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Evaluation of the Effectiveness of Pulsed Ultraviolet Devices in Medical Premises of the Emergency Department of a Hospital Under Conditions of Intensive Patient Flow

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INTRODUCTION In the State Budgetary Healthcare Institution N.V. Sklifosovsky Research Institute for Emergency Medicine of the Moscow Health Department (hereinafter referred to as the Institute), the number of visits to the admission and diagnostic departments has more than doubled over the past 15 years. Emergency patients are considered potentially infected, therefore, it is necessary to carry out high-quality and timely disinfection of open surfaces and air. The use of pulsed ultraviolet disinfection technologies is effective and cost-effective.

AIM OF THE STUDY Evaluation of the microbiological efficiency and economic feasibility of using a portable pulsed ultraviolet unit for disinfecting air and open surfaces during emergency patient reception in conditions of intensive patient flow for the purpose of preventing healthcare-associated infections.

MATERIAL AND METHODS To disinfect the air and surfaces of the premises, we used the "Alpha-09 portable pulse ultraviolet unit" (hereinafter referred to as the Unit) manufactured by NPP Melitta LLC, Russia.

To conduct the study, three rooms were designated in the admissions department: two experimental rooms and one control room.

Routine wet cleaning of the premises was carried out twice a day, and also as needed. Preventive disinfection of work surfaces was carried out after each patient by wiping with the use of approved products.

The experimental premises were treated according to a single standard algorithm, including treatment with the Installation.

To collect microbiological swabs, sampling points were defined in the studied premises (4 in each). The sampling frequency was three times a week, twice a day. A surface swab collection table was filled in for each of the premises. Surface swab samples were signed accordingly and transferred to the bacteriological laboratory for testing. Surface swabs were collected in accordance with MUK 4.2.2942-11. The species affiliation of microorganisms was confirmed by MALDI-TOF-MS.

The obtained results were processed by standard means of mathematical statistics using R, a free software computing environment. The reliability of differences in numerical values was determined using Student's t-test, and categorical values were determined using the χ^2-test or McNamara test .

To assess the economic efficiency of using pulsed UV devices, methods of economic analysis and investment assessment were used.

RESULTS 1. An additional 3-fold irradiation of the procedure room with a pulsed ultraviolet installation during an 8-hour shift reduced the number of positive surface swab samples 12-fold; 2-fold irradiation – 5-fold, compared to the standard procedure for processing rooms.

2. Comparison of annual comparable costs of pulsed ultraviolet devices with annual effects from their use showed the economic feasibility of their use.

CONCLUSION The use of short-term pulsed UV irradiation for disinfection of premises between patient visits is epidemiologically effective and economically feasible.

Keywords: healthcare-associated infections, room disinfection, air disinfection, ultraviolet irradiation, microbiological efficiency, economic feasibility, infection prevention

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CT — computed tomography
HAI — healthcare associated infections
UV — ultraviolet radiation

INTRODUCTION

Changes occurring in the social, economic and demographic structure of Moscow have an impact, among other things, on the situation in medical care for the population. The load on medical institutions and, first of all, on emergency and urgent care services is constantly growing [1].

In the State Budgetary Healthcare Institution "N.V. Sklifosovsky Research Institute of Emergency Care of the Moscow Health Department" (hereinafter referred to as the Institute), the number of visits to the admission and diagnostic departments and hospitalizations in the clinical departments of the Institute has increased more than 2-fold over the past 15 years. All this leads to the fact that emergency medical care in hospitals is rapidly developing and is acquiring ever-increasing importance.

With a significant increase in patient flow, there is a significant need to optimize the logistics of admission and diagnostic departments in order to reduce the time it takes for patients to pass through the admission department, improve the quality of service (including using high-tech methods), and reduce the amount of time and resource costs to improve the processes of providing medical care, taking into account the methodological aspects of optimizing the involvement of medical personnel [2, 3].

