

Special Issue Research Article

Experience with UV-C Air Disinfection in Some Russian Hospitals[†]

Grigory Volchenkov* 

Regional TB Control Center, Vladimir, Russia

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ABSTRACT

Although the environmental control measure of ultraviolet germicidal irradiation (UVGI) for disinfection has not been widely used in the United States and some parts of the world in the past few decades, this technology has been well applied in Russia. UVGI technology has been particularly useful with regard to limiting TB transmission in medical facilities. There is good evidence that UV-C (180–280 nm) air disinfection can be a helpful intervention in reducing transmission of the SARS-CoV-2 virus.

INTRODUCTION

Whole-room ultraviolet germicidal irradiation (UVGI) is quite commonly used in healthcare facilities of Russia and other countries of the former Soviet Union. Our national regulations require that whole-room UVGI to be used for air and surface disinfection along with disinfectant aerosols or air filtration in “aseptic areas” (operation theaters, procedure rooms, etc.) in surgical and infectious disease departments (1). UVGI is also widely used in clean aseptic cabinets for sterile instrument and material storage. Most of the whole-room UV-C fixtures are of wall-mounted design with one or two T8 30W germicidal lamps. Since 2003, when upper-room UVGI was introduced in TB control facilities of the Vladimir region, this approach has been employed in clinics and hospitals. The Regional TB Control Center in Vladimir, Russia, became a center of excellence for TB infection prevention and control (IPC) in 2007, supported by the US Centers for Disease Control and Prevention (CDC, Dr. Paul A. Jensen), and implemented a comprehensive program for the reduction nosocomial TB transmission comprising several components (2,3).

MATERIALS AND METHODS

In high and medium TB transmission risk areas, environmental controls (mechanical ventilation and upper-room UVGI) are used together to reduce the concentration of airborne infectious aerosols for TB transmission risk reduction for patients, medical staff and visitors. Over 240 UV-C fixtures with low-pressure mercury lamps (emitting primarily UVGI in the UV-C 254-nm wavelength) are currently installed. The upper-room portion of the UV-C fixture is used 24 h/day, 7 days per

week (24/7) in the high- and medium-risk areas of the Center’s hospital building. With total floor area of 6,000 square meters, there is approximately one UV-C fixture per 18 m².

A schematic of the wall-mounted UV-C fixture is shown in Fig. 1. When irradiation of the upper portion of the room was desired (i.e., upper-room UVGI), the upper lamp, a T8 straight-tube, 30-W, 254-nm UVGI lamp (OSRAM, Philips or others, procured on tenders with acceptance criteria for total UVGI output) was turned on. The UVGI would be emitted through the “slot” in the upper portion of the UV-C fixture. Depending on the room geometry, including the ceiling height, the upper baffle would be moved to emit more or less UVGI. The goal was to have safe UVGI levels in the occupied space and UVGI levels as high as possible in the upper portion of the rooms. National norms still require the use of whole-room UVGI two-to-three times a day, for a minimum of 45 min. During these time periods, the lower UVGI lamp would be energized and not occupants were allowed in the space. Warning signs were posted. Staff and patients were trained and educated on the rationale for upper- and whole-room UVGI as well as its safe use. Fig. 2a and b show one of these UV-C fixtures operating with the room lights on and with the room lights off to better show their operation.

These UV-C fixtures are installed in patient rooms, corridors, waiting areas, procedure rooms, intensive care units, toilets, physician’s rooms, *et al.* As previously stated, the upper-room UVGI portion of these UV-C fixtures was operated 24/7. Before using the whole-room UVGI portion of the UV-C fixture, all surfaces are be cleaned and chemically disinfected. A typical patient room in the hospital is designed for two beds and has a floor area of 17 m², ceiling height 3.2 m and is equipped with one UV-C fixture.

These UV-C fixtures are installed 2.2–2.3 m above the floor level and have a separate switch for each lamp as well as a warning light, located in the corridor at the entrance to the room (Fig. 3), along with the

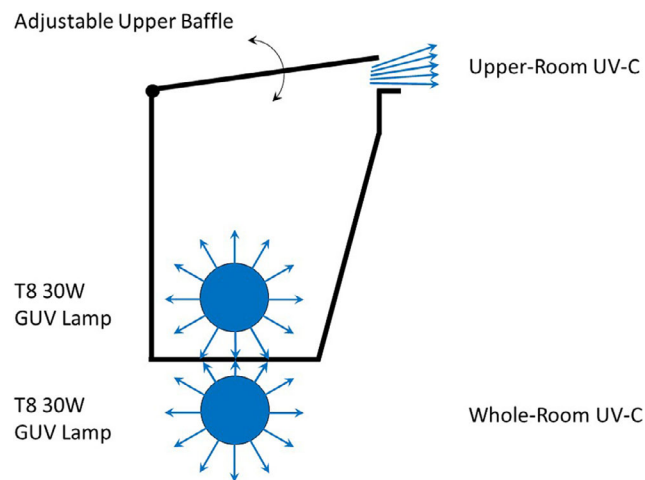


Figure 1. Schematic of side view of UV-C fixture manufactured in Vladimir, Russia

*Corresponding author emails: vlchnkv@yahoo.com, root@tubdisp.elcom.ru (Grigory Volchenkov)

