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ORIGINAL RESEARCH

The Application of Multifunctional Endoscope Transport Carts in Bedside Endoscopy in Intensive Care Unit Patients

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Background: This study aimed to investigate whether the application of multifunctional endoscope transport carts, in bedside endoscopy in intensive care unit (ICU) patients, can improve the cleaning quality of the endoscopes.

Methods: A total of 175 endoscopes, used for bedside endoscopy in ICU patients in a hospital in China during November 2023 to January 2024, were randomly classified into the control group (n=88) and the experimental group (n=87). Multifunctional transport carts were used to deliver the endoscopes in the experimental group and traditionally used transport trolleys were used in the control group. Adenosine triphosphate (ATP) tests were performed to measure the relative light unit (RLU) values for the outer surfaces and forceps channels of the endoscopes, and a satisfaction survey was conducted with nurses who used the endoscope transport trolleys/carts and the endoscope cleaning staff.

Results: The ATP values for the outer surfaces and forceps channels of the endoscopes in the experimental group were 10.0 (6.0, 17.0) RLU and 7.0 (4.0, 11.0) RLU, respectively, lower than 33.5 (9.3, 77.0) RLU for outer surfaces and 14.0 (5.0, 39.8) RLU for forceps channels in the control group. The pass rates for cleaning quality of the outer surfaces and channels of the endoscopes in the experimental group were 98.9% and 100%, respectively, higher than 88.6% for outer surfaces and 93.2% for channels in the control group ($P < 0.05$). The satisfaction scores of the nurses who used the multifunctional endoscope transport carts and the endoscope cleaning staff in the experimental group were 39.7±1.87 and 18.45±1.41, respectively, higher than 19.83±2.08 for nurses and 9.08 ±1.71 for cleaning staff in the control group ($P < 0.05$).

Conclusion: The application of multifunctional endoscope transport carts in bedside endoscopy in ICU patients could improve the quality of endoscope cleaning.

Keywords: transport carts, intensive care unit, bedside endoscopy, adenosine triphosphate test

Introduction

In recent years, enteral nutrition therapy has become an important part of comprehensive care for intensive care unit (ICU) patients. Nutritional support is one of the basic treatment options for every critically ill ICU patient.[1] However, ICU patients have limited mobility, requiring continuous and rigorous monitoring and support of vital signs. Bedside gastroscope-guided nasoenteric tube placement can effectively avoid the risk of unexpected events occurring during transfers of critically ill patients. For patients admitted to the ICU due to massive acute upper gastrointestinal hemorrhage, or for ICU patients who have sudden gastrointestinal hemorrhage after admission to the ICU, there are high degrees of surgical difficulty, high surgical risk and high mortality in case of uncertain diagnosis. Under these

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circumstances, an emergency bedside endoscopy, under intensive monitoring in the ICU, can identify the cause of hemorrhage. This can directly carry out endoscopic hemostasis, thereby significantly improving the success rate of rescue.[2] Bedside endoscopy plays an important role in the treatment of ICU patients. However, the cleaning and disinfection of endoscopes after use can be a problem.

The results of Muscarella[3] have shown that having a gastrointestinal endoscopy is a risk factor for the transmission of Enterobacteriaceae and relevant multidrug resistant bacteria. Unthorough cleaning and disinfection of gastrointestinal endoscopes is highly likely to lead to iatrogenic infections. There have been several reports of gastrointestinal endoscopy-related infections in recent years.[4] Blood stains, secretions, and other contaminants left on the outer surface of the endoscope, and in the forceps channel of the endoscope, dry up easily, and biofilms form easily in these dried contaminants due to bacteria. Once the biofilm is formed, the pathogenic microorganisms contained in the dried contaminants can be protected and can not be impacted by medical multi-enzyme detergents or sterilizing agents, resulting in the failure of subsequent endoscope cleaning and disinfection procedures.[5]

According to the Regulation for Cleaning and Disinfection Technique of Flexible Endoscope (WS 507–2016), released by the National Health and Family Planning Commission of the People's Republic of China,[6] bedside pre-treatment should be performed on the endoscopes immediately after use. Cleaning and disinfection procedures should then be undertaken on the endoscope as soon as possible. Meanwhile, the outer surfaces and forceps channels of the endoscopes should be kept moist during delivery to the Digestive Endoscopy Center for cleaning, so as to avoid the forming of biofilms.[7] Due to the lack of endoscope cleaning and disinfection facilities in the ICU, endoscopes must be delivered to the Digestive Endoscopy Center for cleaning and disinfection. However, they can take a long time to transport, which can cause the contaminants on the outer surface and forceps channel of the endoscope to dry up. This will eventually affect the quality of cleaning and disinfection of the endoscope.