The strategic objective of healthcare remains to ensure the quality of medical care and create a safe environment for patients and medical workers in organizations carrying out medical activities [4].

An unresolved problem of modern medical - practice is the problem of healthcare-associated infections (HAI), which potentially accompany all types of medical activities, and it is also one of the global world problems [5–9]. The relevance of HAI prevention is determined by their widespread distribution, negative consequences for the health and lives of patients, personnel of medical organizations, an increase in the cost of providing medical care, including in inpatient settings due to an increase in the duration of treatment, a decrease in bed turnover, leading to an increase in the health care industry's need for additional resources [10–12].

Therefore, one of the priority areas of healthcare is the development and implementation into practice of modern and highly effective measures to ensure the epidemiological safety of medical activities, including the use of high-tech methods.

Due to the fact that all patients urgently admitted to the Institute's emergency departments are considered potentially infected, when providing medical care there is a need to carry out a high-quality, timely and complete range of preventive and sanitary-anti-epidemic measures using new technologies and means.

The main section of ensuring the epidemiological safety of medical activities is the implementation of comprehensive disinfection measures to disinfect the air and surfaces of premises [13], and one of the most effective and efficient technologies for the simultaneous disinfection of air and working surfaces of premises is their irradiation with continuous-spectrum ultraviolet (UV) radiation generated by a pulsed xenon lamp [4, 14]. Pulsed UV units created by the Russian Scientific and Production Enterprise Melitta on the basis of this technology have shown high biocidal activity in numerous studies. A series of studies on the effectiveness of disinfection of air and various types of surfaces conducted at the Federal Budgetary Scientific Institution Research Institute of Disinfection of Rospotrebnadzor, the Federal Budgetary Scientific Institution Central Research Institute of Epidemiology of Rospotrebnadzor, and the Federal State Institution Moscow Research Institute of Epidemiology and Microbiology named after G.N. Gabrichevsky Rospotrebnadzor and the 48th Central Research Institute of the Ministry of Defense of the Russian Federation demonstrated the ability of pulsed UV units to inactivate a wide range of dangerous bacterial and viral carriers of infection in a short period of time (up to 10 minutes) with high efficiency (up to 100%) - *MRSA* , *VRE* , MDR and XDR strains of Mycobacterium ttuberculosis, *Clostridium difficile spores, Aspergillus niger* conidia, *SARS-CoV - 2* coronavirus , etc. [15, 16]. Studies at the Central Research Institute of Epidemiology revealed the ability of a portable pulsed UV unit to disinfect the air and open surfaces of a therapy room with an intensive patient flow in 1 minute with an efficiency of 95.0% in the conditions of an outpatient appointment between patient appointments [17–19]. At the moment, there are no comparable solutions in the world. For the first time for UV-based installations, Roszdravnadzor registered target modes in 2018 and 2020 for new-generation installations "Alpha-06" (mobile) and "Alpha-09" (portable) for air disinfection ("Bactericidal", "Emergency") and surfaces ("Bactericidal", "*COVID* - 19", "Sporicidal", "Tuberculocidal and fungicidal" [15].

Studies of the effectiveness of pulsed UV units in a hospital providing emergency and urgent care were conducted at the N.V. Sklifosovsky Research Institute for Emergency Medicine of the Moscow Health Department during disinfection of the emergency operating room of the surgical block, the minor operating room of the resuscitation and intensive care unit for emergency detoxification, the dressing room of the burn department, in the workrooms of the bacteriological laboratory, in the morgue and the basement of the pathology department. The units ensured a 2–5-fold reduction in contamination of room surfaces with an initially high level [16].

Currently, the Institute successfully uses about 70 pulsed UV units of all models. They are used in operating rooms, intensive care and clinical departments, burn and vascular centers, as well as in laboratories.

