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Discuss the Risk of the Ventilator and Evaluate the Effect of Ozone Disinfection

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Abstract: *Objective:* To understand the possibility of nosocomial risk in the internal pipeline of the ventilator, and to discuss the necessity of disinfection of the internal pipeline by comparing the total number of colonies in the experimental sampling pipeline. *Methods:* It is innovatively proposed to put the ventilator in a cubic confined space, and start the ventilator in the running state. For the first time, ozone gas is used for the ventilator to smoke the whole process of the ventilator, and design the prototype of the whole process of the ventilator pipeline disinfection machine. *Results:* by sampling the ventilator intake, outlet total colonies before disinfection and disinfection, with reference to health standards, test results show that the ventilator before disinfection internal management total colonies overweight phenomenon, the total number of bacterial colonies after disinfection detection results within the health standard, according to the statistical method analysis P value is 0, think the bacterial colonies before and after the ventilator disinfection have significant differences. *Conclusion:* The test result proves that the number of bacteria is lower than the standard value of 20, and the disinfection method has obvious effect. The internal pipe of the ventilator has the risk of hospital sensation. The disinfection method of ozone smoke is effective and safe, and the market needs the product of a ventilator.

Keywords: Ventilator, Internal Pipeline, Infection, Disinfection

1. Introduction

Ventilators play an important role in the treatment of critically ill patients with COVID-19, but when infectious patients use ventilators, ventilators and their associated accessories are easily contaminated by the transmission of droplets or aerosols carrying pathogens, which is a high-risk route of nosocomial transmission [1]. When breathing, coughing, or sneezing, droplets spray from the patient's mouth and nose, larger droplets settle, and smaller particles are suspended in the air for a long time. And because of low indoor ventilation rate, the source of microbial particles easily in indoor enrichment, according to the principle of ventilator equipment if such particles floating around the ventilator, these microbial particles easily from the turbine compressor suction suction into the breathing internal structure of the pipeline, the internal structure pipe is difficult to clean and disinfection has a high risk of infection [2] Have data show that 9%~40% of the respiratory tract infection related to the use of the ventilator, at present, the ventilator after using disinfection management mainly focus on the ventilator external pipe disinfection, because the ventilator internal pipe contains various precision electronic components is difficult to remove, so the disinfection of the ventilator internal pipeline research is less, routine disinfection method cannot completely disinfection [3] The purpose of this study is to sample and analyze whether the pipeline of the internal structure of ventilator has the risk of nosocomial infection, demonstrate whether the use of ozone for disinfection of the internal structure of ventilator is effective, and explore the necessity of disinfection.

2. Materials and Methods

2.1. Demonstration of Disinfection Necessity

The ventilator has the difference between external and internal pipelines. At present, the disinfection of the gas pipeline of the ventilator mainly refers to the disinfection of the external pipeline of the ventilator, and the disinfection method of the internal pipeline of the ventilator is less studied. The external pipe consists of the ventilator external pipe, humidification tank, water cup, face mask, bacterial filter, etc. [4] The outer tube of the ventilator is easy to install and remove, and the disinfection method is relatively mature at present. The internal pipeline of the ventilator is integrated in the main engine. In addition to the internal pipeline, it also includes various precision components, such as turbine compressor (air pump), air and oxygen mixing cavity, flow sensor, pressure sensor, solenoid valve, check valve and other components, which need trained professionals to disassemble and assemble [5].

Although the air intake and exhaust ports of the ventilator are equipped with filters to filter 99% of the particles in the exhaled breath, various pathogenic microorganisms such as Escherichia coli, P. aeruginosa, B. pneumoniae, Staphylococcus aureus and Acinetobacter baumannii can survive for a long time on the ventilator [6]. It was reported that S. aureus can survive for 7 months in ventilator tubes, Klebsiella pneumoniae for 30 months, Pseudomonas aeruginosa for 16 months, and A. baumannii for 5 months. The incomplete disinfection and sterilization of these pathogenic microorganisms is an important cause of nosocomial infection during the use of ventilator. Therefore, in the daily maintenance of the ventilator [7].

2.2. Refer to the Technical Specifications

"Disinfection of medical institutions" WS / T367-2012 mentioned respiratory pipe is moderately dangerous items, the definition of moderate dangerous items: contact with complete mucosal phase, and do not enter the human sterile tissue, organs and blood flow, do not contact damaged skin, damaged mucosal items, such as gastric tendon endoscopy, tracheoscope, laryngoscope, anal meter, the table, mouth table, ventilator pipe, anesthesia machine pipe, tongue plate, anorectal pressure measurement catheter, etc. The technical specification points out that the respiratory pipe is a medium dangerous article, and the disinfection method to achieve the effect above medium level disinfection should be adopted. After disinfection and sterilization, the total number of colonies of 20 CFU / piece (CFU / g or CFU / 100c m^2) is required, and pathogenic microorganisms shall not be detected [8].

