Application of Service Robots for Disinfection in Medical Institutions

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Abstract. Service robots are increasingly present in all fields of medicine. This paper presents a review of the service robots in medicine with an emphasis on service robots for disinfection in medical institutions. It is shown and described how more and more disinfectant service robots are contributing to a very simple, fast and effective disinfection in medical institutions. Work of the service robot with all necessary components for its function as well as its good and bad sides are in details elaborated and clarified. The aim is to demonstrate the application and use these service robots in medical institutions. Use of these service robots reduces the risk of infection, cost of traditional cleaning and disinfection, and most importantly acquires confidence and security in medical facilities.

Keywords: Service robots · Medical facilities · Disinfection · Infection

1 Introduction

At each visit hospitals or clinical centers we try to leave everything, if possible. This is because of the danger of new bacteria is high. It is mostly MRSA (methicillin-resistant Staphylococcus aureus), C. diff. (Clostridium difficile), VRE (Vancomycin-resistant enterococci) and of new pathogens such as MERS (respiratory syndrome). These microorganisms are resistant to antibiotics, and commonly referred to as “superbugs”. As a result of infection by these pathogens often involve considerable pain and suffering and many deaths. These infections are major problems and significant costs of modern health sector. Cleaning and disinfection are expensive and are not effective enough due to inaccessible areas. Since there is no way to force people to disinfect hands remains to introduce robots to disinfect[1].

The robots, which will be described in this paper is an attempt to reduce the risk of hospital infections. There are many ways of transmitting infections, and studies have shown that the greatest cause of contact surface such as: remote control, door handles or cabinets, a button to call for help, etc. UV-C disinfection robot provides an economical and effective measure in limiting the spread of bacteria. When bacteria are exposed to UV-C light of their DNA absorbs light energy and causes cell damage that prevents new infecting others. The robot is controlled by the medical staff and the time for which disinfect a room is 10–15 min depending on the size of the room. When operating the robot nobody should be present in the room because the UV-C light damages eyesight and adversely affects organism people.
Studies have shown that this method of disinfection kills more than 70% of bacteria compared to the traditional way, so it is necessary to introduce these robots in hospitals for prevention, reducing the spread of infections and reduce the cost of treatment of the same.

2 UV Light

UV-C has been a proven technology for disinfecting air, water and instruments for over a century. Niels Finsen was awarded the Nobel Prize for Medicine in 1903 for being the first to use “light therapy” to treat disease with direct disinfection of skin. By the 1930s, UV had come into common use throughout hospitals for air and water treatment and by WWII, UV was in widespread use in processing plants, water treatment facilities, and anywhere microbial contamination was a concern. UV gained fame in the 1950s for helping to eradicate TB before fading in use in the 1960s with the proliferation of antibiotics and chemical disinfectants [2, 3].

Now with the current focus on solving the crisis of rising multidrug resistant organisms (MDROs), healthcare acquired infections (HAIs), and treatment costs, UV has once again risen to the top of the list in the war against superbugs. After 100 years in healthcare use, UV has found a new application in hospitals providing surface disinfection of patient rooms, bathrooms, operating rooms (ORs), equipment rooms, and mobile devices[4].

The sun is by far the strongest source of ultraviolet radiation in our environment. Solar emissions include visible light, heat and ultraviolet (UV) radiation. Just as visible light consists of different colours that become apparent in a rainbow, the UV radiation spectrum is divided into three regions called UVA, UVB and UVC. As sunlight passes through the atmosphere, all UVC and most UVB is absorbed by ozone, water vapour, oxygen and carbon dioxide. UVA is not filtered as significantly by the atmosphere.

Particularly at wavelengths around 260–270 nm, UV breaks molecular bonds within microorganismal DNA, producing thymine dimers that can kill or disable the organisms [3].

- Mercury-based lamps emit UV light at the 253.7 nm line.
- Ultraviolet Light Emitting Diodes (UV-C LED) lamps emit UV light at selectable wavelengths between 255 and 280 nm.
- Pulsed-xenon lamps emit UV light across the entire UV spectrum with a peak emission near 230 nm [3] (Fig. 1).