In accordance with this, it seems relevant and justified to evaluate the effectiveness of using complex disinfection measures in the premises of the admissions department in conditions of intensive patient flow with the additional use of the "Alpha-09 portable pulsed ultraviolet unit for disinfection of air and surfaces of premises" manufactured by Melitta LLC (hereinafter referred to as the Unit).

The aim of the work is to evaluate the microbiological efficiency and economic feasibility of using a portable pulsed UV unit for disinfection of air and open surfaces of medical premises "Alpha-09" manufactured by LLC "Melitta" in the admission department of an emergency hospital in conditions of intensive patient flow for the purpose of preventing HAI while observing the rules for cleaning and carrying out all types of preventive and focal disinfection provided for by sanitary legislation.

MATERIAL AND METHODS

To disinfect the air and surfaces of the premises, the "Alpha-09 portable pulse ultraviolet unit according to TU MYURA.941712.009" (hereinafter referred to as the "Unit") manufactured by Melitta LLC, Russia (Fig. 1) was used.

Fig. 1. General view of the Alpha-09 device

Registration certificate No. RZN 2019/8554 dated 27.06.2019. Certificate of conformity GOST R No. ROSS RU C-RU.AK01. H.05300/19 until 06.08.2022. EURASIAN ECONOMIC UNION, DECLARATION OF CONFORMITY, Registration number of the declaration of conformity: EAEU N RU D-RU.PA05.B.44499/22, Date of registration of the declaration of conformity: 09.08.2022

The unit has high performance and mobility, is equipped with a touch panel and remote control, synchronized with each other, which ensures ease of operation. It is designed to disinfect air and open surfaces of medical premises from all types of pathogenic microorganisms (bacteria, their polyresistant hospital strains and spore forms, fungi and viruses, including *SARS-COV* -2), for preventive and focal disinfection, as well as emergency disinfection in medical premises with a large patient flow.

There are target and emergency modes for disinfecting air and open surfaces, an individual user password to prevent unauthorized activation of the unit, a security system that automatically switches off the unit when people enter the room being treated, and a built-in treatment log with detailed data on all disinfection sessions performed.

Three rooms in the Central Admissions Department have been designated as the premises for the study, taking into account the main requirements of SanPiN 3.3686-21 "Sanitary and Epidemiological Requirements for the Prevention of Infectious Diseases" and SP 2.1.3678-20 "Sanitary and Epidemiological Requirements for the Operation of Premises, Buildings, Structures, Equipment and Transport, as well as the Conditions of Operation of Economic Entities Selling Goods, Performing Work or Providing Services":

— Immunoprophylaxis room #1123; the room was chosen as a control room and was not exposed to the irradiation by the Unit. Dimensions: length — 5.86 m, width — 3.05 m, height — 3.5 m, volume — 53.62 m3 · Types of manipulations performed — vaccination (injections of immunobiological drugs). Patient flow during the day — 0.8 people/hour;

— procedure room #1131; the room was chosen as an experimental one and was processed by the Installation. Dimensions: length — 5.83 m, width — 3.55 m, height — 3.5 m, volume — 72.44 m3 · The main type of manipulation is taking blood from a vein. Patient flow during the day — 3.3 people/hour;

— computed tomography (CT) room #1377; the room was selected as an experimental one and was processed by the Unit. Dimensions: length — 8.75 m, width — 5.2 m, height — 3.5 m, volume — 159.25 m^3. Types of manipulations: undressing/dressing the patient, putting on X-ray protective clothing, laying the patient on the table, fixing the patient, conducting studies. Patient flow during the day — 1.9 people/hour.

The parameters of each room (length, width and height) were recorded in the installation's memory. The study was conducted from April 25 to July 18, 2022.

