CONTAMINATED AIR:
The Invisible Threat to Patients and Healthcare Workers

Dr. Linda D. Lee, MBA

April 7, 2020

LEARNING OBJECTIVES

- Understand how air becomes contaminated in a hospital environment
- Explain how pathogenic particles travel on air currents
- Describe the dangers that pathogenic air particles pose to the patient and the healthcare worker
- Describe the relationship between positive and negative air pressure and how it affects the hospital environment
- Learn how ultraviolet light in the C spectrum (UV-C) air purification can reduce aerosols and minimize contamination on surrounding surfaces as a mitigation strategy.

BIOGRAPHY

- Chief Medical Affairs and Science Officer, UV Angel
- Founding member of Stericycle
- MD Anderson Cancer Center, AVP Admin Facilities and Campus Operations
- Adjunct Faculty, UT Health School of Public Health, University of Houston, Walden University
- CH2M Hill, Global Public Health Director
- WM Healthcare Solutions, Director of Operations
- Speaker - SHEA, AIHce, IPAC-Canada, C. Diff Foundation, ASHAE, AHE, APIC
- Published author – AHA
- DrPH- The University of Texas Health Science Center Houston
- MS- University of Arkansas College of Engineering
- BS- Indiana State University Environmental Health Science

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Why we are here…

HEALTHCARE ASSOCIATED INFECTIONS: THE UNKNOWN KILLER

"CDC estimates that ***1 in 31*** hospital patients gets a HAI (an infection while being treated in a medical facility)."

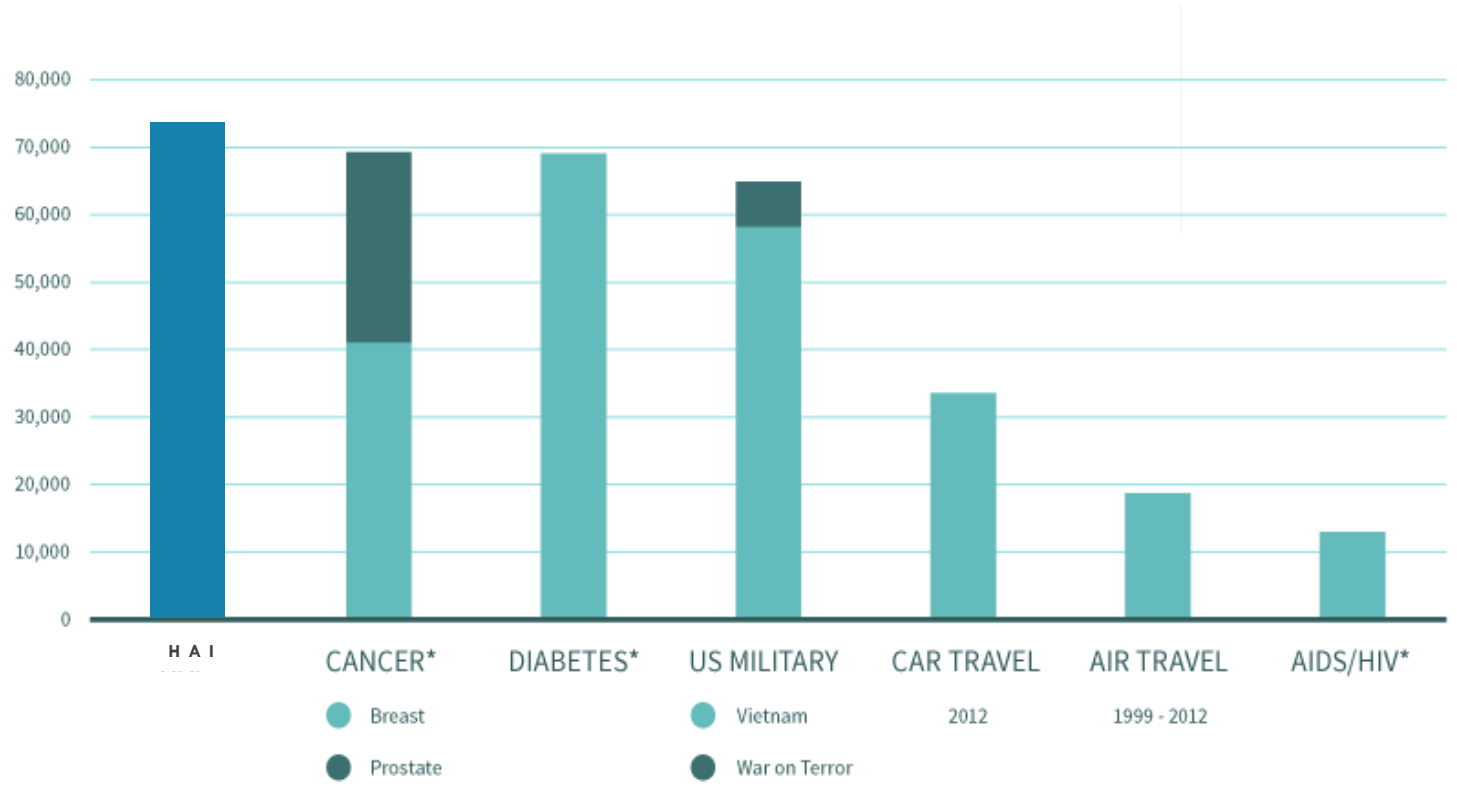
+720,000

US citizens that contract healthcare-associated infections annually

+72,000

US citizens that die from healthcare-associated infections annually

(Source: cdc.org)



PENALTIES AND COSTS

CMS - Centers for Medicare & Medicaid Services

$35-45 Billion	**Cost Annually Directly from Healthcare-associated infections (HAIs) in US** (Source: cdc.org)
$96-147 Billion	Total Cost Impact from direct, indirect, and nonmedical social costs of HAIs (Source: beckershospitalreview.com)
	Hospital-Acquired Condition Reduction Program Medicare payments are significantly reduced for the worst performing hospitals with regards to Hospital Acquired Conditions

Typical Excess Costs Per Patient of Common HAIs

CDI (Clostridium difficile Infection) • $11,000 • 3.3 extra days	VAP (Ventilator-Associated Pneumonia) • $40,000 • 13.1 extra days
SSI (Surgical Site Infections) • $20,800 • 23 extra days (w/ MRSA)	CLABSI (Central Line-associated Blood Stream Infection) • $45,800 • 15.7 extra days (MRSA)
CAUTI (Catheter-Associated Urinary Tract Infections) • $1,000 extra per patient	

