UDC616.728.2/.728.3-089-77:616-06-002.3:616-071-089.844

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EFFICIENCY OF LAMINAR CLEAN AIR OR ULTRAVIOLET RADIATION IN ORTHOPEDIC OPERATING ROOMS

Key words: *clean air, laminar air, HEPA, UV, ultraviolet.*

Abstract. *The study compares the efficacy of air disinfection in orthopedic operating rooms by laminar supply of HEPA filtered air against UV radiation. Qualitative and quantitative parameters of air in two operating rooms were assessed in dynamics. One of the operating rooms was equipped with laminar air supply with high efficiency particulate air filters, the other with ultraviolet lamps for air disinfection. Total bacterial count of the air in the first operating room was nearly 60 times lower than in the second one. Unlike in the operating room with UV light, the air in the operating room with HEPA filtered air supply did not contain any potentially pathogenic species able to cause surgical sight infection. HEPA filtration for air disinfection possesses a number of significant advantages: species spectrum of airborne bacteria is improved – no species known to cause infections in human are found; the air is not only cleaned and disinfected but also conditioned, providing comfortable environment for staff and patients (prevents miscellaneous complications); microbiological parameters of air quality are maintained at high level throughout the working time; air filtering and conditioning is continuous while patients and staff are in the operating room.*

Introduction

Analysis of literary sources showed that studies on reasons of surgical site infection after major orthopedic surgeries such as joint replacement, osteosynthesis in large segments of limbs, spine, and pelvis often focus off such an important causal factor of surgical wound and instrument contamination as airborne bacteria in operating rooms [1, 3, 5, 9]. Many developed countries have developed standards and regulations limiting biological contamination in clean rooms, including orthopedic operating rooms (ISO 14698-1/2) [9, 10].

Ultraviolet radiation has been traditionally used for air and surfaces disinfection in medical facilities for decades. However, this method has several disadvantages: impossibility to use it in presence of staff or patients due to possible eye and skin damage, production of ozone in concentrations harmful for human health unless eliminated by proper ventilation, limited efficiency [4, 10, 11].

Laminar supply of sterile air derived by high efficiency particulate air (HEPA) filtration has been implemented in many surgical clinics in developed countries [6, 9].

John Charnley pioneered in designing and implementing laminar supply of clean air in operating rooms in 1969 to reduce the infection rate after total hip replacement. It was John Charnley who performed the first total replacement of an affected hip joint with endoprosthesis using cement fixation of components to the bone in 1963. The effect of laminar sterile airflow was dramatic: as reported by Charnley, Eftaknan et al., 1972, early surgical site infection rate after hip replacement reduced ninefold from 9% to 1% [5, 10]. In absolute numbers it meant thousands of patients who avoided infectious complications. Other studies published on the subject report similar picture [2, 5, 6].

Wide spread of joint replacement, which means implanting massive foreign body (artificial joint) into the organism for decades, often even for a lifetime, made infection prevention a priority issue. Number of the procedures per year rose to tens of thousands, then to hundreds of thousands. In the USA alone over 500000 primary hip and knee replacements were performed in 2011. Expenses on one surgery were estimated as 35000 US dollars; EU members spend 14.7 to 19.1 billion euro per year on treatment of periprosthetic infections. This makes surgical site infection prevention after major orthopedic surgeries both an important medical and social issue [4, 5, 9]. Relevant data in Ukrainian population is missing.

Last but not least, comfortable environment in operating rooms, including controlled temperature,

humidity, and airflow velocity ensures that surgical and anesthesiological team concentrates maximum effort on their job, which improves its quality and thus can be considered a complications prevention measure [7].

Before 1989, laminar clean air was produced by high impulse ventilation systems containing compressor and filters. Positive pressure maintained in the operating room provided that no contaminated air is sucked into the room from neighbor rooms. It did not take into account convectional airflows around warm objects such as staff, lamps, and equipment, and high airflow velocity caused turbulences mixing clean air with ambient non-sterile air in the room. These two problems were addressed in a new design developed by Airsonett (Angelholm, Sweden) in 1989 to 1997 which combined filtering, ventilation, and air conditioning, "Airsonett airshower". It is a computer controlled low impulse heat, ventilation, and air conditioning (HVAC) system with HEPA filters, which creates downward sterile laminar airflow due to temperature gradient. Low velocity prevents turbulences; cooled air redirects upward convectional currents from warm objects [3, 7, 8].