To collect microbiological swabs, sampling points were defined in the study rooms. Four sampling points were defined in each room: upper surface of the bench; upper surface of the trolley table; cabinet surface; refrigerator surface. Sampling frequency: 3 times a week (Monday, Wednesday, Friday). Sampling was carried out twice a day: the first sample was collected during the day between procedural manipulations and before treatment with the unit; the second sample was collected in the evening after procedural manipulations and after treatment with the unit. Swabs were taken from the surfaces in accordance with MUK 4.2.2942-11 "Methods of sanitary and bacteriological studies of environmental objects, air and sterility control in healthcare organizations". The species of microorganisms was confirmed by matrix-activated laser desorption/ionization time-of-flight mass spectrometry (*MALDI-TOF-MS*). Microorganisms related to sanitary-indicative microflora were identified on the surfaces of objects in the hospital environment.

The obtained results were processed by standard means of mathematical statistics using *R* - a free software computing environment. The average errors of the indicators were calculated. The statistical significance of differences in numerical values was determined using Student's t -test, and categorical values - using the χ^2 criterion or McNamara criterion. In both cases, the level of statistical significance *p-value* was chosen to be 0.05 [20].

In order to assess the economic efficiency of using pulsed UV units, methods of economic analysis and investment assessment were used [21–26], while annual comparable costs for the units were compared with the annual effects of their use in the hospital as a whole, as well as an assessment of annual comparable costs taking into account the technical and economic characteristics of the units (cost, capacity, duration of 1 processing cycle, standard service life of the unit, number of processing cycles by 1 unit per day).

RESULTS

The disinfection of the premises of the admission department was carried out in accordance with the current SP 2.1.3678-20 "Sanitary and epidemiological requirements for the operation of premises, buildings, structures, equipment and transport, as well as the conditions of activity of business entities engaged in the sale of goods, performance of work or provision of services" and SanPiN 3.3686-21 "Sanitary and epidemiological requirements for the prevention of infectious diseases". Clause 3574 of this document requires the use of equipment and (or) chemicals permitted for this purpose, the following technologies for disinfecting the air in the premises: exposure to UV radiation using open and combined bactericidal irradiators (including pulse units), used in the absence of people. Due to the intensive work schedule of the admission department in the context of *the COVID* -19 epidemic, we took into account the recommendations of Rospotrebnadzor in MR 3.1.0229-21 "Recommendations for the organization of anti-epidemic measures in medical organizations providing medical care to patients with a new coronavirus infection (*COVID* -19) (suspected disease) in inpatient settings", approved by the Chief State Sanitary Doctor of the Russian Federation A.Yu. Popova on 01/18/2021. "... When carrying out final disinfection in wards, as well as for disinfecting the air in rooms in the absence of people, pulsed xenon bactericidal irradiators of a continuous spectrum can be used ..." (clause 3.14). According to the order of the Ministry of Health of the Russian Federation No. 388n dated June 20, 2013 "On approval of the Procedure for the provision of emergency, including emergency specialized, medical care (as amended on February 21, 2020)", the standard equipment of the admission department and the computed tomography room includes a Bactericidal irradiator/air purifier/device for disinfection and (or) filtration of air and (or) disinfection of surfaces. The installation fully complies with this term.

Routine wet cleaning of the premises was carried out at least twice a day, and also as needed. Preventive disinfection in the immunoprophylaxis room #1123 (control room), procedure room #1131 (experimental room) and CT room #1377 (experimental room) was carried out as follows: after each patient, the surface of the couch and manipulation table with which the patient came into contact were manually wiped using detergents and disinfectants approved for use.

Also, in each room under study, air was disinfected using a bactericidal wall-mounted UV recirculator. The disinfectants used at the Institute are ToriOksi, ToriCid; skin antiseptic is ETAL GEL.

For the purpose of uniformity, a standard algorithm has been defined for processing experimental rooms with the Installation.

After sampling for each of the two rooms, a table of sampling swabs from the room surfaces was filled in. The samples of swabs from the surfaces were signed accordingly and transferred to the bacteriological laboratory of the State Budgetary Healthcare Institution "N.V. Sklifosovsky Research Institute for Emergency Medicine of the Moscow Health Department" for sowing and analysis. After receiving the sowing results, a table of etiological decoding of swabs from the room surfaces was filled in.