DISEASE TRANSMISSION

Source of Pathogen

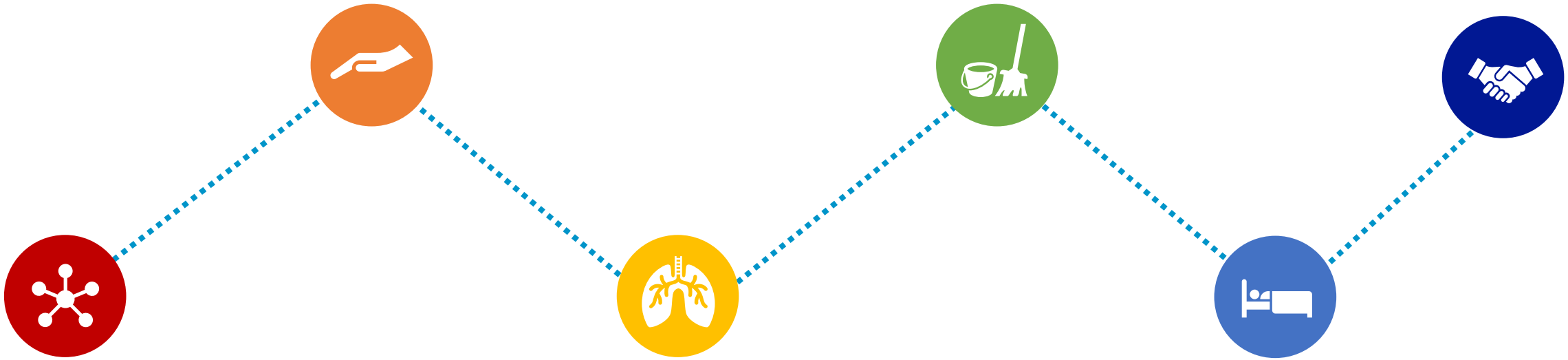
Reservoir: dirty surfaces, air, water or insects

Volume of Pathogens Left Behind

Some survive or are missed during cleaning

Route of Entry

Ingestion, inhalation, puncture or contact



Infectious Pathogen

Bacteria, Viruses, Fungus, Parasites

Portal of Exit

How pathogens exit body: coughing, bleeding, open wounds

Susceptible Host

Pathogens travel on air currents and land on surfaces

WHY IS THE AIR IMPORTANT?

SURFACE CLEANING EFFORTS ARE NOT ENOUGH

Well-child visits account for 700,000+ new influenza cases costing $500m annually

2011 study of 150,000 people, 82% visited doctor or dentist prior to diagnosis, without visiting hospital

69% of infrequently touched (high-dust) surfaces positive for *C. difficile* in elderly ward

Is Alzheimer's caused by fungus?

380,000 die in LTCF annually (CDC)

MRSA and C. difficile survive for months on surfaces

Airborne dispersion plays role in non-respiratory infections

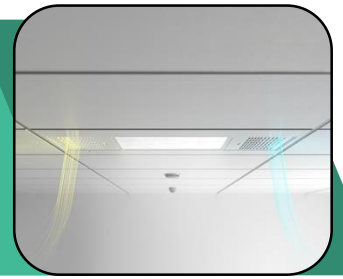
HIERARCHY OF CONTROLS

CDC, EPA, OSHA

ENGINEERING

UV Angel Air Handler,

UV Angel surface disinfection device



ADMINISTRATIVE

Surface cleaning, UV towers, hand hygiene, prevention/prophylaxis, UV Clean & Charge

PPE

Masks, gloves, protective equipment

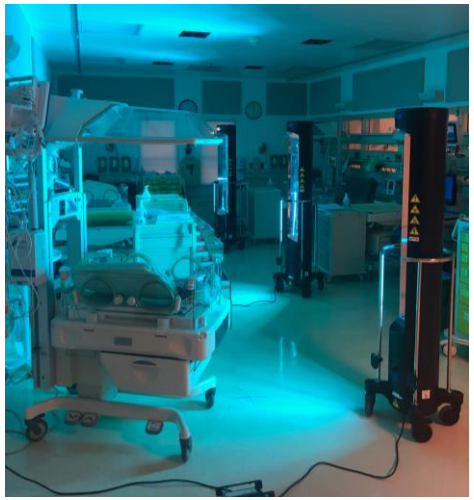
HEALTHCARE: PRIMARY CURRENT CLEANING PROCEDURES

Our workers clean… and clean… and clean…

HANDWASHING

CLEANING

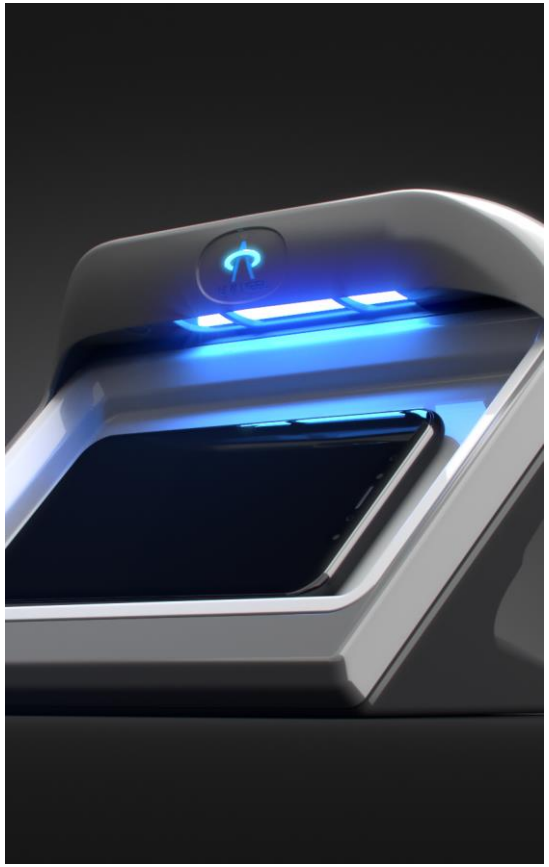
TERMINAL CLEANING



HIGH TOUCH SURFACES

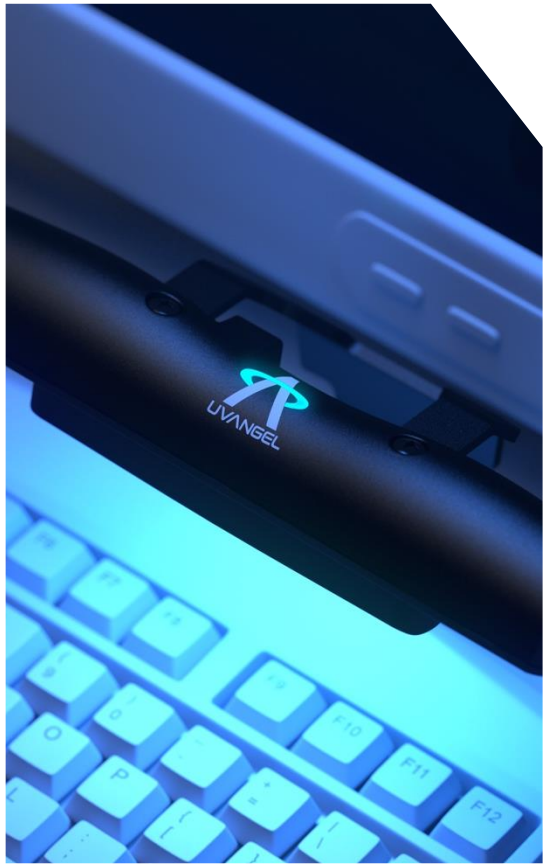
TECHNOLOGY IS TAKING CHARGE

Portable Medical Carts



Mobile Disinfection

UV Air & Surface Disinfection



Integrated Technology

UV technology has a long history in healthcare.