The first system of the new design and, to our knowledge, the first laminar clean air system in operating room in Ukraine was installed in Center of Traumatology and Orthopedics, Chernivtsi, Ukraine, in 2007. Air quality in the operating room with the "Airshower" system switched on complies with the international standard ISO 5 for clean rooms by suspended particle count [3].

Therefore, the results of implementing the new, progressive method of air sterilization in clinical setup, primarily in operating rooms, need further research. This, in turn, requires further studies on advantages and possible problems of HEPA filtered laminar airflow in comparison with current standard method of air disinfection in hospitals in Ukraine, UV radiation.

Aim of study

Compare the efficiency of air disinfection in orthopedic operating rooms by HEPA filtered laminar air delivery and by UV radiation.

Material and Methods

Qualitative and quantitative microbiological parameters of air and their dynamics were assessed in two operating rooms. In the first one laminar HEPA filtered air supply was used for air sterilization, in the second one – UV lamps. Aspiration samples were taken using Krotov's impaction air sampler, in accordance with its operating manual. The sampler was positioned on the operating table. Air flow rate was 30 liters per minute, duration of sampling was 3 minutes, and total volume of air collected per one sample was 90 liters. Every sample was doubled for more consistency. For studying the dynamics of qualitative

Table 1

Total bacterial count of the air in operating rooms with different methods of air disinfection

Method of air disinfection	Total bacterial count (CFU per 1m^3)		
	Before surgeries	After 1 surgery	After 2 surgeries
Laminar HEPA filtered air	18.9 ± 4.15	17.8 ± 4.77	19.9 ± 5.44
	n=5	n=5	n=5
UV radiation	1309.6 ± 470.14	1210.2 ± 343.66	977.1 ± 303.24
	n=5	n=6	n=4
Student's test	2.74	3.47	3.16
Probability of error	P < 0.05	P < 0.01	P < 0.05

Table 2

Occurrence of bacteria and fungi in the air from operating rooms with different air disinfection methods (%)

Microflora	Operating room with laminar clean air	Operating room with UV radiation	Student's test t	Probability of error P
Samples taken	26	28		
No growth	34.6 ± 16.17	0.0 ± 13.1	1.67	> 0.05
Micrococcus spp.	34.6 ± 16.17	64.3 ± 11.50	1.5	> 0.05
Corynebacterium spp.	0.0 ± 14.00	28.6 ± 16.27	1.33	> 0.05
Bacillus spp.	7.7 ± 19.22	39.3 ± 15.00	1.3	> 0.05
„saprophytic" staphylococci	46.2 ± 14.68	82.1 ± 8.13	2.14	< 0.05
S. aureus	0.0 ± 14.0	3.6 ± 18.90	0.15	> 0.05
E. coli	0.0 ± 14.0	3.6 ± 18.90	0.15	> 0.05
Streptococcus spp.	0.0 ± 14.0	3.6 ± 18.90	0.15	> 0.05
Candida spp.	0.0 ± 14.0	3.6 ± 18.90	0.15	> 0.05
Mold fungi	11.5 ± 18.81	82.1 ± 8.13	3.45	< 0.01

and quantitative air parameters during working day, samples were collected before surgeries, after the first surgery, and after two surgeries. Total amount of samples collected in the operating room with laminar clean air supply was 26, and in the operating room where UV radiation was used for air disinfection – 33 samples. The sampling lasted from 05.12.2012 to 01.03.2013.