Microbiological examination of work surfaces in rooms No. 1123, 1131 and 1337 showed the following.

The results of the microbiological study in room No. 1123 (control) from 04/25 to 07/25/2022 are presented in Table 1.

When analyzing the results of swab samples from the surfaces of the control room, presented in Table 1, the insufficient effectiveness of the generally accepted schemes of anti-epidemic measures (provided for by the current sanitary regulations) is shown, expressed in the presence of 6.9% of positive samples at the beginning of the day (10:00) with a - gradual statistically significant increase to 7.6% by 14:00 (p = 0.00001, McNamara criterion).

The results of the microbiological study of room No. 1131 (experimental) from 25.04. to 25.07.2022 are presented in Table 2.

Table 1

Microbiological study in room #1123 (control)

Sampling points	Total number of samples	Number of positive samples	% ratio of positive samples	Total number of samples	Number of positive samples	% ratio of positive samples
Sampling time	10:00			14:00		
Upper surface of the bench	36	6	16.7	36	6	16.7
Upper surface of the rolling table	36	2	5.6	36	4	11.1*
Upper surface of the cabinet	36	1	2.8	36	0	0*
Upper surface of the refrigerator	36	1	2.8	36	2	5.6*
Total number of samples in the room	144	10	6.9	144	12	7.6*

Notes: * — a statistically significant increase in the number of positive samples is observed at 10:00 and 14:00 hours

Table 2

Microbiological study of room #1131 (experimental)

Sampling points	Total number of samples	Number of positive samples	% ratio of positive samples	Total number of samples	Number of positive samples	% ratio of positive samples
Sampling time	Before processing (10:00)			After processing (14:00)		
Upper surface of the bench	36	7	19.4	36	1	2.8*
Upper surface of the rolling table	36	1	2.8	36	0	0*
Front surface of the cabinet	36	1	2.8	36	0	0*
Front surface of the refrigerator	36	3	8.3	36	0	0*
Total number of samples in the room	144	12	8.3	144	1	0.7*

Table 2 shows statistically significant results of statistical analysis of surface swab samples from experimental room No. 1131. It was determined that the procedure of irradiating surfaces with the Installation with a frequency of 3 times a day (morning, afternoon, evening), using 2 treatment points and 5 minutes of exposure in between procedures, leads to a statistically significant significant decrease in the level of surface contamination by 12 times (from 12 positive samples to 1, respectively) (p = 0.00001, McNamara criterion) compared to the control room No. 1123 (Fig. 2).

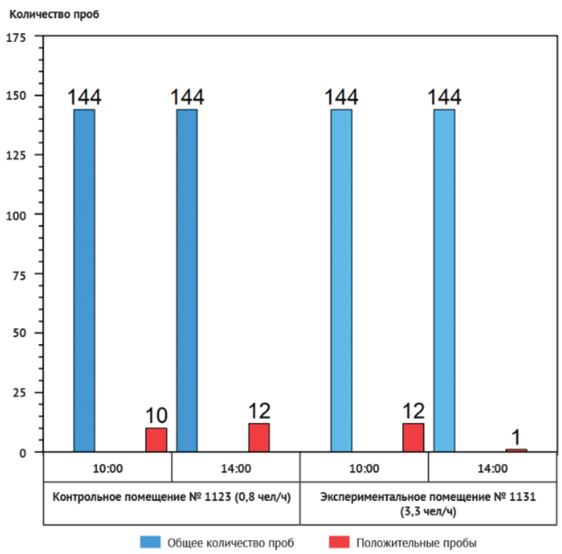

Fig. 2. Comparison of the number of positive samples between control room #1123 and experimental room #1131 with three-time daily treatment

The results of the microbiological study of room No. 1337 (experimental) from 25.04. to 25.07.2022 are presented in Table 3.