Upper room air disinfection

UV “robots”

Biological safety cabinet

Air handlers & air conditioning units

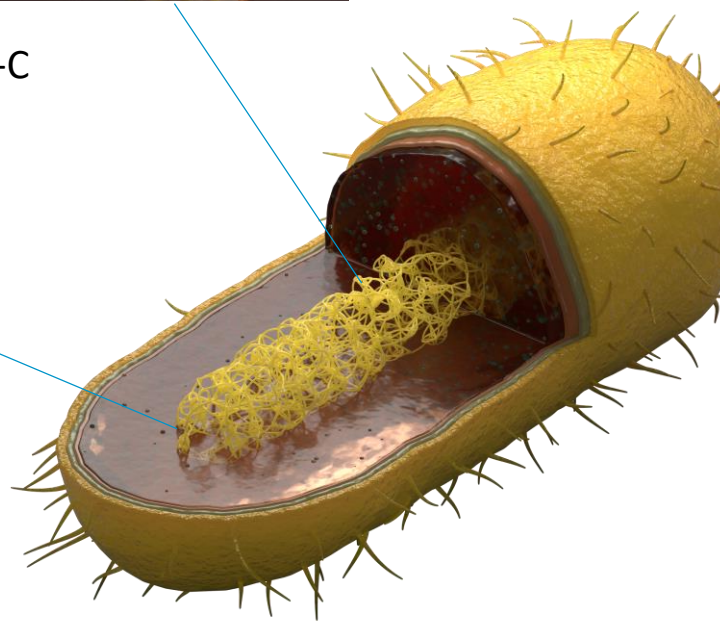
UV lamps in water treatment

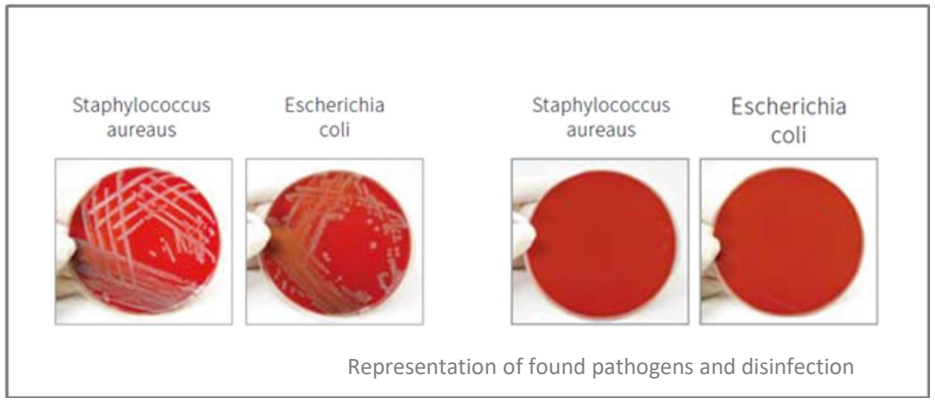
UV-C SURFACE AND AIR TREATMENT

- UV-C light provides rapid, effective inactivation of microorganisms through a physical process.
- When bacteria, viruses, and fungi are exposed to the germicidal wavelengths of UV light, they are rendered incapable of reproducing and infecting.

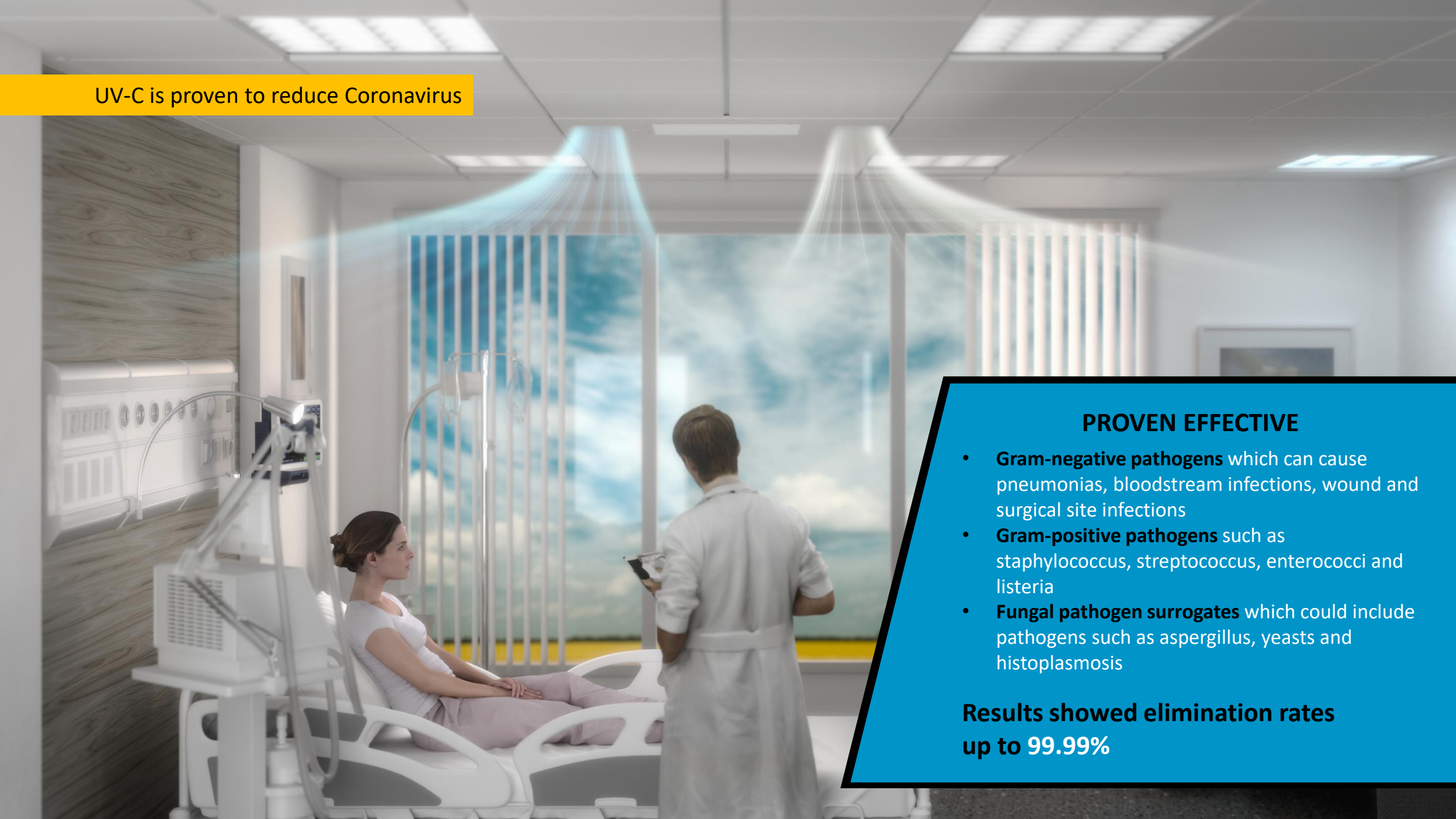
Before UV-C

After UV-C





Representation of found pathogens and disinfection



UV-C is proven to reduce Coronavirus

PROVEN EFFECTIVE

- **Gram-negative pathogens** which can cause pneumonias, bloodstream infections, wound and surgical site infections
- **Gram-positive pathogens** such as staphylococcus, streptococcus, enterococci and listeria
- **Fungal pathogen surrogates** which could include pathogens such as aspergillus, yeasts and histoplasmosis

