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Application and Effect of Intelligent Disinfection Robot in Non-Negative Pressure Isolation Ward of Novel Coronavirus Pneumonia Designated Hospital

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Abstract

The application of intelligent disinfection robot in designated non-negative pressure isolation ward during the outbreak in novel coronavirus pneumonia. The construction and competition, disinfection mode of intelligent disinfection robot, the setting of disinfection point built on area and number of isolation ward, can be introduced below. Frequency can realize remote control when staff uses a table to give instruction and set disinfection mode, and then the intelligent disinfection robot returns automatically to the charging pile to charge when the instruction is completed. It can also autonomously move to sterilize without human participation, which makes man-machine separation and accurate disinfection come true. The chance of contact infection and exposure is decreased when an intelligent disinfection robot is used to sterilize the environment and object surface in an isolation ward, which can also reduce occupational exposure, achieve occupational protection of medical workers and ensure there is no hospital infection.

Keywords

Intelligent Disinfection Robot, Novel Coronavirus Pneumonia, Non-Negative Pressure Isolation Ward

1. Introduction

Novel coronavirus pneumonia (hereinafter referred to as COVID-19) [1] broke out. As an acute respiratory infectious disease caused by a novel coronavirus

pneumonia infection, the source of it includes patients infected with COVID-19 and asymptomatic carriers. The primary way that COVID-19 appears to spread is by exhaled droplets and contact infection, and aerosol transmission is possible when exposed to high concentration aerosol in a relatively closed environment for a long time [1]. Fever, fatigue, dry cough, shortness of breath, runny nose, cough, chest tightness and other cold-like and respiratory-related symptoms are common, but digestive symptom such as diarrhea also can appear, which makes the crowd generally susceptible. COVID-19 has been incorporated into category B infectious disease stipulated by the ***Law of the PRC on the Prevention and Treatment of Infectious Diseases***, which is prevented, controlled and managed to adopt Isolation treatment according to category A infectious disease.

As one of the Third-class hospitals with the ability to treat patients with COVID-19 infection in Guangdong Province, the general ward in our hospital has been converted into a non-negative pressure isolation ward from January 20, 2020. All settings are based on the requirements of isolation ward: strictly according to the clean area, buffer zone, contaminated area, medical staff passage, patients channel, which is divided into three zones and two passages. The divisions are specific and the logo is clear. There are 16 wards with 34 beds in the inpatient area. 108 suspected patients and 22 confirmed patients have been admitted, 76 men and 32 women are covered aged 4 months to 80 years since 22 January.

In strict accordance with the ***Regulation of Disinfection Technique in Healthcare Settings***, The isolation wards clean and disinfect medical apparatus and instruments, contaminated articles, object surface, ground surface, etc. Air disinfection is also carried out according to the ***Management Specification of Air Cleaning Technique in Hospitals***. The common problem facing provinces and cities across the country is a lack of materials under the severe outbreak [2]. In order to ensure the accurate and efficient completion of all disinfection measures in the isolation ward, savings in manpower and materials and safety protection for frontline health workers, the intelligent disinfection robot developed by Shanghai Taimi Robot Technology Co. Ltd has been introduced into the ward to sterilize the isolation ward since February 1. It not only achieves disinfection effect, alleviates the human resources of nurses, reduces the working pressure of nurses, effectively controls the supply of protective materials, ensures the supply of protective materials to some extent, but also reduces exposure of frontline health workers, especially nurses, guarantee the personal safety of frontline health workers and achieves the goal of zero infection among medical staff.

2. The Application of Intelligent Disinfection Robot in Isolation Ward

2.1. The Components of Disinfection Robot

Consists of four parts. The first is the robot charging pile, the second is the robot part, which is the whole core part, the third is the router that provides the net-

work and the last one is a table computer that controls a robot. The robot is partly formed from omnidirectional mobile chassis, hydrogen peroxide dry fog generator (including liquid storage box, fan), ultraviolet disinfection lamp tube, air purifier, lidar, visual radar, ultrasonic radar, charging seat, emergency charging cable, power cord, tablet computer, etc. By integrating the environmental information collected by various sensors, the robot can accurately and completely reflect the characteristics of the environment, which uses the autonomous navigation SLAM algorithm and moves autonomously according to the given route.

2.2. A Variety of Disinfection Modes

Basic disinfection mode + combined with a variety of disinfection modes, can reach a high level of disinfection. The disinfection modes of disinfection robot include gasification of hydrogen peroxide, ultraviolet disinfection, air filtration purification, gasification of hydrogen peroxide + ultraviolet + air filtration purification, gasification of hydrogen peroxide+ ultraviolet radiation and other basic disinfection modes that can be freely combined. There are also manual disinfection modes under particular circumstances, which can deal with various high, medium and low level disinfection effects in hospital multi-environment.