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a)



b)

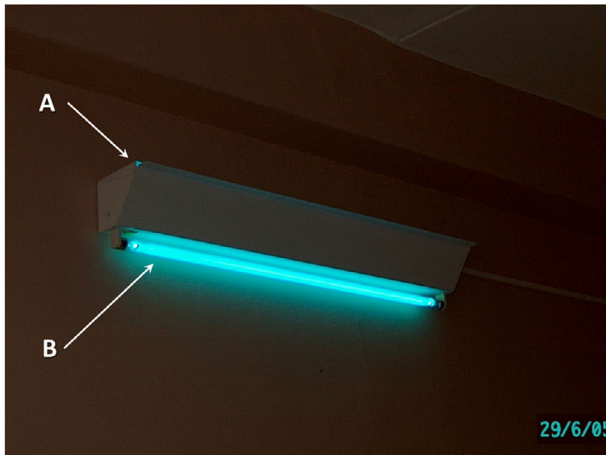


Figure 2. UV-C fixture in a Waiting Room at Regional TB Hospital with room lights on. These fixtures, manufactured in Vladimir, Russia, employ two T8 30W low-pressure mercury lamps. (A) Upper-room UVGI. The upper lamp, which is currently on, is operated 24/7 (i.e., when the room is occupied or unoccupied). (B) Whole-room UVGI. The lower lamp, which is currently off, is turned on for whole-room irradiation, when the room is unoccupied

appropriate signage. Our UV-C fixtures are inexpensive and were easy to manufacture by local company “Spetstekhnika-Vladimir LLC” using design concept developed by Paul A. Jensen (CDC). The total UVGI output of the upper-room portion of these fixtures is 0.41W, as measured using a modified Rudnik method (3,4). Mechanical ventilation and heating radiators provide air mixing to improve upper-room UVGI disinfection efficiency.

A trained technician uses a Gigahertz-Optik X9_{11μ} UV-C meter with a UV-3718-4 detector (Gigahertz-Optik, GmbH, Türkenfeld, Germany) for monitoring UV-C fixture performance for both air disinfection effectiveness and safety for occupants in lower-room space. Based on lamp depreciation measurements made during the first few years of operation, we found that the measured UVGI level of 254 nm in the air treatment zone at 1m should exceed 250 $\mu\text{W cm}^{-2}$ with less than 1% reduction in 168 h. In addition, UVGI measurements were taken at standing eye height (1.65 m) as well as other locations throughout the space to ensure the irradiance was no more 0.1 $\mu\text{W cm}^{-2}$, the current Russian regulation. These assessments were performed every six months and dutifully recorded. Lamp replacement is based on the biannual UVGI measurement at 1 m distance from the UV-C fixture in the upper-room. Maintenance



Figure 3. Multi-use UV-C fixture is shown in a hallway adjacent to a patient room along with the two-function switch for operation of: (a) the upper louvered, UVGI lamp for upper-room UVGI and is operated 24/7, including when occupied; and, the lower, an unshielded UVGI lamp for whole-room UVGI

of these UV-C fixtures includes routine (every 2 months) lamp and fixture cleaning with 70% ethyl alcohol and lintless gauze or cotton.

RESULTS AND DISCUSSION

In our 17 years of experience with these UV-C fixtures in the hospital, no overexposure cases have been reported with respect to operating the upper-room UVGI portion of the UV-C fixture. Unlike the upper-room UVGI configuration, whole-room irradiation misuse has caused, although rarely, some overexposure incidents. Staff and patients are very compliant in using the upper-room UVGI portion of these UV-C fixtures 24/7. Due to the comprehensive TB IPC program implemented in the Vladimir region, which includes administrative and environmental measures (including mechanical ventilation and upper-room UVGI) along with personal respiratory protection, TB transmission risk has been reduced dramatically. The occupational TB relative risk dropped from a value of 22 to values less than 1.0 during first 3–4 years of program implementation and has remained low ever since. In 2003, we had approximately 250 employees and we now have 350 employees. Employees are screened on an annual basis as well as if symptomatic.

This airborne TB IPC program, with added contact precautions, appears to be very effective in controlling SARS-CoV-2 transmission as well. No transmission has been reported among hospitalized TB and HIV patients; however, several community-acquired COVID-19 cases among the Center staff took place in April-June 2020. All staff and patients are screened daily for body temperature and symptoms. Symptomatic persons are immediately placed in isolation and a rapid test is performed using Xpert SARS-CoV-2. Monthly, all staff are tested for IgG and IgM. In addition, Xpert SARS-CoV-2 testing I performed on previously positive patients to assess infectiousness and assist in determining when to discontinue isolation.

As in most other countries, other hospitals which did not have upper-room UVGI (i.e., only had traditional whole-room UVGI) and other effective airborne precautions (rapid SARS-CoV-2 testing followed by prompt airborne isolation, controlled ventilation,

certified FFP2 or N95 respirators within personal respiratory protection program) as routine IPC measures experienced high SARS-CoV-2 transmission among the hospital staff. Upper-room UVGI is also used in other Russian regions (Orel, Karelia, Khabarovsk, etc.) as well as in other countries of Eastern Europe and Central Asia (Belarus, Ukraine, Tajikistan, Kyrgyzstan, Kazakhstan etc.).

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