The relatively long-wavelength UVA accounts for approximately 95% of the UV radiation reaching the Earth’s surface. It can penetrate into the deeper layers of the skin and is responsible for the immediate tanning effect. Furthermore, it also contributes to skin ageing and wrinkling. For a long time it was thought that UVA could not cause any lasting damage. Recent studies strongly suggest that it may also enhance the development of skin cancers.
3 Service Robots in Medicine

Robots have broad application in healthcare. Such robots include roving machines mounted with ipads to provide physician tele-presence, surgical assistance robots such as the Da Vinci system, drones for delivery of emergency or other medical equipment, assistive and therapeutic robotic devices used to increase the individual’s capability or rehabilitate, empathic robots used in the care of the older or physically/mentally limited individual, and industrial robots such as those used to sterilize patient rooms or for supply delivery. Other robots are in research and development stage now and still other applications of robotics in healthcare are being considered for the future. The world of service robots is in its infancy [5, 6] (Fig. 2).

![Comparison of UV LED and Mercury Lamp](chart.jpg)

**Fig. 1.** Comparison of UV LED and mercury lamp

**Fig. 2.** Service robots in medicine
Robots and robotics have entered the healthcare arena in a dramatic manner [5]. Countless needs are being addressed in new and different ways, and sometimes, for the first time! Robots, already, have wide-ranging healthcare applications within surgery, ambulation in the disabled, hospital operations, neuro-muscular rehabilitation, and emotional care and aging care, to name a few. Robust, exciting research of new applications of robotics in healthcare is thriving [5].

As robots take care of our more intimate needs, such as personal caregiving, human to robot and robot to human interactions will become a central focus of study and philosophical discussion. There is much unknown regarding the ultimate acceptability of robots in intimate settings, or at work. Comfort with robots may depend on multiple variables, such as the individual, culture, particular application, or industry. Trust is at the core of the use of autonomous robots in healthcare, and safety must be proven [7].

Once the qualifications of optimal design, answered needs, safety, and trust are met, “the sky is the limit” for robots and robotics in health [5]!

4 Service Robots for Disinfection

To solve the hospital disinfection problem, several design requirements had to be imposed. There are a myriad of design requirements for a commercial robotic disinfecter and even more if the robot is to operate in a hospital. The robot produces UV light in a hospital room and in 5 min it can drastically reduce the germs in room [8] (Fig. 3).

The device is run when the room is empty after a patient discharge and terminal cleaning. The xenon bulb in the device will pulse for 5 min disinfecting an area around the device. During this time the user stays outside the room. UVC light cannot go through safety glasses, walls or windows. However with prolonged exposure UVC
could damage eyes so always run the robot in an empty room. For additional safety there is an orange cone that stays outside of the room and guards at the door as well as caution signs for the door. Inside the room the gray cone watches the entrance to the room and detects motion. Should motion be detected during the pulsing of the light the gray cone will turn the device off you will use the device after you’ve finished cleaning a room but before the bed is made. For most rooms treating the bathroom with the UVC light first will save time because it is possible to work in the room while it is treating the bathroom (Fig. 4).

Like common illnesses for which humans ingest antibiotics, each pathogen that causes the most common healthcare associated infections has a known dosage, specifically a UVC dosage, at which it is deactivated or terminated. UVC disinfection dosage is a function of total intensity of UVC light and the length of exposure. Using higher intensity UVC light decreases the time needed to reach the appropriate dosage. Likewise, using lower intensity UV light lengthens the amount of time needed to reach the right UV dosage to kill dangerous pathogens [3].

What that means is that running a UV robot for less time than needed to achieve the germ-killing UV dosage enables HAI-causing pathogens to survive, creating the opportunity for patients to become seriously ill. The best way to prevent under-dosing, is to use UV robots that automatically measure room conditions in real time to calculate the power and time needed to achieve the right dosage.

With germ-killing UV light robots, there’s no guessing when disinfection is achieved. This patent pending SmartDosage UV technology incorporates proprietary algorithms that automatically adjust UVC dosage and treatment time as the robot operates, ensuring effective, complete treatment irrespective of variables such as room size, layout, furnishings, and environmental characteristics.

Figure 5 shows a robot which is used for disinfection of surgical theaters. From this we conclude that their use in medical institutions is represented in all departments. UVC robots provide hospitals, nursing homes and other critical care environments with the assurance that dangerous pathogens like Clostridium difficile (C. diff), Acinetobacter and M.R.S.A., to name a few, are attacked before the next patient occupies the room [7].
There is a large database of UVC effect on various organisms, from bacteria and viruses to fungi and spores. Standard term used effective dose is defined as the UVC light required to inactivate 90% of a given population (also called log1). Effective dose is defined as $H = \frac{UVC \text{ power} \times \text{time/irradiated area}}{	ext{Ws/m}^2}$. For example, E. coli requires a dose 30 Ws/m$^2$ while the standard fungi like Aspergillus niger requires a dose of 1320 Ws/m$^2$.