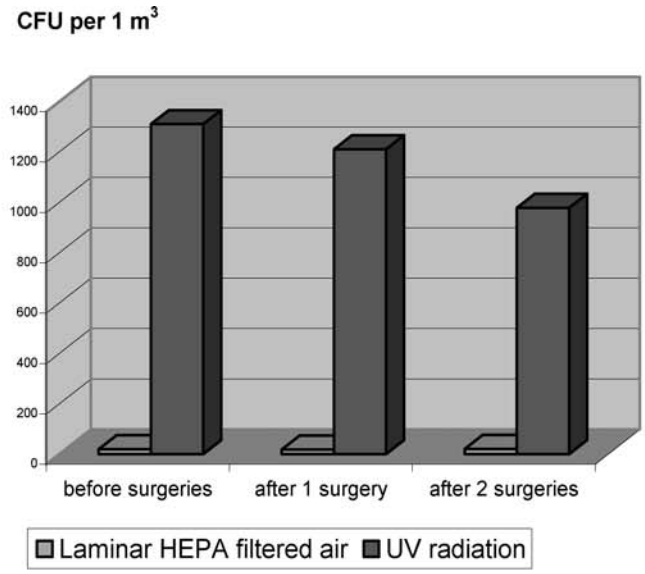
The growth medium was blood agar plates. Bacteria were identified using standard methods used in clinical microbiology. Acquired digital data was processed using methods of variation statistics.

Results and their discussion

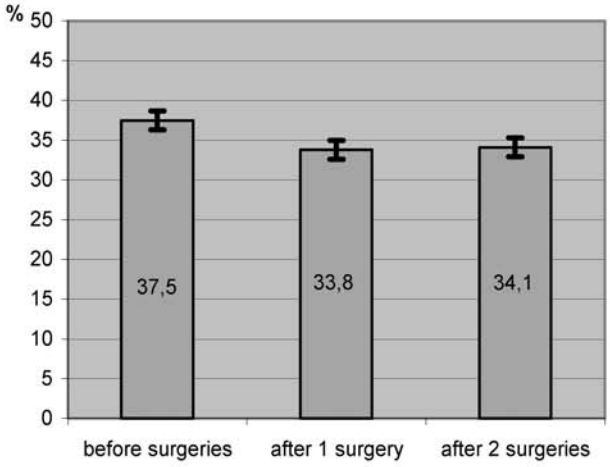
Total bacterial count of the air in the operating room with laminar clean air supply was 50-70 times lower than in the operating room with UV radiation for air disinfection (table 1, picture 1).

Species spectrum of airborne bacteria in the operating room with laminar HEPA filtered air included saprophytic genera: Micrococcus, Bacillus. Staphylococci were only represented by S. epidermidis and S. saprophyticus. A few mold fungi were encountered.

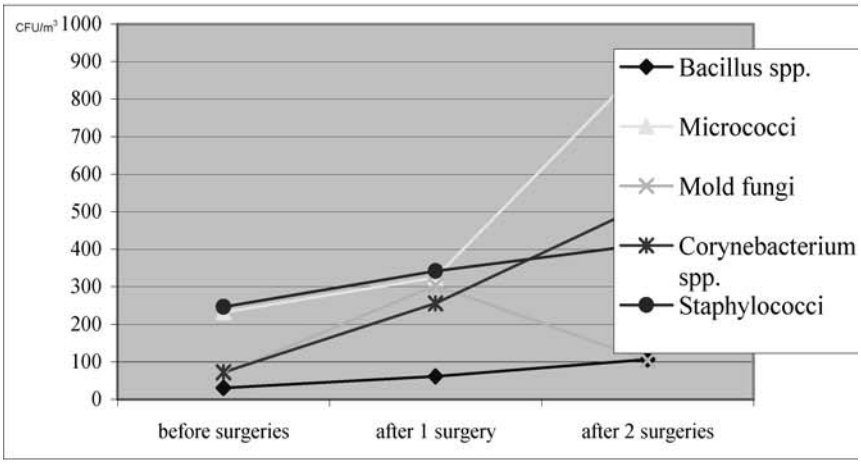
Species spectrum of airborne bacteria in the operating room with UV radiation for air disinfection was considerably broader. Besides Micrococcus spp., who are saprophytes and are often found both in the air and on surrounding objects, Corynebacterium spp., and S. epidermidis were identified, who belong to microbiocenoses of the skin, mucous membranes, and intestines in human. Spore-forming bacteria of Bacillus genus were also registered. They are saprophytes and are mostly found in vegetable foods