Results showed elimination rates up to 99.99%

THE INVISIBLE THREAT

PRIOR ROOM OCCUPANCY INCREASES RISK

WHERE DID THE PATHOGENS COME FROM IN TERMINALLY CLEAN ROOM?

Study	Healthcare-associated pathogen	Likelihood of patient acquiring HAI based on prior room occupancy (comparing previously 'positive' room with a previously 'negative' room)
Martinez 2003	VRE – cultured within room	2.6x
Huang 2006	VRE – prior room occupant	1.6x
	MRSA – prior room occupant	1.3x
Drees 2008	VRE – cultured within room	1.9x
	VRE – prior room occupant	2.2x
	VRE – prior room occupant in previous 2 weeks	2.0x
Shaughnessy 2008	C. *difficile* – prior room occupant	2.4x
Nseir 2010	A. baumannii – prior room occupant	3.8x
	P. aeruginosa – prior room occupant	2.1x

Air Transports the Pathogens that Contaminate People and Surfaces

Up to 8 times

- Hospital air samples, on average, are up to 8 times more contaminated than surfaces

15 minutes

- MRSA counts remain elevated up to 15 minutes after bed making

69% Untouched

- A hospital study on C. diff showed 69% of untouched areas in a C. diff patient's room were contaminated

66% Reduced Contamination

- Hospital evidence shows reducing pathogens from the air can reduce surface contamination by as much as 66%

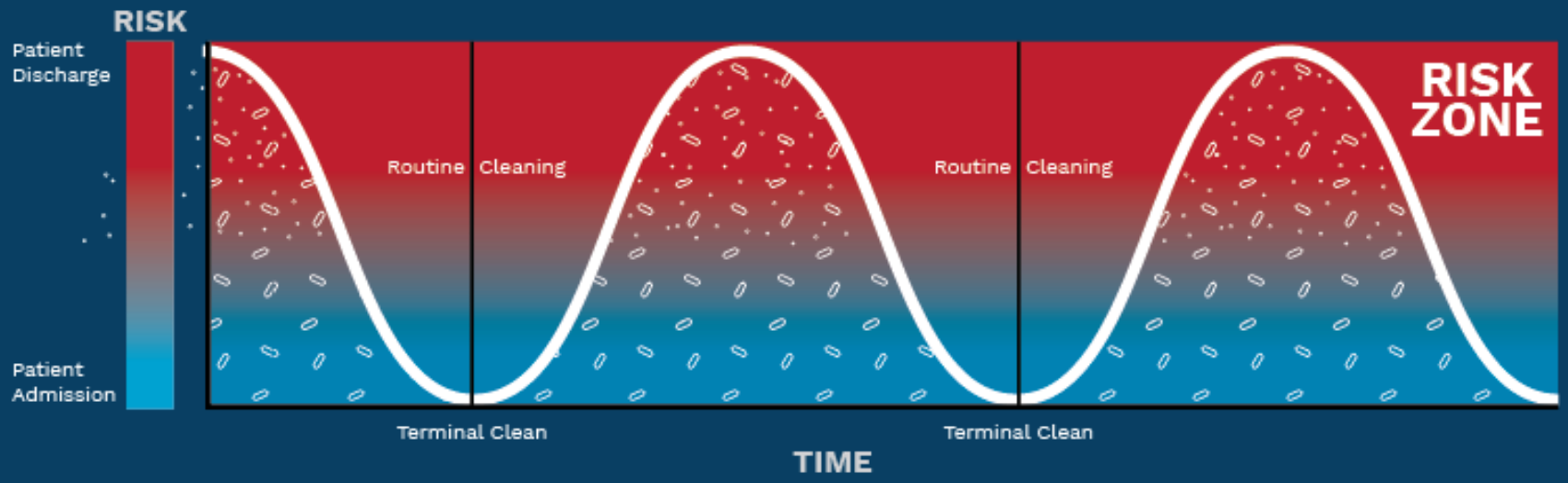
PATHOGEN SURVIVAL RATE

SOME PATHOGENS CAN HIDE FOR MONTHS

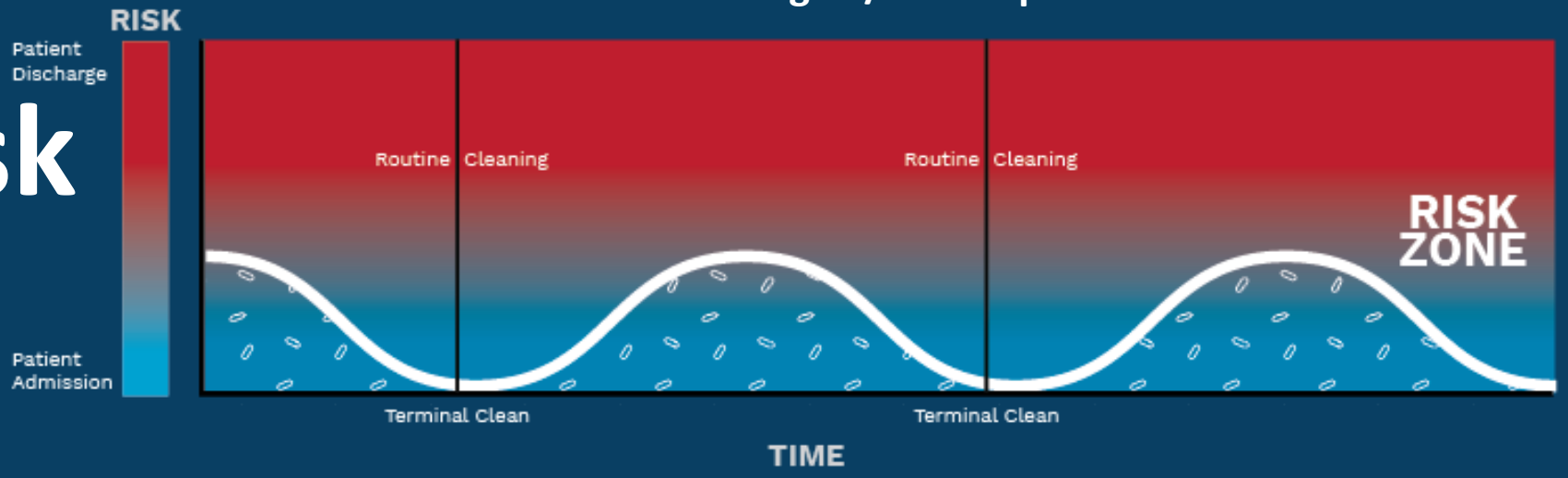
Organism	Survival period
Clostridium difficile	35- >200 days
Methicillin resistant Staphylococcus aureus (MRSA)	14- >300 days
Vancomycin-resistant enterococcus (VRE)	58- >200 days
Escherichia coli	>150- 480 days
Acinetobacter	150- >300 days
Klebsiella	>10- 900 days
Salmonella typhimurium	10 days- 4.2 years
Mycobacterium tuberculosis	120 days
Candida albicans	120 days
Most viruses from respiratory tract (eg: corona, coxsackie, influenza, SARS, rhino virus)	Few days
Viruses from the gastrointestinal tract (eg: astrovirus, HAV, polio- or rota virus)	60- 90 days
Blood-borne viruses (e.g.: HBV or HIV)	>7 days

