

Procurement of low-quality or counterfeit detergents, which may contain insufficient active ingredients or harmful impurities, not only compromises cleaning results but may also damage instruments and pose health risks to personnel.

**1.4 Process and Method Factors**

(1) Disconnect between collection and pretreatment:

Clinical departments may fail to perform immediate point-of-use rinsing after instrument use, causing contaminants to dry and harden. By the time instruments reach CSSD, thorough cleaning becomes difficult. The lack of effective communication and collaboration mechanisms between CSSD and clinical departments prevents timely feedback and process optimization.

(2) Unscientific classification and loading:

Improper placement of instruments—such as mixing different types, stacking, leaving lumens closed, or not using dedicated cleaning racks—obstructs water flow and detergent contact, creating cleaning "dead zones."

(3) Unreasonable cleaning program parameters:

For different types of instrument sets, appropriate cleaning programs (e.g., cycle time, detergent dosing) may not be selected or validated. Newly introduced instruments may lack timely cleaning compatibility verification, potentially causing cleaning failure or instrument damage.

(4) Incomplete drying:

If instruments are not fully dried after cleaning, residual moisture can dilute lubricants and become a breeding ground for microorganisms during subsequent packaging and sterilization. It also increases the risk of instrument corrosion.

**1.5 Instrument-Specific Factors**

(1) Structural complexity:

Instruments with long, narrow lumens, tight crevices, movable joints, blind ends, or internal channels—such as powered surgical devices (e.g., drills, staplers)—are recognized as cleaning challenges. Water and detergents may not reach all surfaces effectively, leaving residual contaminants.

(2) Material diversity:

Different materials have varying tolerance to cleaning agents. For instance, aluminum is sensitive to strong alkalis, and certain plastics cannot withstand high temperatures. Using incorrect cleaning methods can damage instruments and reduce their service life.

(3) Nature and drying state of contaminants:

Fresh blood is easier to remove, whereas dried blood clots, bone fragments, fat, or contrast agents are highly resistant to cleaning. The type of surgery (e.g., orthopedic or neurosurgical) also influences the tenacity of contaminants.

**1.6 Management and Environmental Factors**

(1) Incomplete quality management system:

Many CSSDs lack systematic plans for monitoring cleaning quality, procedures for traceability and handling of non-conforming items, and mechanisms for continuous quality improvement (CQI). Managers often underestimate the importance of the cleaning process and allocate limited resources, making it difficult to sustain an effective quality system.

(2) Low level of informatization:

The cleaning process often lacks digital traceability, preventing closed-loop management from collection, cleaning, and packaging to sterilization. This makes it difficult to accurately identify problem points and hinders continuous improvement efforts.

(3) Unreasonable workspace layout:

Inadequate separation of the "three zones" within CSSD—the decontamination area, inspection/packaging/sterilization area, and sterile storage area—leads to cross-traffic of personnel and materials, increasing the risk of secondary contamination. Poor ventilation in the decontamination area can also affect staff health and comfort during operations.

(4) Lack of multi-department collaboration mechanisms:

There is often no effective communication platform between CSSD, clinical departments, equipment management, and procurement. As a result, issues such as new instrument introduction, feedback on instrument

damage, and consumable needs are delayed, negatively impacting the smooth execution of cleaning tasks.

## 2. Strategies and Recommendations for Improving CSSD Cleaning Quality

### 2.1 Strengthening Personnel Competence

Personnel capacity should be treated as a strategic priority, with the development of a systematic and ongoing training system. Training should go beyond rote memorization of operational steps and explain the scientific principles behind cleaning, including the physicochemical properties of contaminants, mechanisms of detergents, and biofilm formation and removal, enabling staff to understand both "what" and "why." Training methods should be diversified, combining case studies, scenario simulations, and practical assessments to ensure effective knowledge-to-skill transfer[3]. Clear job descriptions and performance evaluation systems should assign responsibility for cleaning quality to individual staff, motivating intrinsic engagement. Managers must also pay attention to staff psychological well-being and job satisfaction by optimizing schedules, improving work environments, and establishing incentive mechanisms, thereby alleviating burnout and fostering a positive quality-focused culture.