The use of an adenosine triphosphate (ATP) test to measure the quality of endoscope cleaning is the endoscope cleaning quality monitoring method recommended by the Regulation for Cleaning and Disinfection Technique of Flexible Endoscope (WS 507–2016).[6] ATP is found in every microbial cell. The amount of ATP, reported as relative light unit (RLU) value, is detected after endoscope cleaning. RLU can reflect the amount of patients' blood stains and secretions remaining on the outer surface and forceps channel of the endoscope.[7,8] This study aimed to investigate whether the application of multifunctional endoscope transport carts, in bedside endoscopy in ICU patients, can improve the cleaning quality of the endoscopes. A questionnaire survey was conducted among nurses who used multifunctional endoscope transport carts and endoscope cleaning staff to investigate the levels of their satisfaction with multifunctional endoscope transport carts.

Methods

Ethics Approval and Consent to Participate

This study was conducted in accordance with the Declaration of Helsinki. All research methods were carried out in accordance with the relevant guidelines and regulations. Ethics approval of this study was obtained from the Biomedical Research Ethics Committee of West China Hospital of Sichuan University [2023 (1791)]. Informed consent was obtained from all participants.

Material

The model numbers of the endoscopes used in this study were Olympus GIF-Q260/CF-Q260AI/GIF-Q260J/GIF-H260Z. The multifunctional endoscope transport carts (brand: Jin Jian Yi Liao; model number: DGN) with the patent number of CN201821141765.7, SHINVA multi-enzymatic detergents, 3M^{TM} Clean-Trace^{TM} NGi luminometers, 3M^{TM} Clean-Trace^{TM} water ATP swabs, and 3M^{TM} Clean-Trace^{TM} surface ATP test swabs were used in this study.

Grouping and Method of Transport

A total of 175 endoscopes, used for bedside endoscopy in ICU patients in a tertiary Grade A hospital in Sichuan, China during November 2023 to January 2024, were included in this study. They were randomly classified into the control

group and the experimental group. Of them, 88 were classified into the control group and 87 were classified into the experimental group. The two groups of endoscopes were pre-treated using the same bedside pre-treatment method, according to the requirements of the Regulation for Cleaning and Disinfection Technique of Flexible Endoscope (WS 507–2016)[6] after use. The endoscopes in the control group were delivered to the Digestive Endoscopy Center using the traditionally used transport trolleys (Figure 1) after being put in the disposable transport bags. The endoscopes in the experimental group were transferred to the Digestive Endoscopy Center using the multifunctional transport carts (Figure 2). The multifunctional endoscope transport cart contained a tank for placing the clean endoscopes and a tank for placing the contaminated endoscopes. This separates the clean endoscopes from the contaminated ones. The tank for contaminated endoscopes was configured with medical multi-enzyme detergents for soaking the endoscopes after use. The multifunctional transport cart has the feature of one-touch drainage. After the endoscope soaking procedure was completed, the multi-enzyme detergents in the tank for contaminated endoscopes could be discharged after clicking the drainage button. This met the cleaning and disinfection guidelines' requirements of discarding the multi-enzyme

Figure 1 Traditionally used endoscope transport trolley.