Episodic Cleaning Protocols Have Inherent Risk

Before using 24/7 UV-C protocols



After using 24/7 UV-C protocols



HAZARDS OF SHARED MEDICAL EQUIPMENT

INCREASED RISK

- In 2017 AJIC study*, hospitalized patients had **1.4 interactions** per hour with medication carts that traveled between patient rooms.

TRANSMISSION

- Patients frequently had direct or indirect interaction with medical equipment or other fomites that were shared with other patients.

PROOF

- Equipment was often found to be contaminated with healthcare-associated pathogens.
- **12%** of the cultures found MRSA, VRE or *C. difficile*.

"Our findings suggest that there is a need for protocols to ensure effective cleaning of shared portable equipment"

Suwantarat, et. al

*Nuntra Suwantarat, Laura A. Supple, Jennifer L. Cadnum, Thriveen Sankar, Curtis J. Donskey, Quantitative assessment of interactions between hospitalized patients and portable medical equipment and other fomites, *AJIC*, Volume 45, Issue 11, Pages 1276–1278

10 HOSPITAL SITE ANALYSIS, N=2,079

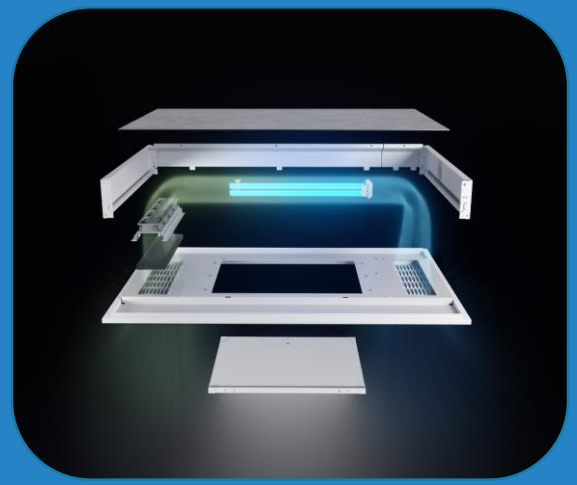
Of the 2,079 samples 1,464 samples were positive for clinically relevant organisms (70%) Below are the average CFU for the organisms tested. (hospital group no-pass policy greater than 10 CFU)

Organism	Average CFU
Total aerobes	111*
Staphylococcus aureus	34
Methicillin-resistant Staphylococcus aureus	35
Enterococcus	137
Vancomycin-resistant enterococcus	54
Gram-negative bacilli	196
Candida spp.	60
Clostridioides difficile	N/A
Too Numerous To Count (limit is 250 CFU) Gram Negative Enterococcus	38% (549) 199 42

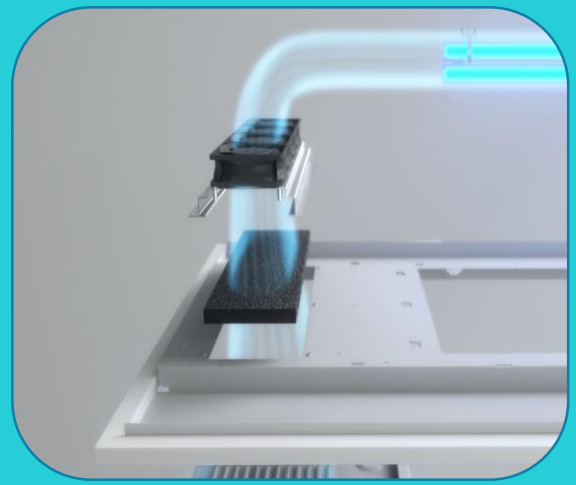
- All surfaces sampled; WOW Work Surfaces, WOW Keyboard, Wall Arm Keyboard, Nurse Station Keyboard, Patient Vitals Monitor, Pyxis Machines, IV Pumps
- Surface with the highest number of samples positive for HAI Bacteria: Nurse Keyboard (26%), WOW Work Surface (25%), Wow Keyboard (23%)
- Most contaminated surface by avg CFU'S: Pyxis Machine (171 CFU), WOW Work Surface (114 CFU), WOW Keyboard
- Most clinically relevant surface contamination by percent: Wall arm keyboard (86%), WOW Work Surfaces (79%)

HOW IN CEILING UV-C AIR PURIFICATION WORKS

Replaces conventional lighting systems so no staff intervention is required



A fully sealed UV-C chamber is enclosed above normal LED room lighting



Fans quietly draw air into the sealed UV-C chamber

WHERE CAN UV-C SOLUTIONS BE MOST EFFECTIVE IN A HOSPITAL?

