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Coronavirus Pandemic

Evaluation of environmental cleaning quality: an observational study at a tertiary hospital in Wuhan, China

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Abstract
Introduction: The COVID-19 pandemic highlights the role of environmental cleaning in controlling infection transmission in hospitals. However, cleaning practice remains inadequate. An important component of effective cleaning is to obtain feedback on actual cleaning practice. This study aimed to evaluate the cleaning process quality from an implementation perspective.
Methodology: An observational study was conducted in a tertiary public hospital in Wuhan, China and 92 cleaning processes of units housing patients with multidrug-resistant organism infections were recorded. The bed unit cleaning quality and floor cleaning quality were measured by six and five process indicators respectively. Descriptive statistics were used to describe the cleaning quality.
Results: For bed unit cleaning quality, the appropriate rates of cleaning sequence, adherence to cleaning unit principle, use of cloth, use of cloth bucket, separation of clean and contaminated tools, and disinfectant concentration were 35.9%, 71.7%, 89.7%, 11.5%, 65.4%, and 48.7%, respectively. For floor cleaning quality, the appropriate rates of adherence to cleaning unit principle, use of cloth, use of cloth bucket, separation of clean and contaminated tools, and disinfectant concentration were 13.4%, 50.0%, 35.5%, 11.0%, and 36.7%, respectively.
Conclusions: The cleaning staff showed poor environmental cleaning quality, especially the floor cleaning quality. The findings can help reveal deficiencies in cleaning practices, raise awareness of these deficiencies, and inform targeted strategies to improve cleaning quality and hospital safety.

Key words: Environmental cleaning; process quality; cleaning staff; infection prevention and control; COVID-19.

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Introduction

Healthcare-acquired infection (HAI) is a substantial risk to patient safety, causing morbidity and mortality and increasing hospital stay [1]. The pooled HAI prevalence was 7.6% in high-income countries and 10.1% in the developing world [1]. Along with it, the emergence of antimicrobial-resistant strains gradually becomes a global public health problem. One global report estimated that antimicrobial-resistant strains claimed about 700,000 lives annually. Unless action is taken, the number of deaths could balloon to 10 million lives a year by 2050 [2]. Furthermore, the ongoing COVID-19 pandemic has caused more than 109 million confirmed cases and 2.4 million deaths as of February 19, 2021 [3].

Infection control measures are crucial to controlling the spread of HAI and COVID-19 in hospitals [4,5], among which environmental cleaning is an essential component [5]. Given that some pathogens can survive weeks to months on unclean surfaces, contaminated surfaces can therefore be directly or indirectly involved in the transmission of pathogens [6]. Cleaning can reduce the environmental reservoir of these pathogens and interrupt such transmission [7,8].

However, environmental cleaning remains inadequate, and the suboptimal cleaning quality is prevalent [9-11]. Previous studies found that only 49% high-risk surfaces were appropriately cleaned across 23 acute care hospitals [9], and about 35% surfaces in patient bedrooms were cleaned [10]. In addition, 63% of surfaces were culture positive for *Clostridium difficile* after cleaning; 90% of drawer handles were still contaminated [11]. Furthermore, recent studies found extensive contamination of ward surroundings by SARS-CoV-2 [12-13].

An important component of effective cleaning is to obtain feedback on actual cleaning practice. Cleaning quality is usually measured by methods such as visual inspection, fluorescent marker, adenosine triphosphate (ATP) detection, or microbial culture [14]. Visual inspection was proved to be unreliable and it is limited by the invisible nature of the cleaning outcome [14,15]. Fluorescent marker can only determine whether a surface has been cleaned, but provides no indication on the cleaning efficacy [10]. Microbial culture is time-consuming and costly and takes a long time to obtain results [14,15]. Fluorescent marker, ATP, and microbial culturecannot fully evaluate cleaning quality because of limited sampling points. Furthermore, these methods cannot assess the potential cross-contamination risks among different patient units caused by cleaning activities. Evaluating the cleaning process quality froman implementation perspectivecan make a comprehensive evaluation of cleaning quality, which may help make up for the above deficiencies. Moreover, process quality is a crucial part of the quality model, comprising three levels of structure, process, and outcome quality [16].