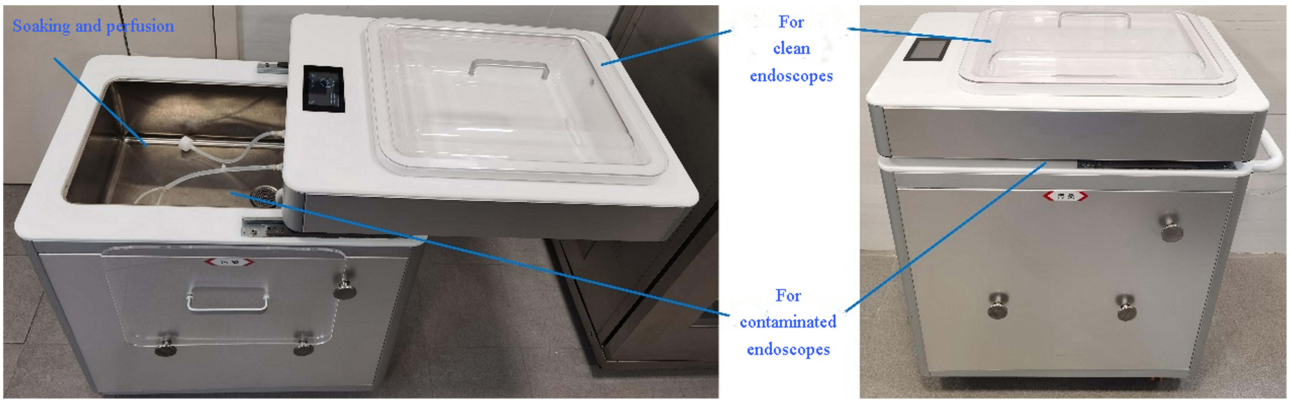

Figure 2 Multifunctional endoscope transport cart.

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detergents after each use.[9] The multifunctional transport cart was equipped with full line perfusion tubing. During transport, the full line perfusion connector would be connected and full line perfusion would be performed on the endoscope channel for more than 2 minutes.

After the endoscopes arrived at the Digestive Endoscopy Center, they were cleaned and rinsed manually according to relevant guidelines. Then, they were subject to the ATP test. The cleaning and disinfection methods for all connectors were similar to those for the endoscopes. Multi-enzyme detergents were used for cleaning and soaking before rinsing. Then, peracetic acid disinfectant was used for soaking before final rinsing. The endoscope forceps channel and connectors were perfused with multi-enzyme detergents and disinfectants simultaneously for disinfection according to the requirements of the guidelines, so as to be ready for reuse.

ATP Test

The RLU values for the outer surfaces and forceps channels of the endoscopes were measured using a 3M^{TM} Clean-Trace^{TM} NGi luminometer. The sample collection procedure for outer surface of the endoscope was as follows: the 2mL sterile phosphate buffer solution was taken into a sterile test tube. The sample collection ring was immersed into the collected phosphate buffer solution after being taken out from the 3M^{TM} Clean-Trace^{TM} surface ATP test swab. Then, the sample collection ring was rotated on the outer surface of the endoscope for sample collection. A sample was collected from an area between the tip of the insertion section of the endoscope and the location at 10cm in depth. The sample collection ring was inserted back into the swab after collecting the sample. The swab was shaken quickly so that the sample could be mixed with the reaction liquid from the bottom of the swab. Then, the swab was placed in the ATP luminometer to measure the RLU value. The sample collection procedure for forceps channel of the endoscope was as follows: the 40mL sterile phosphate buffer solution was absorbed using a syringe, and the syringe was inserted to the forceps channel opening, then the phosphate buffer solution was slowly injected into the forceps channel of the endoscope. The samples were collected using the measuring cups. The 40mL air was injected to completely collect the phosphate buffer solution. The sample collection ring was taken out from the 3M^{TM} Clean-Trace^{TM} water ATP swab. Then, the sample collection ring was immersed into the collected phosphate buffer solution. The swab was gently shaken to remove residual air bubbles. Then, the sample collection ring was inserted back into the swab. The swab was shaken quickly so that the sample could be mixed with the reaction liquid from the bottom of the swab. Then, the swab was placed in the ATP luminometer to measure the RLU value.

Satisfaction Survey

In the control group, 4 nurses used the traditionally used transport trolleys and 2 cleaning staff members cleaned the endoscopes. In the experimental group, the same 4 nurses used the multifunctional endoscope transport carts and the same 2 cleaning staff members cleaned the endoscopes. The nurses and the cleaning staff members received the training on the use of multifunctional endoscope transport carts, endoscope cleaning procedures and cleaning effect testing methods, and passed the assessments prior to the start of this study.