2.2.1. Gasification of Hydrogen Peroxide

Hydrogen peroxide is a strong oxidant whose aqueous solution is commonly known as hydrogen peroxide, and it's a kind of colorless transparent liquid. Because it has four atoms covalently combined into a nonpolar H-O-O-H structure, the chemical properties of hydrogen peroxide solution are very active and easy to decompose into oxygen and water with no residual toxicity. Hydrogen peroxide will not cause secondary pollution to the environment, so it is called the cleanest disinfectant [A]. In recent years, the development and research of hydrogen peroxide has become one of the hottest disinfection fields because of the introduction of stricter environmental protection and safety regulations, particularly in the combination of hydrogen peroxide disinfection and automatic control technology, the fastest progress has been made in the killing of special microorganisms, safety control in the process of disinfection, disinfection and sterilization during minimally invasive surgery, monitoring of sterilization efficacy, space disinfection robot and so on. Gasified hydrogen peroxide utilizes ultrasonic energy to form fine droplets in the gas phase, produce ultrasonic waves on the surface of the vibrating liquid, separate and break the droplets from the surface by an amplitude peak, and the disinfectant is ejected into 5 microms fine and uniform droplets, and the machine is equipped with 9 ultrasonic oscillations. Atomized droplets are carried into the air by jet stream and accelerate evaporation and vaporization to form gaseous hydrogen peroxide in the process of vibration.

2.2.2. Low Ozone Ultraviolet Lamp Group

Equipped with 9 25W low ozone ultraviolet lamp tubes, the disinfection robot

can achieve 70 uw/cm^2 irradiannce at least, and it is 6 - 8 times greater than the radiation power of ordinary ultraviolet lamp. When the robot starts to work, the lamp protection board opens, the top of it rises and 9 ultraviolet lamp tubes are exposed at the same time to begin to disinfect. The ultraviolet lamp tube shrinks and the protection board closes when the ultraviolet lamp tube is not working.

2.2.3. Plasma Air Purification

There are 2 plasma air purification modules on the side of the robot, which can provide plasma air disinfection and air purification, and a PM2.5 replaceable filter is placed in the filter panel.

2.3. Setting of Disinfection Points

It depends on the area and number of the isolation ward. There are 42 disinfection points. According to the effective wavelength of ultraviolet radiation, the distance between disinfection points is about 3 meters. There are 2 disinfection points in the double room, one disinfection points in the single room, 4 disinfection points in the six person room. 12 disinfection points are set in the corridor, one disinfection point is set in front of each ward, two disinfection points are set in the nurse station, and one disinfection point is set in the treatment room.

2.4. Remote Control

The staff gives instructions on the tablet computer and then the robot reaches the designated place to conduct the disinfection work according to the set disinfection mode. They do not need to enter the contaminated area, and the task can be completed by real-time monitoring robot on the tablet computer.

2.5. Self-Charging

A robot is equipped with a charging pile, which is installed in the nurse station according to their own installation conditions and the working requirements of the isolation ward. As long as meeting power supply and accessibility these two conditions, the charging pile can be installed. The charging pile can be plugged into the power supply at any time in the state of charging reserve. After the power is insufficient or the task is completed, the robot will automatically return to the charging pile through machine vision and the set route for charging.

2.6. Operational Procedure

The mode, time (immediate disinfection or regular disinfection) and place of disinfection are set up on the basis of the floor plan, the number of ward and the planned route of the area. The staff gives instructions on the tablet computer and then the robot reaches the designated place to conduct the disinfection work according to the set disinfection mode. The robot returns to the charging pile according to the planned route and charge automatically after disinfection (**Figure 1**).