"Medical institutions disinfection technical specification" WS / T367-2012 mentioned ozone belongs to the high level of disinfection, high level of disinfection definition: kill all fine pick reproduction including mycobacteria, painful poison, fungi and embrace and most of bacteria shoot to achieve a high level of disinfection, common methods include oxygen preparations, chlorine dioxide, adjacent formaldehyde, peracetic acid, hydrogen peroxide, ozone, iodine tincture, and can achieve the effect of sterilization of the chemical disinfectant under the prescribed conditions, with the appropriate concentration and effective action time for disinfection method [9]. Ozone can disinfect the breathing pipes at a high level.

2.3. Disinfection Method of Ozone Gas

The internal pipe position structure of the ventilator is complex and difficult to remove, and the conventional disinfection methods are difficult to implement. Both the effectiveness of disinfection effect and the influence of disinfection process on the safety of electronic components should be considered. Respiratory internal pipe due to the particularity of electronic equipment should avoid water flushing, spray, high temperature fumigation disinfection, so choose gas disinfection, using ozone gas to ventilator internal pipe similar smoke disinfection, the least damage to equipment, ozone is a kind of manufacturing convenient, cheap and effective, environmental protection of disinfection gas [10]. Ozone is produced by ozone generator, whether gas or liquid has broad spectrum, efficient bactericidal effect, ozone as a disinfectant can widely kill all kinds of pathogens and pathogenic microorganisms, including bacteria (such as Escherichia coli, Staphylococcus aureus, etc.), all kinds of cell spores, fungi and viruses (such as hepatitis virus, influenza virus, norovirus and coronavirus, etc.), ozone exists in the air in the form of small molecules, fast, fast, decomposition, and action can natural decomposition and left without any harmful residues, this is the choice of ozone as an important reason for air disinfection.

2.4. Disinfection Space Design

In this test, a 1 cubic meter confined space (box) can place a ventilator. equipped with ozone gas generator, ozone sensor, timer, power plug, simulated lung, respiratory circuit pipeline and door. Outside the box, there is an ozone gas generator (using Shenzhen Sydney ST-2BU bed unit ozone sterilizer, the product ozone output is 400mg / m^3), the ozone gas is injected into the box space through the pipeline, a 220V power plug (providing power for the ventilator), ozone probe (observing ozone concentration), and a timer is placed outside the box (for disinfection timing). According to the "Technical Specification for Disinfection of Medical Institutions" WS / T367-2012, ozone air disinfection is mentioned in a closed space and unmanned state, in a closed space, the humidity of the phase is 70%, the ozone with the concentration of 60mg / m^3 is used, acting in 60min and 120min, and the killing rate of natural bacteria on the surface reaches 99%.

2.5. Sampling Method

A quick and simple detection method is needed to sample samples before and after the ventilator. At present, swab sampling analysis of the internal pipeline of the ventilator is the most accurate testing method, but the sampling process is complicated, it is difficult to unify different structural components, and the assembly process is easy to cause secondary infection. In the guidelines for ventilator pneumonia published by the CDC, it is clearly stated that the routine disassembly and disinfection of the internal air circuit system of the ventilator is not recommended [11]. Therefore, it is a relatively simple, convenient and reasonable detection method to detect the air inlet of the ventilator (the suction inlet of the turbine compressor on the back or side of the machine) and the outlet. It is a reliable detection method by sampling and microbial culture of the ventilator inlet and outlet swab [12]. The total number of bacterial colonies is used to determine the degree of bacterial contamination of the ventilator pipe and the hygienic quality. It reflects whether the ventilator pipe meets the hygiene requirements, so as to make an appropriate hygienic evaluation of the inspected samples. The total number of colonies is a certain indicator of the quality of health of medical devices [13].

2.6. Test Steps

Before disinfection: sample the ventilator intake and outlet respectively, and save the specimen. Open the box, push the ventilator into a confined space box, plug the ventilator and connect the breathing pipe, simulate the lung, start the ventilator, set the oxygen concentration to 21% (i.e., no external oxygen), and set the regular operation mode (no IPPV PCV, SIMP, CPAP mode) [14], Set the conventional tidal volume, frequency, end-call pressure, etc., and start the operation. At this time, the ventilator is in the autonomous operation state, and close the box door.