A satisfaction survey was conducted with nurses who used the multifunctional endoscope transport carts and the endoscope cleaning staff. A self-designed questionnaire was used in this study. Every item in the questionnaire had 5 response options: satisfied, moderately satisfied, neutral, moderately dissatisfied, and dissatisfied, which were assigned with a score of 5, 4, 3, 2, and 1, respectively. The questionnaire for satisfaction among nurses contained 3 components (effect of cleaning, functions, and appearance of endoscope) and 9 items. The maximum and minimum scores for the questionnaire for satisfaction among nurses were 45 and 9, respectively. The questionnaire for satisfaction among endoscope cleaning staff contained 2 components (levels of cleaning difficulty, and time-saving and labor-saving) and 6 items. The maximum and minimum scores for the questionnaire for satisfaction among endoscope cleaning staff were 30 and 6, respectively.

Statistical Analysis

SPSS 23.0 was used for statistical analysis. The categorical variables were presented using frequency or percentage (%). The Chi-square test and the Fisher's exact test were performed for comparisons between groups. The normally distributed continuous variables were presented as mean ± standard deviation ($\bar{x}$ ± SD). The non-normally distributed continuous variables were presented as median and its interquartile range with the lower and upper quartiles [M (P25, P75)], and the *t*-test and the rank sum test were performed for comparisons between groups. The two-tailed test was performed. A statistically significant difference was identified by $P < 0.05$.

Results

Quality of Cleaning

The amount of ATP on the outer surfaces of the endoscopes in the experimental group was 10.0 (6.0, 17.0) RLU, lower than 33.5 (9.3, 77.0) RLU which was the amount of ATP on the outer surfaces of the endoscopes in the control group. The pass rate for cleaning quality of the outer surfaces of the endoscopes in the experimental group was 98.9%, higher than in the control group (88.6%). The ATP value of the forceps channels of the endoscopes in the experimental group was 7.0 (4.0, 11.0) RLU, lower than 14 (5.0, 39.8) RLU which was the ATP value of the forceps channels of the endoscopes in the control group. The pass rate for cleaning quality of forceps channels of the endoscopes in the experimental group was 100%, higher than the control group (93.2%), with a statistically significant difference ($P < 0.05$), as shown in Table 1.

Satisfaction Scores

The questionnaire survey results revealed that the satisfaction score of the nurses who used the multifunctional endoscope transport carts in the experimental group was 39.7±1.87, higher than the control group (19.83±2.08). The satisfaction score of the endoscope cleaning staff in the experimental group was (18.45±1.41), higher than the control group (9.08±1.71), with a statistically significant difference ($P < 0.05$), as shown in Table 2.

Table 1 Quality of Cleaning

Groups	Adenosine Triphosphate Test		Pass Rate for Cleaning Quality	
	RLU Value for Outer Surfaces	RLU Value for Channels	RLU Value for Outer Surfaces	RLU Value for Channels
Experimental group (n=87)	10.0 (6.0,17.0)	7.0 (4.0,11.0)	86 (98.9%)	87 (100.0%)
Control group (n=88)	33.5 (9.3,77.0)	14 (5.0,39.8)	78 (88.6%)	82 (93.2%)
Z /χ^2	−6.056	−4.050	7.748	–
P	<0.001	<0.001	0.005	0.029

Abbreviation: RLU, relative light unit.

Table 2 Satisfaction Scores

Items	Experimental Group (n=87)	Control Group (n=88)	*t*	*P*
Satisfaction score of nurses who used the multifunctional endoscope transport carts	39.70±1.87	19.83±2.08	−39.491	<0.001
Satisfaction score of endoscope cleaning staff	18.45±1.41	9.08±1.71	−66.458	<0.001

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Discussion

The endoscope transport trolley/cart is an useful tool used to facilitate the cleaning and disinfection of endoscopes when the reprocessing room is not close to the point of use. It plays the role of transporting endoscopes, and it can prevent the contamination and cross-infection of endoscopes during transportation.[10] For traditionally used endoscope transport trolleys for bedside endoscopy in ICU patients, due to the lack of a full line perfusion function, blood stains and secretions attached to the surface and forces channel of the endoscope dry up easily after use, thus affecting the quality of cleaning and disinfection.