High risk patients

High contamination areas

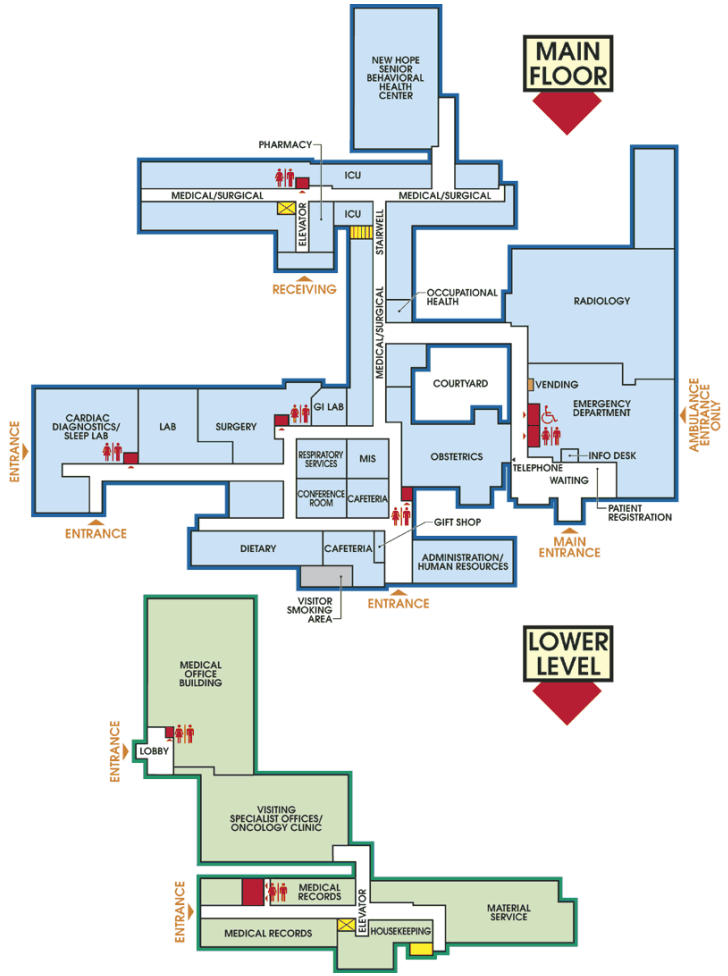
High density locations

- ICU
- NICU
- PICU
- SCU
- Geriatric
- Oncology
- Hematology
- Burn units
- BMT units

- Bronchoscopy Suites
- Areas surrounding the ORs
- Decontamination rooms
- Employee break rooms
- Soiled utility rooms
- Isolation rooms
- Toilet rooms
- TB-Isolation