### 2.2 Optimizing Equipment and Facility Management

Equipment management must shift from "reactive maintenance" to "proactive prevention." CSSD should scientifically plan and prospectively configure cleaning equipment according to hospital development and instrument portfolio, ensuring hardware capability aligns with operational needs. A comprehensive lifecycle management system should be established, including daily inspections, periodic functional testing (e.g., physical parameter monitoring, cleaning efficacy test card verification), and professional annual preventive maintenance. All maintenance activities should generate complete and traceable records. Water quality management is equally critical. Online water quality monitoring instruments should be installed to monitor key parameters, such as conductivity and hardness, in real time, with periodic third-party comprehensive water testing to ensure cleaning water consistently meets national standards.

### 2.3 Standardizing Consumable Management

The core of consumable management is "precise matching" and "standardized use." CSSD should work with infection control, nursing, and equipment departments to form a consumables review team, strictly evaluating the qualifications and performance of detergents, lubricants, and other products. Priority should be given to products highly compatible with the hospital's main instruments and contaminant types. During use, information technology solutions (e.g., automated dilution systems or barcode-based dispensing) should strictly control detergent concentration and dosage, eliminating human error. Additionally, establish expiry alerts and inventory rotation mechanisms to prevent use of expired or degraded products, ensuring chemical cleaning effectiveness and safety from the source.

### 2.4 Improving Standard Operating Procedures

Standardization is the foundation of consistent quality. CSSD should develop detailed, illustrated SOPs covering all instrument types, based on national regulations, manufacturer instructions, and hospital-specific requirements. SOPs should specify operational details, including pretreatment water temperature, brushing strength and frequency, loading density and arrangement, and program parameter selection, with regular reviews and updates. Collaboration with clinical departments should be reinforced through agreements and joint training, shifting point-of-use pretreatment responsibilities forward to ensure instruments arrive at CSSD in optimal condition. Any newly introduced instruments must undergo cleaning validation as a prerequisite for clinical use, confirming that existing cleaning processes are effective[4].

### 2.5 Building a Lean Management System

Long-term improvements in cleaning quality require modernized management systems. Total Quality Management (TQM) principles should be fully implemented, with continuous improvement guided by the PDCA cycle. A dedicated quality control team should regularly analyze multi-source data, such as visual inspection, ATP testing, and protein assays, using tools like fishbone diagrams and 5Whys to identify root causes and validate corrective measures. Information technology should be leveraged to enhance CSSD operations. Implement professional SPD information systems to achieve instrument barcoding, automated workflows, data visualization, and full traceability, moving quality management from "human defense" to

"technical defense." Finally, break down departmental silos by establishing a multidisciplinary team (MDT) led by CSSD, including infection control, nursing, operating rooms, and equipment departments, to address challenges throughout the instrument lifecycle and form a strong collaborative force for ensuring cleaning quality.

## Conclusion

The cleaning quality of reusable instruments in the CSSD is the first and most critical defense line in hospital infection prevention. Influencing factors are complex, spanning personnel, equipment, consumables, processes, instrument characteristics, and management systems. Neglect in any single link can compromise the entire cleaning process and threaten patient safety. Improving cleaning quality is not instantaneous; it requires systematic thinking, full staff engagement, and sustained investment. The future development of CSSD should focus on professionalization, standardization, informatization, and intelligentization. By establishing a scientifically sound quality management system, strengthening core personnel competencies, embracing advanced technology and equipment, and creating seamless collaboration with clinical departments, the cleaning quality of reusable instruments can be fundamentally ensured. This not only upholds a solemn commitment to patient health and safety but also fulfills the intrinsic requirements of high-quality modern hospital development.

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