In disinfection: start the external ozone generator, the ozone output is 400mg / m³, so that the ozone gas is blown into the box. According to the working principle of the ventilator, the ventilator absorbs the surrounding air through the turbine compressor (gas pump) and is output to the terminal (gas volume), pressure and frequency of the set tidal volume), and the turbine compressor (air pump) operates in a fixed mode and constantly absorbs and blows out. ventilator turbine compressor suction box inside the air into the ventilator inner pipeline, then fixed frequency quantitative pressure output to the external pipe, at this time, the ventilator inhalation ozone disinfection gas, and through the internal-external pipes to form a gas disinfection cycle, similar to a suction external ozone gas flow through the internal pipe and components of the process, can disinfect the whole process of ventilator internal pipe, solenoid valve, sensors, mixed cavity and other components [15]. When the ozone concentration sensor ozone concentration reaches 60mg / m³, the killing rate of natural bacteria reaches 99%, start the timer to start the timing, and the disinfection continues for 60min. Always pay attention to the ozone sensor data to keep the ozone concentration stable at about 60mg / m³.

After disinfection: 60min time, turn off the ozone generator power, wait for 20 minutes for the ozone analysis, the ventilator is still in operation, constantly exhaled the pipeline residual ozone gas, pay attention to the ozone sensor data for 0mg / m³, open the box power close the ventilator, the ventilator box, when the whole disinfection program is finished. Then the ventilator inlet and outlet were sampled separately, marked and stored the specimen.

3. Test Results

In this experiment, 11 ventilators in use in the cardiothoracic department, respiratory department, emergency department, ICU and other departments were selected for sampling and analysis according to the Hospital Disinfection Health Standard GB15982-2012, and each machine respectively sampled the air outlet before and after disinfection.

A total of 44 specimens from the air inlet were compared. The results are as follows:

Table 1. Comparison of test results before and after disinfection of ventilator internal pipes.

	sampling position	Check product name	surveillance project	Pre-disinfection test results (CFU / piece)	Ozone concentration (mg / m³)	sterilizing time	Box of the relative humidity of (%)	Standard requirements	Post-disinfection test results (CFU / piece)
1	cardiothoracic department	Ventilator 1 (air outlet)	The number of colonies	180	60mg/m³	60min	70%	≤20	14
2	cardiothoracic department	Ventilator 1 (air inlet port)	The number of colonies	182	60mg/m³	60min	70%	≤20	14
3	pneumology department	Ventilator V601 (air outlet)	The number of colonies	112	60mg/m³	60min	70%	≤20	13
4	pneumology department	Ventilator V601 (air inlet)	The number of colonies	120	60mg/m³	60min	70%	≤20	12
5	pneumology department	Ventilator 1 (air outlet)	The number of colonies	131	60mg/m³	60min	70%	≤20	13
6	pneumology department	Ventilator 1 (air inlet port)	The number of colonies	135	60mg/m³	60min	70%	≤20	13
7	emergency call	Ventilator 1 (air outlet)	The number of colonies	175	60mg/m³	60min	70%	≤20	15
8	emergency call	Ventilator 1 (air inlet port)	The number of colonies	164	60mg/m³	60min	70%	≤20	14
9	emergency call	Ventilator 2 (air outlet)	The number of colonies	105	60mg/m³	60min	70%	≤20	10
10	emergency	Ventilator 2 (air	The number	106	60mg/m³	60min	70%	≤20	<10

	sampling position	Check product name	surveillance project	Pre-disinfection test results (CFU / piece)	Ozone concentration (mg / m³)	sterilizing time	Box of the relative humidity of (%)	Standard requirements	Post-disinfection test results (CFU / piece)
	call	inlet)	of colonies						
11	Zone ICU 1	Ventilator 1 (air outlet)	The number of colonies	196	60mg/m³	60min	70%	≤20	15
12	Zone ICU 1	Ventilator 1 (air inlet port)	The number of colonies	194	60mg/m³	60min	70%	≤20	14
13	Zone ICU 1	Ventilator 2 (air outlet)	The number of colonies	178	60mg/m³	60min	70%	≤20	14
14	Zone ICU 1	Ventilator 2 (air inlet)	The number of colonies	170	60mg/m³	60min	70%	≤20	13
15	Zone ICU 2	Ventilator 1 (air outlet)	The number of colonies	102	60mg/m³	60min	70%	≤20	<10
16	Zone ICU 2	Ventilator 1 (air inlet port)	The number of colonies	110	60mg/m³	60min	70%	≤20	<10
17	Zone ICU 2	Ventilator 2 (air outlet)	The number of colonies	189	60mg/m³	60min	70%	≤20	15
18	Zone ICU 2	Ventilator 2 (air inlet)	The number of colonies	181	60mg/m³	60min	70%	≤20	13
19	Zone ICU 2	Ventilator 3 (air outlet)	The number of colonies	170	60mg/m³	60min	70%	≤20	13
20	Zone ICU 2	Ventilator 3 (air inlet)	The number of colonies	162	60mg/m³	60min	70%	≤20	11
21	Zone ICU 2	Ventilator 4 (air outlet)	The number of colonies	154	60mg/m³	60min	70%	≤20	10
22	Zone ICU 2	Ventilator 4 (air inlet)	The number of colonies	149	60mg/m³	60min	70%	≤20	<10