Table 3 and Fig. 3 clearly show the results of the studies of experimental room No. 1337. It was found that the additional use of the Installation led to a statistically significant (p = 0.00001, McNamara criterion) decrease in the total number of positive swabs after processing at 14:00 by 4.8 times compared to samples before processing at 10:00 (29 positive samples instead of 6). The number of positive samples on surfaces with an increased risk of infection (roll-over table and tomograph surfaces) was reduced 3.8–6 fold (p = 0.00001, McNamara criterion). A comparison of the results in two experimental rooms No. 1131 and No. 1337 (see Fig. 3) shows that the number of positive samples taken from surfaces after treatment with the unit at 14:00 is statistically significantly higher - 6 positive samples versus 1 (p = 0.0027, McNamara criterion), which is probably due to a reduction in the number of treatments carried out in this room with the Unit per day (two treatments instead of three).

As a result of the assessment of economic efficiency using methods of economic analysis and investment assessment, it was determined:

— taking into account the accepted total volume of hospital premises to be processed, the estimated number of units is 132 units;

— required capital investments in premises disinfection installations — 271.92 million rubles, while annual comparable capital investments amount to 62.8 million rubles;

Table 3

Microbiological study of room No. 1337 (experimental)

Sampling points	Total number of samples	Number of positive samples	% ratio of positive samples	Total number of samples	Number of positive samples	% ratio of positive samples
Sampling time	Before processing (10:00)			After processing (14:00)		
Upper surface of the tomograph table	36	5	13.9	36	0	0*
The side surface of the tomograph table is below the edge of the disposable diaper	36	11	30.6	36	3	8.3*
Front surface of UV recirculator	36	1	2.8	36	1	2.8*
Upper surface of the rolling table	36	12	33.3	36	2	5.6*
Total number of samples in the room	144	29	20.1	144	6	4.2*

Notes: * — a statistically significant increase in the number of positive samples is observed at 10:00 and 14:00 hours

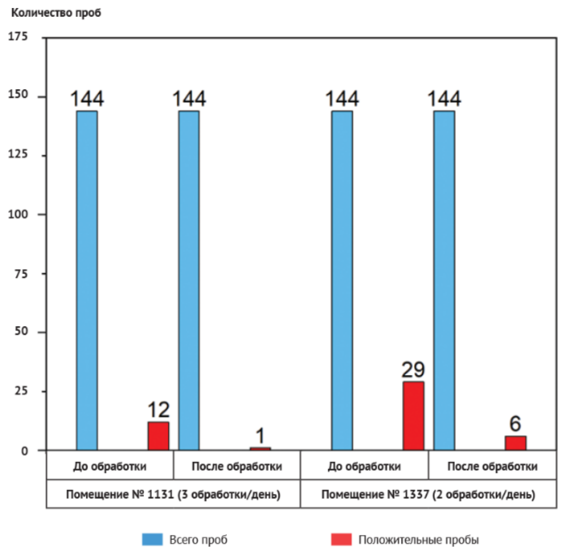

Fig. 3. Comparative results of studies of treated rooms No. 1131 and No. 1137

— annual comparable costs, taking into account annual comparable capital investments, with the standard service life of the installations (5 years) are: costs for electricity consumption, taking into account the electricity tariff and technical maintenance, including the cost of consumables (replacement of lamps in the Installations) are 74.6 million rubles.

In order to assess the effects of using the Installations, it should be noted that scientific publications often note that HAIs significantly increase both the length of stay of patients in hospital and the costs for each such patient, which confirms the idea of a significant effect of reducing bed days and optimizing the use of hospital beds when using pulse Installations.

Due to the lack of possibility of obtaining within the framework of this study a statistically significant volume of observations on the reduction in bed-days from the use of the Installations in the example we are considering, it is advisable to estimate the value of the reduction in bed-days, the minimum required to ensure the payback of the project.