Therefore, this study aimed to evaluate cleaning process quality through observing the whole process of cleaning activities, to help identify and improve deficiencies in cleaning practices and ultimately improve infection prevention and control.

Methodology

Study design and participants

A cross-sectional observational study was carried out at a tertiary public teaching hospital in Wuhan, Hubei Province, Central China from January to March 2019. The hospital has more than 6,000 inpatient beds and provides over 250,000 inpatient and 300,000 outpatient services every year. The Regulation for Cleaning and Disinfection Management of Environmental Surface in Healthcare [17] and Standard Operating Procedure for Environmental Cleaning (established by this hospital) were implemented in this hospital.

The cleaning staff who worked in inpatient wards were included in this observational study. The cleaning processes of cleaning units housing patients with multidrug-resistant organism infections were observed and recorded. The cleaning unit is the environmental surface adjacent to a patient, including bed, bedside table, and medical instruments. [17]. The observation of each cleaning activity took about 20 min.

Measurement

The cleaning process quality was measured using process indicators: six indicators for bed unit cleaning quality and five indicators for floor cleaning quality (Table 1) [17,18]. About 400-700 mg/L of the chlorine-containing disinfectant used at the hospital was considered appropriate [17]. Greater than 700 mg/L was

Table 1. Process indicators of cleaning quality and assessment criteria.

	Process indicators	Assessment criteria
Bed unit cleaning quality	Appropriate cleaning sequence	Cleaning from light to heavy contamination and top to bottom areas; otherwise, the sequence would be considered inappropriate. Heavily contaminated areas were high-touch surfaces (bed rail, bed head, bed foot, bed handle, bedside table, ventilator control panel, and medical trash can). Lightly contaminated areas included intravenous poles, windows, windowsills, and bed units of other patients not infected with MDROs. The top and bottom areas were relative. Generally, the top areas referred to such points as intravenous poles, medical instruments, and bed rails; bottom areas referred to such points as the surrounding floor and bed foot
	Adhering to cleaning unit principle	Not exceeding the boundary of the cleaning unit being cleaned
	Appropriate use of cloth	Used only for one MDRO infection patient
	Appropriate use of cloth bucket	Used only for MDRO infection patients
	Separation of clean and contaminated tools	Clean clothes and buckets were separated from the contaminated
	Appropriate disinfectant concentration	400-700 mg/L
Floor cleaning quality	Adhering to cleaning unit principle	Not exceeding the boundary of the surrounding floor of the unit being cleaned
	Appropriate use of mop	Used only for patients MDRO infection
	Appropriate use of mop bucket	Used only used for patients with MDRO infections
	Separation of clean and contaminated tools	Clean mops and buckets were separated from the contaminated
	Appropriate disinfectant concentration	400-700 mg/L

MDRO(s): multidrug-resistant organism(s).

effective for disinfection, but excessive concentration could cause secondary environmental pollution. Disinfectant Concentration Test Paper Type G-1 was used to assess the disinfectant concentration, which was developed by the Institute of Microbiology and Epidemiology, Academy of Military Medical Sciences (Beijing Sihuan Sanitary and Pharmaceutical Equipment Factory, Beijing). By comparing the color of the disinfectant used by the cleaning staff with the standard color on the test paper, whether the concentration was acceptable was determined.

Statistical analysis

Descriptive statistics were used to describe the sample and calculate the frequency and percentage of process indicators for cleaning quality. The analyses were performed by SPSS 19.0 (SPSS Inc., Chicago, IL, USA).

Results

Basic information about the sample

A total of 92 cleaning processes of 25 cleaning staff were recorded in 14 wards of 11 departments. The 11 departments were orthopedics, thoracic surgery, hepatobiliary surgery, intensive care unit, neurosurgery, respiratory medicine, infectious disease, rehabilitation medicine, cardiothoracic surgery, neurology and traditional Chinese medicine. The frequency of observations for each cleaning staff ranged from 1 to 6, with an average of 3.68.