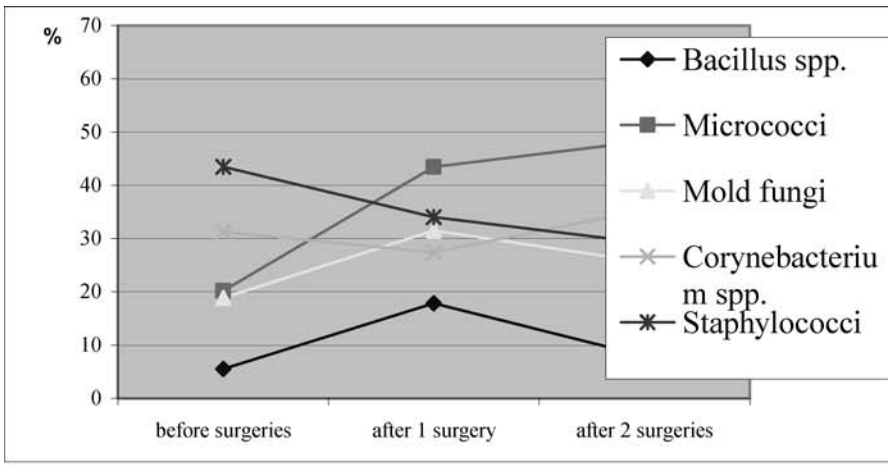
Pic.1. bacterial count of the air in operating rooms with different methods of air disinfection (CFU per 1 m^3)



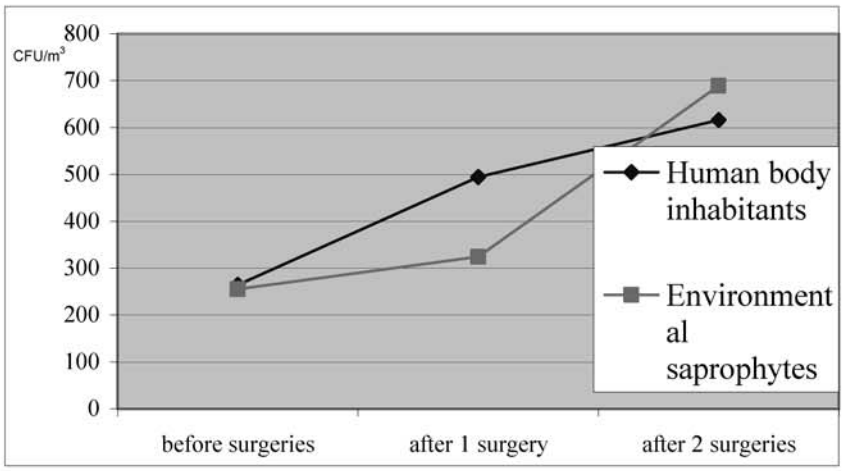
Pic. 2. Absence of growth percentage in the samples taken from the air in the operating room with laminar HEPA filtered air supply (%)



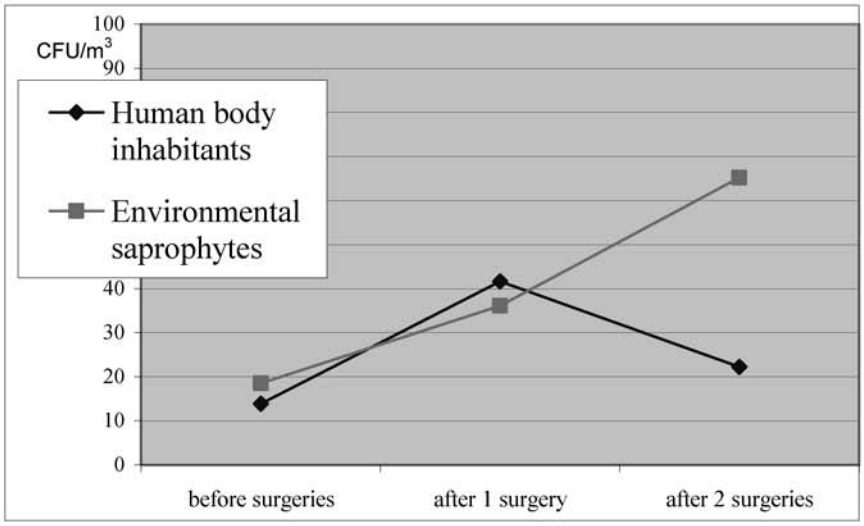
Pic. 3. Dynamics of species occurrence in the air from operating room with UV radiation for air disinfection during working day (CFU per 1 m^3)



Pic. 4. Dynamics of species occurrence in the air from operating room with UV radiation for air disinfection during working day (relative quantity, %)



Pic. 5. Dynamics of airborne microflora in the operating room with UV radiation during the working day (CFU per 1 m^3)



Pic. 6. Dynamics of airborne microflora in the operating room with laminar HEPA filtered air during the working day (CFU per 1 m^3)

and in the soil, but sometimes in human intestines as well. Microscopic fungi were represented by mold fungi and in one occasion – yeast-like fungi belonging to Candida genu.