- Emergency Dept.
- Nurses stations
- Clinics
- Corridors

- Waiting rooms
- Central supply
- Sterile core
- PACU



Air Sampling Process

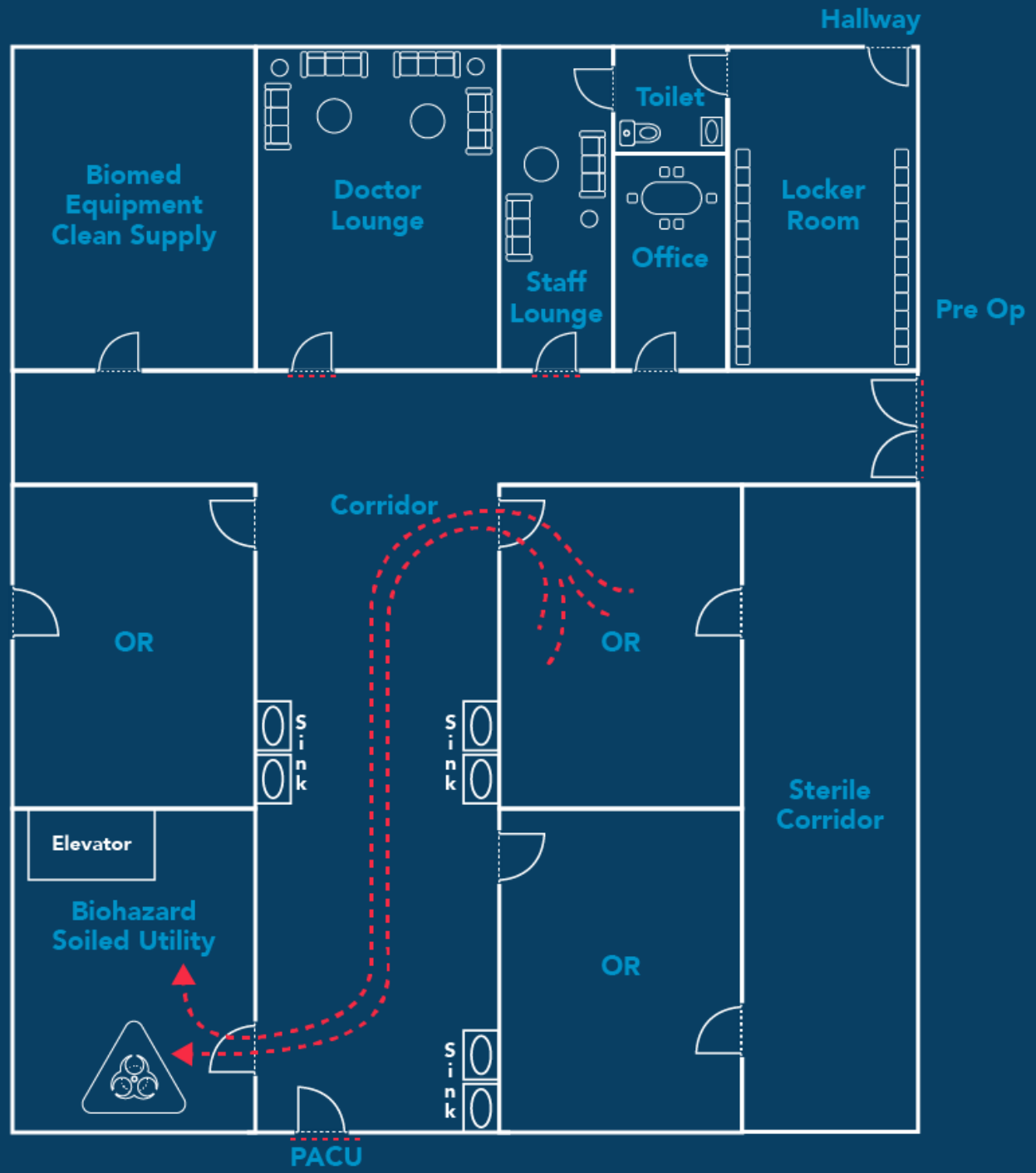
SAS 180 Sampler

Rodac Plates

Blood Agar Plates

Air Flow

The basis of design is not always operational reality



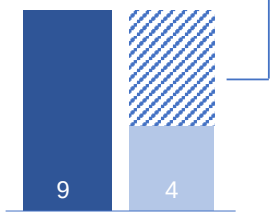
Infection Reduction Results, KY

Hospital ICU in KY, 12-month study

Infection Rate – All Infections

60%

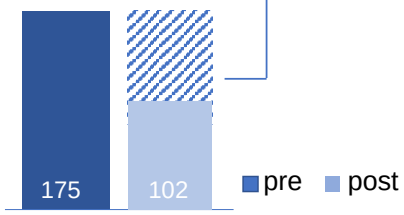
Reduction

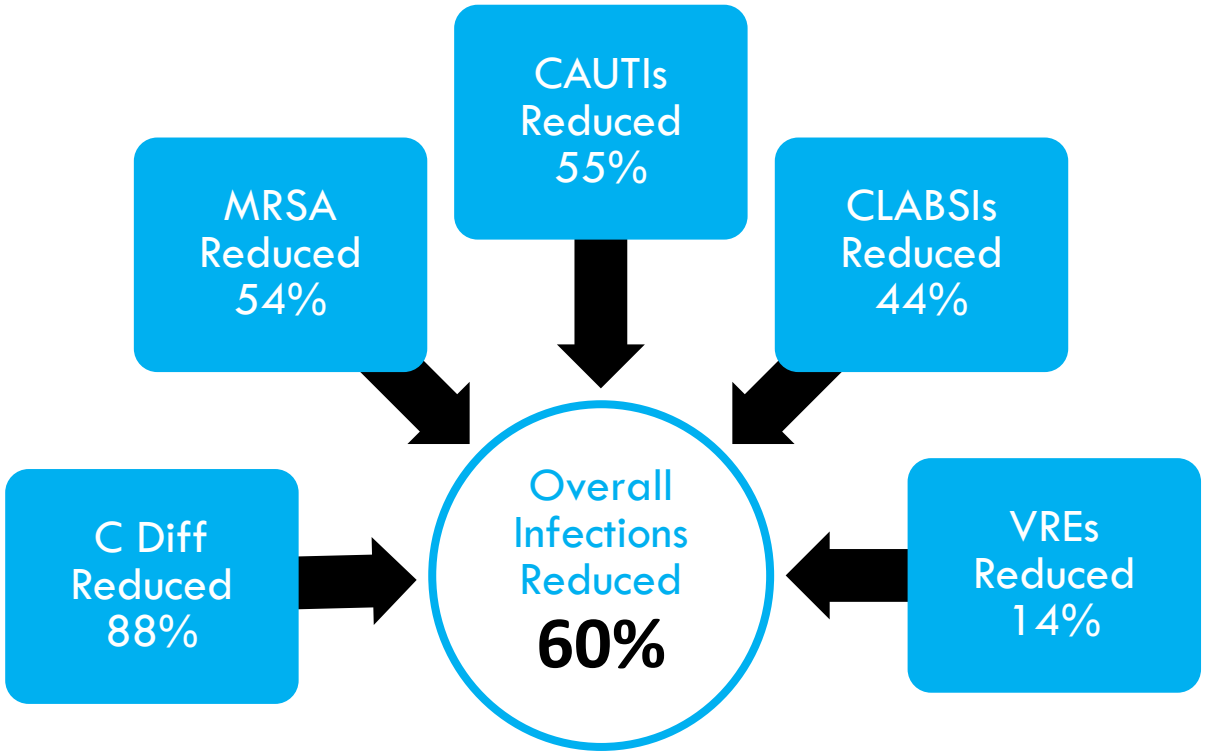


Bacteria Air Sampling – Patient Rooms

42%

Reduction





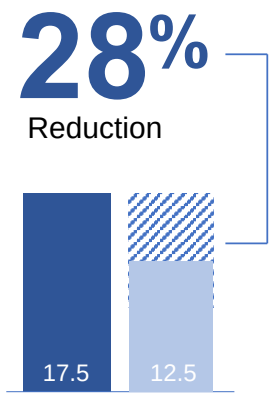
Staff reported that allergy symptoms and odors were minimized, and absenteeism was lowest where UV-C systems were installed

Tina Ethington, MSN, RN, CEN, NE-Bca et. al. Cleaning the Air with UV-C Lessened Contact Infections in an LTAC, AJIC, American Journal of Infection Control, reference number YMIC4661

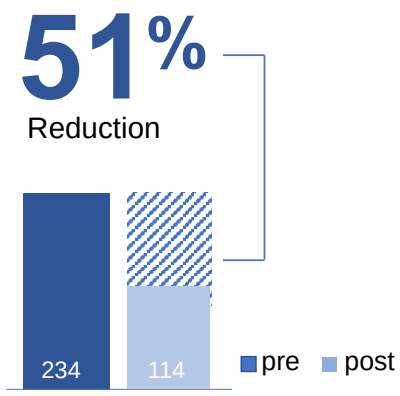
Infection Reduction Results, TN

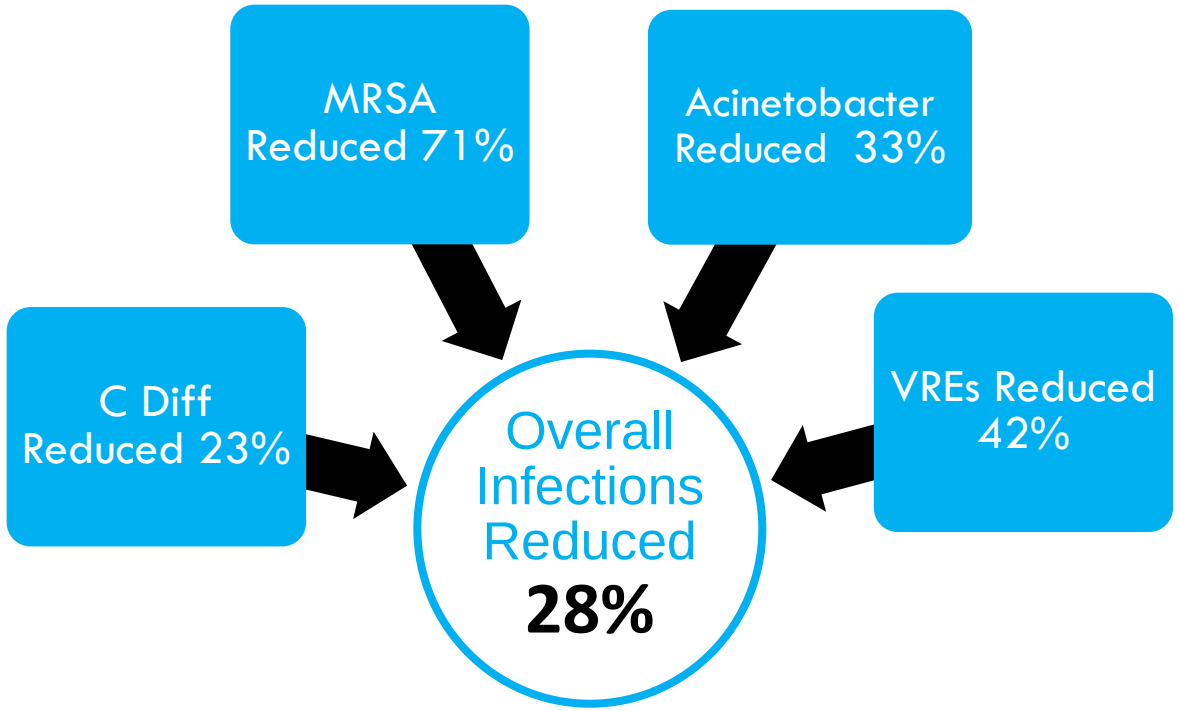
18 patient vent unit in TN, six-month study