Cleaning Process quality

Table 2 shows the appropriate rate of process indicators for bed unit and floor cleaning quality. For the disinfectant concentration for bed unit cleaning, 48.7% was appropriate, 15.4% was insufficient (less than 400 mg/L), and 35.9% was excessive (Greater than 700 mg/L). For the disinfectant concentration for floor cleaning, 36.7% was appropriate, 43.3% was insufficient, and 20.0% was excessive.

Discussion

In this study, we evaluated the environmental cleaning quality at a tertiary hospital from an implementation perspective. Overall, the cleaning staff showed poor environmental cleaning quality. For bed unit cleaning quality, the appropriate rates of three indicators (cleaning sequence, use of cloth bucket, and disinfectant concentration) were below 50%. For floor cleaning quality, the appropriate rates of all five indicators were 50% or below. Greater efforts are needed to improve cleaning quality for infection control.

The findings related to poor cleaning quality are consistent with previously reported suboptimal cleaning quality measured by ATP or microbial culture in hospitals [9-11]. These findings suggest that hospital environment may frequently become contaminated and couldbe a source of pathogen spread. It is plausible to assume that hospital surface contamination would be severe when COVID-19 broke out. Previous studies found extensive contamination of hospital environment by SARS-CoV-2, and about 30% of surface samples were positive for SARS-CoV-2 in units specialized for confirmed patients in China [12,13]. These potentially highly contaminated surfaces may account for the early cases of healthcare-acquired transmission among healthcare workers and visitors when environmental cleaning protocols were not widely implemented and healthcare workers were not aware of the potential risk of indirect transmission of SARS-CoV-2 [12].

In the present study, the value of evaluating cleaning quality with process indicators was immediately apparent in that it helped identify the deficiencies in cleaning practice. Although regular training was carried out for cleaning staff in the

Table 2. Descriptive analysis of process indicators for cleaning quality.

	Process indicators	**N**	**No. of appropriate**	**Appropriate rate (%)**
Bed unit cleaning quality	Cleaning sequence	92	33	35.9
	Adhering to cleaning unit principle	92	66	71.7
	Use of cloth	78	70	89.7
	Use of cloth bucket	78	9	11.5
	Separation of clean and contaminated tools	78	51	65.4
	Disinfectant concentration	78	38	48.7
Floor cleaning quality	Adhering to cleaning unit principle	67	9	13.4
	Use of mop	68	34	50.0
	Use of mop bucket	62	22	35.5
	Separation of clean and contaminated tools	73	8	11.0
	Concentration of disinfectant	60	22	36.7

surveyed hospital, they still showed poor cleaning quality. Of note, 39.3% surface samples of COVID-19 patients' surroundings were still contaminated with SARS-CoV-2 in April in China [13], which indicated that training and audit based on the results from ATP and microbial culture may not be adequate to achieve optimal cleaning practice. Good outcome quality depends on the process quality as cleaning protocols and best cleaning practices are useful only if they are actually followed [19]. According to our findings, the suboptimal cleaning quality may be due to inappropriate cleaning sequence, inappropriate use of cleaning tools, inappropriate disinfectant concentration, and mixture of clean and contaminated tools. Therefore, targeted audit, feedback, and training of cleaning staff regarding specific deficiencies in cleaning practice would help improve cleaning quality more effectively and benefit the prevention and control of HAIs and COVID-19 pandemic, ultimately improving hospital safety.

This study has some limitations. First, the relatively small sample from only one hospital may limit the generalization of our findings. A multicenter study would be conducted in the future if more data are available. Second, the Hawthorne effect may exist during the observation, which may lead to the overestimation of cleaning quality. Third, the outcome cleaning quality was not measured. In future studies, the evaluation of cleaning quality combined with process indicators and outcome indicators should be taken into account.

Conclusions

The present study explored the level of cleaning process quality and revealed some deficiencies in cleaning practice. Our study supports the need for greater efforts to improve environmental cleaning quality, and more attention should be paid to process indicators of cleaning quality. Data about cleaning process quality can inform evidence-based targeted strategies to improve cleaning practice more effectively. Future intervention research in combination with process and outcome cleaning quality is needed to explore the role of process indicators in improving cleaning quality.