It is worth mentioning that opportunistic pathogenic bacteria were found sporadically in the air from the operating room where UV radiation was used for air disinfection. They included Streptococcus spp., E. coli, S. aureus. These bacteria are capable of causing purulent infections in human, including surgical sight infections. The isolated strain of S. aureus was resistant to benzylpenicillin and azithromycin. Furthermore, it was able to produce beta-lactamase, which is characteristic for nosocomial strains. Even among isolated strains of S. epidermidis, a saprophyte which is a normal component in skin and mucous membranes microbiocenoses, ability to produce beta-lactamase was confirmed in 33.3%. Resistance to benzylpenicillin was encountered in 33.3%, and to azithromycin – in 66.6%. That emphasizes the importance of control over their occurrence in the air of operating rooms as a prevention measure against nosocomial surgical sight infections.

Studying the occurrence of different genera and species of bacteria and fungi in the air of the operating room with laminar HEPA filtered air showed the absence of growth in 35.1 % (pic. 2). That can be interpreted as the air being sterile.

All the samples taken from the operating room with UV radiation for air disinfection had growth (table 2). All the species identified in the study had higher occurrence in the samples taken from the operating room with UV radiation than from the operating room with HEPA filtered air. The difference was statistically

significant for mold fungi and saprophytic staphylococci (table 2).

Based on the data acquired, dynamics of total bacterial count and species spectrum was analyzed for the two operating rooms.

As shown in table 1 and pic. 1, total bacterial count in the operating room with UV radiation had a tendency to decline during the working day. However, the changes were statistically insignificant.

Analysis of dynamics for every separate species occurrence in the air of the operating room with UV radiation revealed no distinct tendencies by absolute or relative parameters besides elevation in saprophytic airborne micrococci (pic. 3, 4).

The species found in the samples from the two operating rooms can be divided into two groups. The first one comprises saprophytes usually found in the surrounding environment: Micrococcus spp., Bacillus spp., and mold fungi. The other includes microbes typically dwelling in different locations of human body: staphylococci, corynebacteria, Candida fungi, streptococci, enterobacteria.

Studying the dynamics of total occurrence in each of these groups in the air of the operating room with UV radiation showed that the number of typical human body inhabitants increases during the working day (pic. 5). The fact that mold fungi were encountered in considerable amounts in 82.1 % samples taken from the operating room with UV radiation (pic. 4) can be the result of high relative humidity. It is well known that high humidity is favorable for microscopic fungi growth, including molds. This example reveals another advantage of HVAC system supplying the clean air in the other operating room: besides filtering away particles and microbes, it conditions the air, providing its stable temperature and reducing relative humidity peaks. Comfortable environment and clean air enhance staff performance and patient's comfort.

Total bacterial count in the operating room with laminar HEPA filtered air showed no noticeable dynamics and, as mentioned above, was very low. Percentage of samples with no growth had no tendency to decrease during the working day (pic. 2). Unlike in the operating room with UV radiation, the occurrence of typical human body inhabitant microbes remained practically the same during the working day in the operating room with laminar HEPA filtered air (pic. 6).

Somewhat lower general microbial count before surgeries can be the result of continuous air filtering in "standby" mode plus absence of any patient or staff activity during the night. The amount of environmental airborne saprophytes increased slightly during the working day in both operating rooms (pic. 5, 6).

Conclusions

1. Total bacterial count of the air in the operating room with laminar HEPA filtered air supply was nearly 60 times lower than in the operating room with UV radiation for air disinfection.

2. Unlike in the operating room with UV light, the air in the operating room with HEPA filtered air supply did not contain any potentially pathogenic species able to cause surgical sight infection.