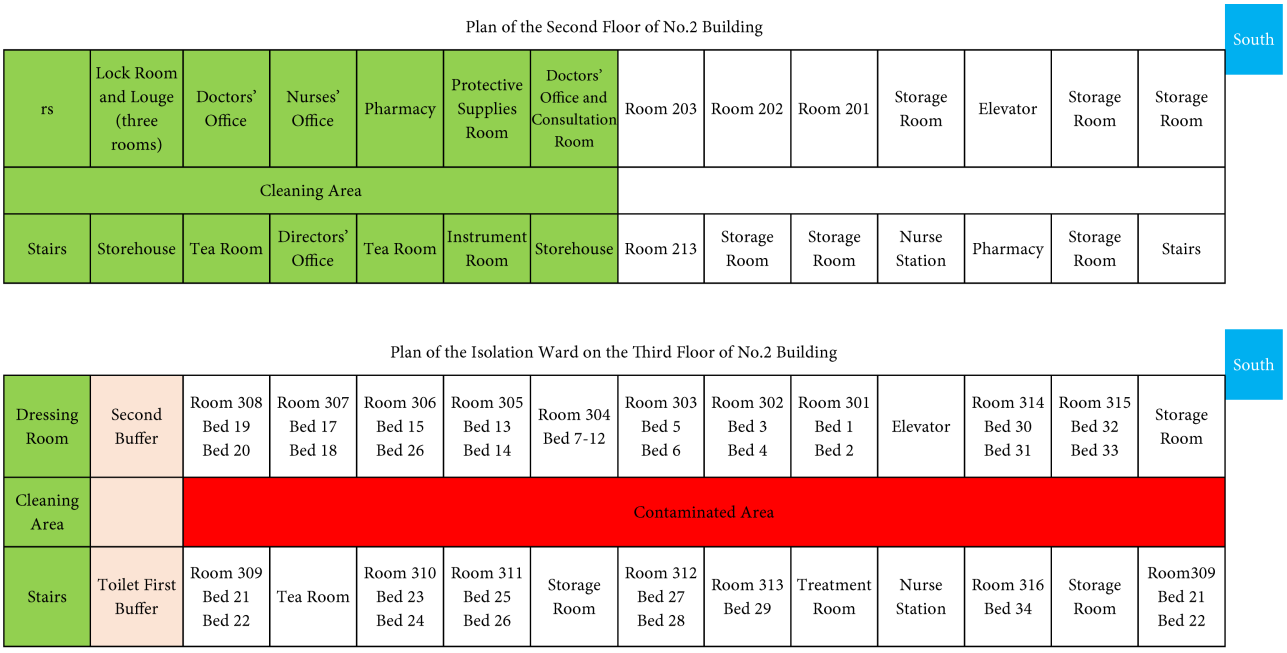

Figure 1. Plan of the isolation ward.

2.7. Set Disinfection Frequency

2.7.1. Regular and Fixed Disinfection

Patients in the isolation ward are confined to the ward for isolation, whose scope of activity, movement [3] and getting around is restricted. The work in the isolation ward is characterized by intensiving treatment and nursing work to reduce the staff's stay in the ward. Therefore, the public area of the isolation ward is only where medical staff is walking. It is easier to set a fixed frequency according to the working characteristics of the ward to sterilize the fixed point. Usually every noon, evening, early morning these three periods during the whole day are periods of low turnover in the ward, so rugular time for disinfection is fixed at twelve at noon, at eight o'clock in the evening and two o'clock in the morning. Disinfection mode is set to ultraviolet lamp irradiation disinfection and 7.5% hydrogen peroxide spray disinfection. The disinfection site is high-frequency point of use: nurse station (two points), treatment room, corridor (12 points). 6 points are disinfected at noon and each point is exposure to ultraviolet light for 30 minutes. 12 points are disinfected at evening and 12 points are disinfected at wee hours, and each point is exposure to 7.5% hydrogen peroxide spray 10 ml/m^3 for 60 minutes.

2.7.2. Sterilize at Any Time

80 - 120 ml perchloric acid spray is used as long as people exist for 60 minutes once in the morning and once in the afternoon.

2.7.3. Terminal Disinfection

High-level terminal disinfection with 7.5% hydrogen peroxide spray 10 ml/m^3 and ultraviolet lamp irradiation are used for 60 minutes, closed for 2 hours.

2.8. Personnel Training

The training is carried out in the clean area of the ward because of the risk of exposure and many inconveniences in the contaminated area of the isolation ward. First, the robot factory technician understands the structure and function of the ward according to the plan of the ward, and calculates the overall area of the ward, the area of the room, the length of the corridor, and the area. Technicians select a robot and a tablet computer that can receive good signal and the router is placed in a fixed, not easily occluded and alive position. Method of simulation training is used for training to ensure everyone gets it and there is a on-spot examination after training.

2.9. Disinfection and Maintenance of the Robot

The robot is made of corrosion-resistant smooth non-metallic material. The surface of machine is disinfected and wiped with the chlorine containing disinfectant twice a day, and the filter panel is removed and cleaned weekly (Figure 2).

3. Discussion

Personal protective articles should be used correctly and scientifically, which are divided into three levels according to the protection level requirements. The primary level of protection is applicable to the medical staff of the preview and triage, fever clinic (emergency) and department of infectious diseases: The requirement is wearing disposable working cap, disposable medical surgical mask and work clothes and, disposable latex gloves if necessary. The second level of protection is applicable to the medical staff of contacting with the patients who are admitted to the outpatient or the inpatient of the department of infectious diseases.