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Authors' Contributions

QXY, XPZ and XQL developed the study design. QXY collected and analyzed data. QXY and AJW drafted the manuscript. XPZ and XQL revised the manuscript. All authors have approved the final version of the manuscript.

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Annex -- Record tables of environmental cleaning activities by cleaning staff in preventing and controlling multidrug-resistant organism infections

Table 1a. Cleaning processes by cleaning staff in preventing and controlling multidrug-resistant organism infections (for general ward).

Department/ward: __________ Number of cleaning personnel: __________ Bed number: __________ Date and time: __________

	MDRO patient																		MDRO patient/Non- MDRO patient														Public area							
Cleaning Unit / Cleaning tools	M	V	IP	IV	EB	C	T	H	R (t)	R (b)	L (t)	L (b)	Ta	Ha	F	O	MT	SF	ME	IV	EB	C	T	H	B(t)	B (b)	Ta	Ha	F	O	MT	SF	L	W	TD	HW	TF	Wa	D	WS
Cloth																																								
Mop																																								

Note: Fill in the blanks with numbers (1, 2, 3…) to record the cleaning order, with superscript 1, 2, 3... to record the 1st, 2nd, 3rd… cloth/mop.
MDRO patient: patients with multidrug-resistant organism infections.

Table 1b. Cleaning processes by cleaning staff in preventing and controlling multidrug-resistant organism infections (for ICU).

Department/ward: __________ Number of cleaning personnel: __________ Bed number: __________ Date and time: __________																																								
	MDRO patient																		MDRO patient/Non- MDRO patient																		Public area			
Cleaning Unit / Cleaning tools	LM	M	V	RM	IV	IP	S	H	LB	LB(b)	RB	RB(b)	Ta	Ha	F	TV	MT	SF	LM	M	V	RM	IV	IP	S	H	LB	LB(b)	RB	RB(b)	Ta	Ha	F	TV	MT	SF	WS	SC	HW	Wa
Cloth																																								
Mop																																								
Note: Fill in the blanks with numbers (1, 2, 3…) to record the cleaning order, with superscript 1, 2, 3... to record the 1st, 2nd, 3rd… cloth/mop. MDRO patient: patients with multidrug-resistant organism infections.																																								

[1] M: monitor; V: ventilator; IP: infusion pump; IV: intravenous pole; EB: equipment belt; C: bedside chair; T: bedside table; H: bed head; R (t): right bed rail (top); R (b): right bed rail (bottom); L (t): left bed rail (top); L (b): left bed rail (bottom); Ta: bed tail; Ha: bed handle; F: foot of the bed; O: others; MT: medical trash can; SF: surrounding floor; ME: medical equipment, such as monitor and ventilator; B(t): bed rail (top); B(b): bed rail (bottom); L: light switch; W: ward door handle; TD: toilet door handle; HW: hand washing sink; TF: toilet floor; Wa: walkway in the ward; D: doorway floor; WS: window/sill; LM: left medical hanging tower; RM: right medical hanging tower; S: syringe pump; LB: Left bed baffle; LB(b): left bed shelf (below bed baffle); RB: right bed baffle; RB(b): right bed shelf (below bed baffle); TV: treatment vehicle; SC: storage cabinets.

Table 2. Cleaning tools.

1.Cloth	□ Used only for one MDRO infection patient		□ Not	
2.Cloth bucket	□ Used only for MDRO infection patients		□ Not	
3.Clean clothes and buckets were separated from the contaminated	□ Yes		□ No	
4.84 disinfectant concentration for cloth	□ Qualified	□ Too high	□ Too low	Specific concentration range: __________
5.Mop bucket	□ Used only used for patients with MDRO infections		□ Not	
6.mop bucket	□ Used only used for patients with MDRO infections		□ Not	
7.Clean mops and buckets were separated from the contaminated	□ Yes		□No	
8.84 disinfectant concentration for mop	□ Qualified	□ Too high	□ Too low	Specific concentration range: __________