Headgear-mers virus is one of RNA viruses and are categorized together should dose between 15–400 Ws/m$^2$. Examples of well-known RNA virus doses are 110 Ws poliovirus/m$^2$, Newcastle disease 15 Ws/m$^2$ SARS 226 Ws/m$^2$. The assessment measured in the same region as high SARS can calculate real-time inactivity like to achieve 90% [3, 9].

5 Robot “IRIS 3200 m”

IRIS 3200 m is the most powerful system for disinfecting UV light in the world. His continuous UVC generate up to 20 times the UVC output tested xenon pulse system and three times the power of other constant light competitors.

The patented PowerBoost technology enables iris 3200 m UVC robot to provide the whole room disinfection one position in far less time than any other unit on the market, but unlike most of the competition, attacking shadows where many of the harmful organisms are staying (in some cases many months).
Built Patent SmartDosage, together with the patented box Balance and PowerBoost technology allow iris 3200 m UV lighting system of disinfection for automatically measuring conditions the room environment, such as the size of the room, temperature and humidity in order to determine in real time the appropriate dose, time, number and power of the lamp is required for complete disinfection of all while providing maximum power permitted in the United States for the production of germicidal UVC energy.

IRIS 3200 m is ideal for the hospital which require the maximum disinfection least amount of time. Managed by easy-to-use, wireless handheld Steri-Strip controller, iris 3200 m germ killing robot frees Environmental Services staff perform other tasks while the system is disinfected the whole room in one procedure.

Benefits Iris 3200 m UV light disinfection system are:

- Faster treatment room
- Higher productivity
- More effective treatments
- Highly pathogenic kills prices
- Whole-room treatments
- One placement
- One treatment

![Fig. 6. Robot IRIS 3200 m](image)
6 Xenex Germ-Zapping Robots

High intensity ultraviolet light is produced by xenon flash lamps across the entire disinfecting spectrum known as UV-C. This UV-C energy passes through the cell walls of bacteria, viruses and bacterial spores. The DNA, RNA and proteins inside the microorganism absorb this intense UV-C energy. Xenex Full Spectrum UV-C provides four mechanisms of damage against pathogens (Fig. 6).

Pathogens are vulnerable to UV-C light damage at different wavelengths depending on the organism. Xenex’s Pulsed Xenon lamps produce a flash of Full Spectrum germicidal light across the entire disinfecting spectrum (from 200 to 320 nm) delivered in millisecond pulses [10, 11].

The primary types of cellular damage caused by Pulsed Xenon UV are photohydration (pulling water molecules into the DNA that prevents transcription), photosplitting (breaking the backbone of the DNA), and photodimerization (improper fusing of DNA bases), all of which prevent cell replication. Additionally, photo crosslinking causes cell wall damage and can cause cell lysis, an irreversible form of cell death. Disinfecting across the entire spectrum helps prevent pathogens from repairing themselves [11] (Fig. 7).

Fig. 7. Four mechanisms of damage against pathogens
There are cheaper ways to generate disinfecting UV light. For example, mercury lamps have been used to disinfect surfaces and liquids for decades, and the bulbs are only about $100. However, they are 25,000 times less intense than a Xenon bulb and the disinfection process can take hours, making them impractical for hospital use. LEDs could also provide cheaper UV light, but they are also far less intense than Xenon bulbs, according to Hart [5, 11] (Fig. 8).

Advantage of UV light is that it kills germs without the use of chemicals. But surfaces need to be cleaned of fluids and dust first. UV light adds a final layer of protection. Xenex shine will destroy anything we can’t see [5]. When produced artificially here on Earth, UV-C rays can be blocked by a barrier as thin as a plastic bag. The robot comes with a motion sensor that turns itself off if it senses movement in the room while it is at work [3, 9].

7 Conclusion

Study showed that a “no-touch” semi-automated system, the UV light, was effective in substantially reducing the heterotrophic bacterial and MRSA burden on high-touch surfaces in rooms vacated by MRSA-positive patients. UVC disinfection may add to the armamentarium against HAI’s without risking the adaptive genetic resistance incurred by pharmaceutical weapons. Implementation including training personnel to operate the device is minimal, and time spent cleaning was not increased. Because there
were separate cycles for bathroom and living room, the surface reduction in aerobic colony counts may be better than with other UV systems; a head-to-head comparison of UV area disinfection devices may be warranted.

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