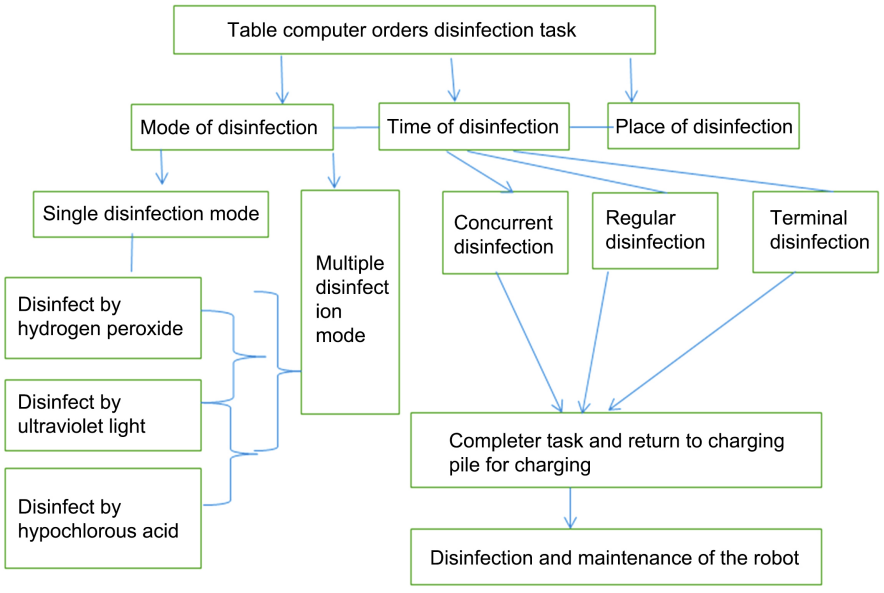

Figure 2. Workflow chart of the disinfection robot.

Specific activities include collecting speciments, handling ecretions or excrement, after using items and touching the dead patient's body. The requirement is wearing disposable work cap, anti-fog protective eyewear, medical protective mask (N95), protective clothing or disposable protective clothing and disposable latex gloves and disposable shoe cover when the medical staff enters the isolation area. The third level of protection is applicable to the medical staff who conducts operation such as suctioning collecting respiratory specimen, trachea intubation, tracheotomy or other similar situations, that are related to respiratory secretions and body fluids. The requirement is wearing disposable working cap, full-scale respiratory protector or positive pressure headset, medical protective mask (N95), protective clothing or disposable protective clothing, disposable latex gloves, and disposable shoe cover.

The primary way that COVID-19 appears to spread is respiratory droplet transmission and contact transmission, aerosol and digestive tract transmission route is undefined. The virus is sensitive to ultraviolet and heat, so 56˚C for 30 minutes, ether, 75% ethanol, chlorine-containing disinfectant, peracetic acid, chloroform and other fatsolvent can effectively inactivate the virus [1]. The major source of COVID-19 is the infected patients, and the asymptomatic carrier may also become the infection source, so people are generally susceptible. Disinfection and isolation is an important measure to prevent cross-infection, so disinfection work is the key and difficult point.

At present, artificial intelligence is more and more widely used in nursing field. Intelligent nursing with high technological content is one of the ways to satisfy the needs of people about nursing service. It can not only meet the needs of patients for high quality nursing care, improve nursing level, but also reduce the nursing staff's working intensity and regulate the distribution of nursing human resource which alleviates the shortage of personnel and the uneven distribution of resources to a certain extent but it's also a new challenge for nursing researchers and managers [4].

4. Conclusion

According to the hospital disinfection policies such as ***Technique standard for isolation in hospitals*** and ***Regulation of Disinfection Technique in Healthcare Settings***, intelligent disinfection is introduced in the isolation ward in allusion to the environmental characteristics and the needs of patients in outpatient and emergency departments, wards (ICU), etc. The robot can move independently to carry on the disinfection through the remote control setting and one key to set the mode, time and place of disinfection without the full participation, which realizes the man-machine separation and accurate disinfection. It reduces the chance of medical workers repeatedly wearing and taking off protective clothing to enter into or walk out of the contaminated area, which also reduces the chance of contact infection and exposure, so as to reduce occupational exposure and achieve occupational protection of medical staff to ensure hospital

zero infection rates. The problem of limited use of medical protective equipment resources caused by the increasingly prominent contradiction between supply and demand of medical protective equipment is solved with the introduction of robots. If an intelligent robot is engaged in disinfection work, the workload of medical staff can be alleviated. Medical workers are liberated from the heavy disinfection work and they can spend more time on patients, which can truly embody the concept of people-oriented. It can also save human costs and prevention and control supplies resources.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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