3. HEPA filtration for air disinfection in operating room possesses a number of significant advantages compared to UV radiation:

- Total bacterial count of the air is decreased by tens of times;
- species spectrum of airborne bacteria is improved – no species known to cause infections in human are found;
- the air is not only cleaned and disinfected but also conditioned, providing comfortable environment for staff and patients (prevents miscellaneous complications);
- microbiological parameters of air quality are maintained at high level throughout the working time;
- air filtering and conditioning is continuous while patients and staff are in the operating room.

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ЭФФЕКТИВНОСТЬ ЛАМИНАРНОГО ПОТОКА СТЕРИЛЬНОГО ВОЗДУХА И УЛЬТРАФИОЛЕТОВОГО ОБЛУЧЕНИЯ В ОРТОПЕДИЧЕСКИХ ОПЕРАЦИОННЫХ

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Резюме. Целью исследования является сравнение эффективности обеззараживания воздуха в ортопедических операционных методом высокоэффективной фильтрации воздуха и методом ультрафиолетового облучения. Проведено изучение качественного и количественного состава воздуха и динамики этих показателей в двух операционных. В первой из них воздух обеззараживался методом высокоэффективной фильтрации, во второй – с помощью ламп ультрафиолетового облучения. Общая обсемененность воздуха в операционных с системой его высокоэффективной фильтрации в 60 раз ниже, чем в операционных, в которых для обеззараживания воздуха используется УФО. В сравнении с операционными, в которых для обеззараживания воздуха используется УФО, воздух операционных с системой его фильтрации не содержит потенциально патогенных видов, способных вызывать послеоперационное нагноение раны. Метод фильтрации воздуха с целью его обеззараживания имеет ряд существенных преимуществ: улучшается видовой состав микрофлоры – в воздухе не определяются виды, способные вызывать гнойно-воспалительные заболевания человека; воздух не только очищается и обеззараживается, но и кондиционируется, в результате чего улучшаются условия работы персонала (также профилактика различного рода осложнений); микробиологические показатели качества воздуха поддерживаются на высоком уровне в течение всего рабочего времени; обеззараживание и очистка воздуха осуществляется в присутствии персонала и больного.

Ключевые слова: обеззараживание воздуха, ультрафильтрация, ультрафиолетовое облучение.

ЕФЕКТИВНІСТЬ УЛЬТРАФІЛЬТРАЦІЇ ТА УЛЬТРАФІОЛЕТОВОГО ОПРОМІНЕННЯ ПОВІТРЯ В ОРТОПЕДИЧНИХ ОПЕРАЦІЙНИХ

С.В.Васюк, Я.М.Васильчишин, В.Л.Васюк

Резюме. Метою дослідження є порівняння ефективності знезараження повітря в ортопедичних операційних методом високоефективної фільтрації повітря та методом ультрафіолетового випромінювання. Проведено вивчення якісного та кількісного складу повітря та динаміку цих показників у двох операційних. В першій з них повітря знезаражувалось методом високоефективної фільтрації, в другій – за допомогою ламп ультрафіолетового опромінення. Загальна засіяність повітря операційних із системою його високоефективної фільтрації у 60 разів нижча, ніж в операційних, у яких для знезараження повітря використовується УФО. У порівнянні з операційними, у яких для знезараження повітря використовується УФО, повітря операційних із системою його фільтрації не містить потенційно патогенних видів, здатних викликати післяопераційне нагноєння ран. Метод фільтрації повітря з метою його знезараження має ряд суттєвих переваг: покращується видовий склад мікрофлори – у повітрі не виявляються види, які здатні викликати гнійно-запальні захворювання людини; повітря не тільки очищується і знезаражується, але й кондиціонується, внаслідок чого покращуються умови роботи персоналу (також профілактика різного роду ускладнень); мікробіологічні показники якості повітря утримуються на високому рівні протягом усього робочого часу; знезараження і очищення повітря виконується в присутності персоналу і хворого.

Ключові слова: знезараження повітря, ультрафільтрація, ультрафіолетове опромінення.

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Clin. and experim. pathol.- 2013.- Vol.12, №3 (45).-P.39-44.

Надійшла до редакції 03.09.2013
Рецензент – проф. С. Є. Дейнека