The test data show that before disinfection, the total number of bacterial colonies of the internal pipe (inlet and outlet) exceeds the requirements of the moderately dangerous medical equipment is 20 CFU / piece; after disinfection, the total number of bacterial colonies of the internal pipe (inlet and outlet) is less than 20 CFU / piece.

According to the statistical analysis (such as Table 2), the rank results give the difference between the two, the number of positive rank cases is 0, the number of negative rank cases is 22, the binding value is 0, the average value of negative rank is 11.5, and the P-value is 0, which is less than the significance level (A = 0.05), so the number of bacterial colonies before and after ventilator disinfection can be considered to have a significant difference. The test results proved that the number of bacteria was lower than the standard value of 20, and the disinfection method had obvious effect.

Table 2. *Statistical analysis of the test results.*

	individual	average	standard deviations	minimum	maximum
Front	22	152.9545	32.09135	102	196
Behind	22	12.1818	2.46183	9	15
Positive rank average	11.5				
Negative rank mean	.00				
P	0				

The results show that the ozone concentration produced by the ozone machine in the 1 cubic closed box increases with the increase of the running time of the machine. After 10min of operation, the ozone concentration exceeds 60mg / m³. For 60min of operation, the inactivation of ozone to microorganisms can reach more than 99%. The longer the contact time between ozone and microorganisms, the better the bactericidal effect. The disinfection results meet the requirements of the total number of bacterial colonies (20 CFU / g or CFU / 100c m^2) and no detection of pathogenic microorganisms.

4. Discussion

4.1. There Has Been a Great Innovative Progress in the Previous Literature

(1) Chen Xuebin et al., in the feasibility analysis of the internal air system disinfection of the ventilator, mainly discussed the problems and countermeasures of the internal air system disinfection and the feasibility of the internal air system disinfection of the ventilator. In this paper, the sampling and detection of the total number of bacterial colonies before and after disinfection as the experimental results, to prove that gas disinfection is a feasible method of internal ventilation system disinfection of ventilator, and to further strengthen the study of internal ventilation system disinfection of ventilator disinfection [16].

(2) In the Study on the Cleaning and Disinfection Effect of the ventilator Pipeline, Wu Shuhong and others mainly studied the disinfection effect of the external circuit pipeline of the ventilator, lacking the research on the internal pipeline and the research on the importance of the disinfection of the internal pipeline of the ventilator. In this paper in the ventilator internal pipeline for a sequence of disinfection

feasibility, and with medical engineers maintenance experience in-depth analysis of the ventilator internal pipeline structure principle, on the basis of medical disinfection technology specification justified to promote the implementation of the ventilator internal pipeline disinfection method, disinfection test results comply with the medical and health technical specification, prove that disinfection effect is effective and feasible.

4.2. Shortcomings of This Study

(1) Due to the lack of scientific research funds and the limited amount of specimens tested, it cannot be collected and compared in multiple hospitals. However, the fact that can be recognized is that it is difficult to clean and disinfect the pipes of the internal structure of the ventilators used for years in the industry, and the pollution situation can be imagined. In this test, 22 samples before disinfection were sampled, and the number of bacterial colonies was basically exceeded the standard, and the test results are of great significance.

(2) The design of the disinfection box is in the primary stage. After the disinfection, the residual ozone gas fails to be quickly discharged and resolved, and the exhaust facilities and activated carbon filter are not installed, which needs to be further improved.

4.3. The Next Research Direction

1) If approved by the research fund, it will further test which specific bacteria, viruses and quantities each specimen contains, such as Escherichia coli, Pseudomonas aeruginosa, B. pneumoniae, Staphylococcus aureus and Acinetobacter baumannii. In-depth understanding of the existence of related infectious diseases in the internal structure pipeline after the use of individual infectious disease cases.