In the experimental group, the endoscopes were put into the multifunctional endoscope transport carts after being pre-treated at the bedside. The endoscopes were perfused with multi-enzyme detergents in the multifunctional endoscope transport carts to prevent contaminants on the surfaces and forceps channels of the endoscopes from drying. The results of this study showed that the ATP values and pass rates for cleaning quality of the outer surfaces and forceps channels of the endoscopes in the experimental group using multifunctional endoscope transport carts were higher than the control group. The continuous perfusion with multi-enzyme detergents and soaking could effectively clean the forceps channels and outer surfaces of the endoscopes. The proteolytic enzymes in the multi-enzyme detergents could break down residual substances. This could help minimize microbial survival and aggregation, reduce the incidence of biofilm formation, and make cleaning more thoroughly, leading to a higher level of cleanliness.

ATP is found in all known organisms. In the past 10 years, ATP testing has been widely used in the United Kingdom and the United States to rapidly evaluate environmental cleanliness of healthcare facilities and the effect of medical device cleaning.[11,12] Each microbial cell has a fixed amount of ATP. Therefore, ATP testing is feasible to detect endoscope bioburden in clinical practice.[13,14] There are no worldwide uniform standards for limits of the ATP-bioluminescence values. Aiken et al[15] reported that luminometers from different manufacturers displayed different results of ATP measurement for the same amount of bacteria, which was considered by many scholars in their studies on endoscopes.[16,17] For the 3M^{TM} Clean-Trace^{TM} NGi luminometers used in our study, a RLU value of < 200 was considered a pass in the evaluation of cleaning effect. The RLU values detected in our study were low, which is consistent with the results of previous studies.[7,8,18,19]

In addition to the tank for contaminated endoscopes, the tank for clean endoscopes was also specifically designed. In order to prevent secondary contamination of the endoscope placed in the tank for clean endoscopes during transportation, the multifunctional transport cart was designed with the function of continuously injecting clean compressed air into the tank for clean endoscopes. This could keep the clean endoscopes dry and prevent the occurrence of bacteria and the secondary contamination.

This study investigated the satisfaction of nurses who used the multifunctional endoscope transport carts, along with endoscope cleaning staff. The questionnaire items covered the cleaning effect, transport function, labor saving, and time saving. The results of this study showed that the satisfaction score of the experimental group was significantly higher than the control group, indicating that the respondents were more inclined to use the multifunctional transport carts. When multiple endoscopes needed to be transported at one time or when the transport distance was long, manpower increase was generally required, and consumption of physical strength in the staff also increased. It has been reported that practitioners of digestive endoscopy in China have a heavy workload and that there is a manpower shortage for digestive endoscopy in the western region and primary healthcare institutions in China.[20] The multifunctional transport cart can transport multiple endoscopes at once. In addition, the multifunctional transport cart is equipped with the function of electric power driving, which is started by pressing a button. This is easy to manipulate and can save manpower.

Limitations

This study has some limitations. First, all the participants were from the same hospital. Selection biases might exist in the results of this study. Second, the sample size of this study was not large. The sample size should be enlarged in future to improve the efficiency of the test.

Conclusions

In summary, the multifunctional endoscope transport cart is characterized by the functions of soaking, perfusion, drying, and electric power. Being applied to the bedside endoscopy in ICU patients, it can improve the quality of endoscope cleaning, prevent secondary pollution, save manpower, and reduce the consumption of physical strength of staff. The application of the multifunctional endoscope transport cart in this study can provide a clinical reference for other digestive endoscopy centers. Further studies can be conducted with multifunctional endoscope transfer carts from different brands and different manufacturers to compare the impact of different endoscope transfer carts on the quality of endoscope cleaning.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding authors on reasonable request.

Ethics Approval and Consent to Participate

This study was conducted in accordance with the Declaration of Helsinki. All research methods were carried out in accordance with the relevant guidelines and regulations. Ethics approval of this study was obtained from the Biomedical Research Ethics Committee of West China Hospital of Sichuan University [2023 (1791)]. Informed consent was obtained from all participants.

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Disclosure

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