In the example under consideration, the reduction in the number of bed days per patient, which would ensure the break-even point of the project, taking into account the annual patient flow, was 0.0746 c/d (less than 1 c/d), while the volume of freed up bed days per year, ensuring the break-even point of the project, was 4,217 c/d per year.

Thus, the results of the conducted analysis confirmed the economic feasibility of the project for the use of pulsed UV installations for disinfection of hospital premises.

For a more accurate assessment of the volume of the expected economic effect, it is necessary to conduct additional studies on reducing the number of days of hospital stay for patients while ensuring the required level of disinfection using the Installations.

CONCLUSION

1. High performance of the portable pulsed ultraviolet unit "Alpha-09", mobility, ease of operation, touch panel and remote control, synchronized with each other, availability of target and emergency modes for air and open surfaces disinfection, individual user password to prevent unauthorized switching on of the unit, security system that automatically switches off the unit when people enter the treated room, built-in treatment log with detailed data of all disinfection sessions ensure high efficiency of surface disinfection in combination with minimal exposure time, simplicity and convenience of disinfection measures.

2. The use of pulsed ultraviolet installations for disinfection of premises of medical organizations is economically feasible due to the reduction in bed-days of patients' stay during the prevention of infections associated with the provision of medical care, as well as the corresponding material costs and labor resources.

3. For the purpose of preventing infections associated with the provision of medical care, the medical device "Portable pulsed ultraviolet unit for disinfection of air and surfaces of premises "Alpha-09" manufactured by LLC "Melitta" (Russia) can be recommended for use in medical and other organizations in premises with an intensive client/patient flow, subject to compliance with the rules for cleaning and carrying out all types of preventive and focal disinfection provided for by sanitary legislation.

FINDING

As a result of the research conducted, it was established:

1. In the premises of the admission department of the N.V. Sklifosovsky Research Institute for

Emergency Care of the Moscow Health Department with a high patient flow (immunoprophylaxis room, procedure room, computed tomography room), despite the daily disinfection measures (repeated wiping of surfaces with solutions of disinfectants, air disinfection with bactericidal ultraviolet recirculators), increased contamination of surfaces with pathogenic microflora remains. In the immunoprophylaxis room, the proportion of positive swab samples at the beginning of the day was 6.9% with a gradual statistically significant increase to 7.6% by the middle of the day (p = 0.00001, McNamara criterion); in the procedure room up to 8.3% of positive samples (p = 0.00001, McNamara criterion), in the computed tomography room up to 20.1% (p = 0.00001, McNamara criterion).

2. Additional short-term treatment with a portable pulsed ultraviolet unit in the treatment room with the following algorithm (daily 3-fold irradiation in between procedures (morning, afternoon, evening), using 2 treatment points and 5 minutes of exposure allows for a statistically significant reduction in the number of positive surface swab samples by 12 times (from 12 positive samples to 1, respectively) (p = 0.00001, McNamara criterion).

3. Additional short-term treatment of the computer tomography room with a portable pulsed ultraviolet unit using the following algorithm (daily 2-fold irradiation, using 2 treatment points and 8 minutes of exposure allows for a statistically significant reduction in the number of positive surface swab samples by almost 5 times (from 29 positive samples to 6, respectively) (p = 0.00001, McNamara criterion).

4. Comparison of the modes of treatment of experimental rooms with a pulsed ultraviolet installation showed that 3-fold treatment of the room, compared with 2-fold treatment, statistically significantly reduces the number of contaminated surfaces 2.4–6 fold (p = 0.0027, McNamara criterion).

5. The project on the use of pulsed ultraviolet installations for disinfection of premises has economic feasibility due to the reduction of bed-days of patients' stay during the prevention of infections associated with the provision of medical care, as well as the corresponding costs. Additional research is required to assess the size of the economic effect.

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