2) In the aspect of internal structure pipeline disinfection medium selection, consider the next choose dry fog hydrogen peroxide as disinfection gas, dry fog sterilization mainly using atomization technology to liquid spore killer (hydrogen peroxide or hydrogen peroxide and peroxyacetic acid mixture) into about 3-5 micron "dry fog" particles, diffusion in the space requiring sterilization, the formation of brown movement without dead Angle spread to every corner to achieve no dead Angle sterilization, dry fog hydrogen peroxide is also a safe and effective way of disinfection.

5. Conclusion

From the Angle of clinical engineers to ventilator internal pipeline analysis and disinfection, breakthrough experiment will ventilator set up in a confined space full of ozone gas, innovative put forward the ventilator in the autonomous operation state inhalation disinfection gas from the whole process of the whole pipeline disinfection mode, through sampling before disinfection after disinfection samples, testing proved disinfection is effective. In this study, the disinfection of internal pipes of ventilators is only an experimental process. With the reports of more and more nosocomial infections caused by the application of ventilators, the disinfection of ventilators after their use also attracts great attention, which is conducive to promoting the market research and production of disinfection equipment of internal pipes of ventilators. What is the next step is to make a ventilator disinfection equipment, put it into clinical trials, and comprehensively test the effect.

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References

[1] Chen Xuebin, Yang Xue, Gao Min, and Li Tianqing. Feasibility analysis of disinfection of internal airway system of ventilator [J]. Chinese medical equipment. 2018, 15 (01): 134-137.

[2] Wang Shuai an Li Zhan. Investigation and analysis of the infection route and pathogen distribution of ventilator-associated pneumonia [J]. Chinese medical equipment. 2017, 14 (01): 35-38.

[3] Peng Hong, Zhou Gang, Shi Qingshan. Comparison of the bactericidal effect of different modes of ozone [J]. The Chinese Journal of Disinfection. 2017, 34 (09): 827-829.

[4] Li Junde, Xu Jianbo, Su Min. Design of automatic cleaning and disinfection device of ventilator exhaled box [J]. Electronic production. 2020, (08): 72-73+97.

[5] Li Tianqing, Chen Xuebin, Wang Huaqing, etc. Current status and coping strategies of false positive alarm of ventilator [J]. Medical and health equipment. 2019, 40 (05): 61-65.

[6] Bu Xianglei, Huang Erliang, Xie Pengcheng and so on. Study on the accuracy evaluation method of ventilator tidal volume based on the zone of interest [J]. Medical and health equipment. 2021, 42 (10): 69-72+105.

[7] Zhang Pengyi Li Huinan Yang Jie Li Lianxin Cao Ranran. Progress in the use of ozone for air and surface disinfection [J]. The Journal of Safety and the Environment. 2021, 21 (03): 1277-1291.

[8] Technical Specification for Disinfection of Medical Institutions WS-T 367-2012.

[9] Hospital Disinfection and Health Standards GB 15982-2012.

[10] Min Zhenzhen Huang Hanpeng, Dai Chunhui, Wang Xindi Yin Qun influencing factors of ventilator-related pneumonia and preventive countermeasures research Chinese Journal of Hospital Infecology. 2018, 28 (21): 3230-3233.

[11] Nie Zhipin. Investigation and analysis of the infection route and pathogen distribution of ventilator-associated pneumonia [J]. The Chinese Journal of Clinicians. 2018, 46 (06): 681-684.

[12] Li Yujuan Wei Li Xu Tao Fang Heng Wen Zou Linfan. Analysis of influencing factors and prevention of multidrug-resistant pneumonia in ICU patients with Zeng Yi [J]. Chinese Journal of Hospital Infecology. 2019, 29 (04): 523-526.

[13] Zou Lianhong Xu Hui Wenhui Guo Xin. Investigation on the status of ventilator disinfection in different levels of hospitals [J]. Practical preventive medicine. 2019, 26 (10): 1262-1264.

[14] Chai Xiying, Shao Chunmei, Li Songying, Song Ying. Application of 8S management mode in the whole process management of ventilator pipeline in disinfection supply center [J]. Nursing management in China. 2021, 21 (09): 1404-1408.

[15] Mai Da Da Xiao Xiangao Wan Yi Li Guiming. Discussion on the practice of ventilator quality control and detection and the maintenance work program [J]. Chinese medical equipment. 2020, 35 (09): 144-148.

[16] Wu Shuhong, Wang Zhengxu, Liu Yanling. Study on the effect of cleaning and disinfection of ventilator pipelines [J]. Chinese Journal of Hospital Infecology. 2016, 26 (04): 953-954.

Biography

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