Infection Rate – All Infections



Bacteria Air Sampling – Patient Rooms

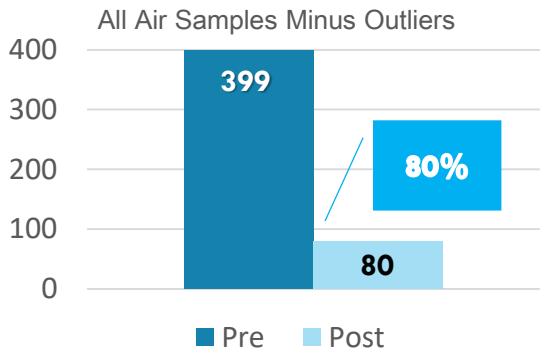


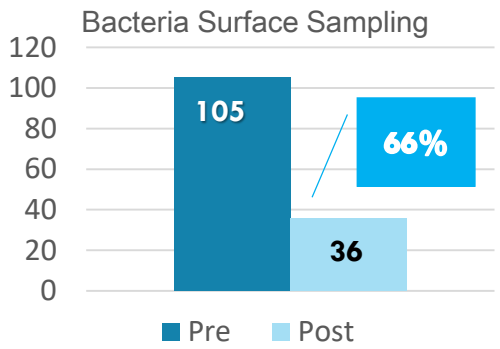


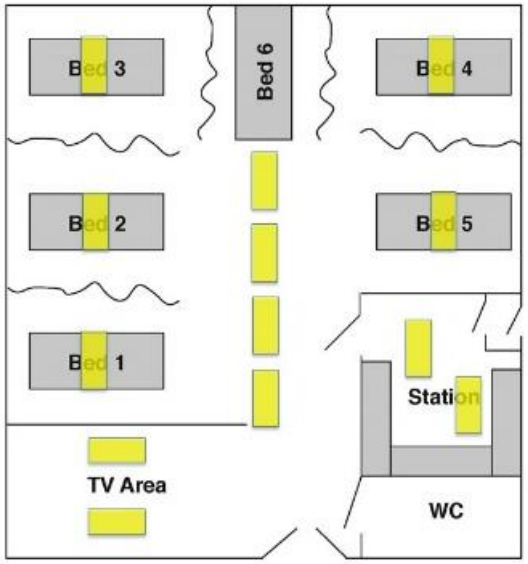
Nurses and staff report odors were reduced and the air felt cleaner and fresher

Kane, Douglas, MD, UV-C Light and Infection Rate in a Long Term Care Ventilator Unit, Canadian Journal of Infection Control, in press

Acute Care Hospital, ED-Psychiatric Holding, Las Vegas







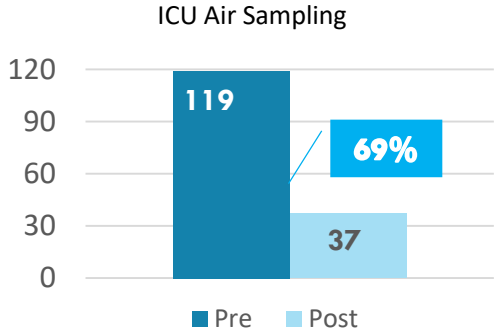
All units of measure are in colony forming units (cfu).

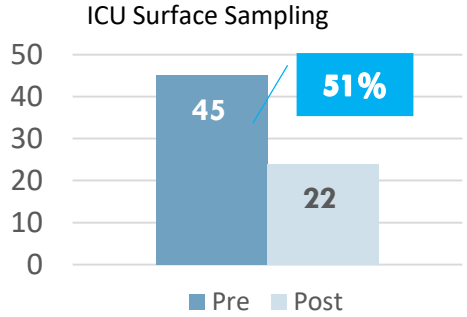
Reported short term study microbe reduction results may not be solely due to product and may not be representative of whole room product microbe reductions.

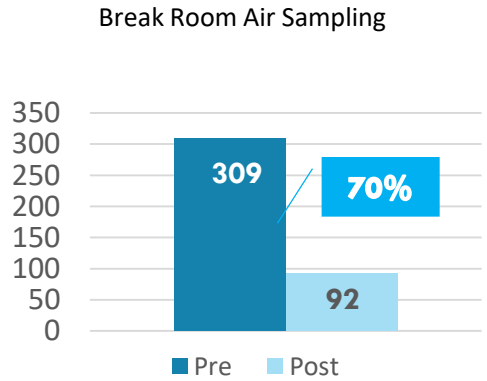
Surface and air: What impact does UV-C at the room level have on airborne and surface bacteria? CJIC, Summer 2017, Vol 32, Issue 2, p.108-111.

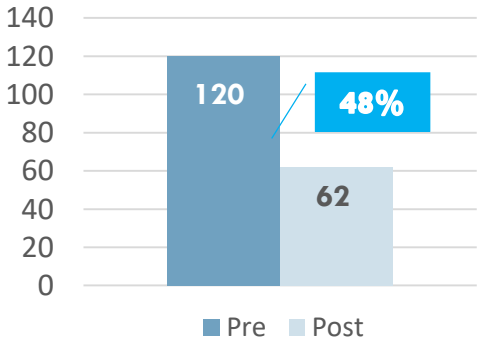
Acute Care Hospital, MA

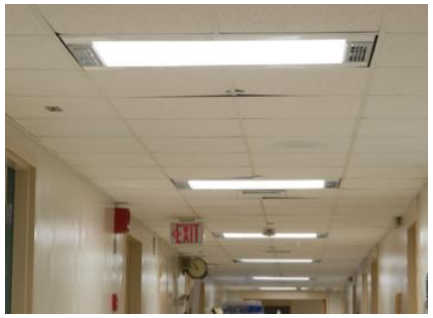
ICU and OR break rooms











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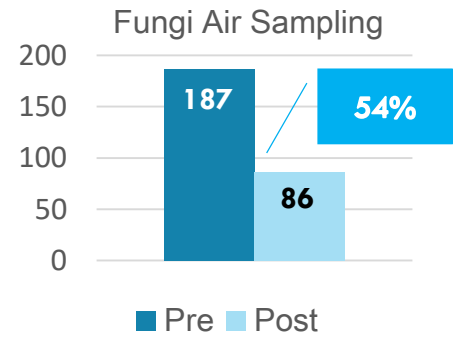
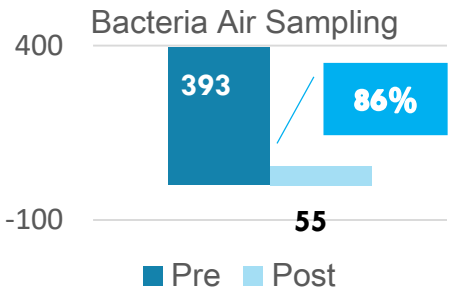
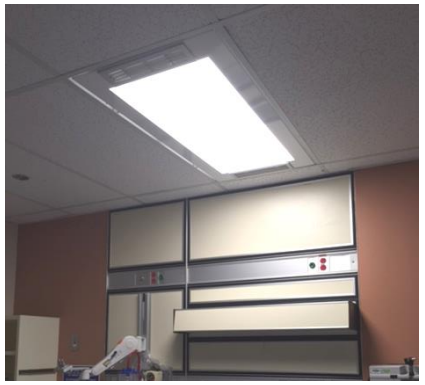
Children’s Hospital Oncology Unit, Texas

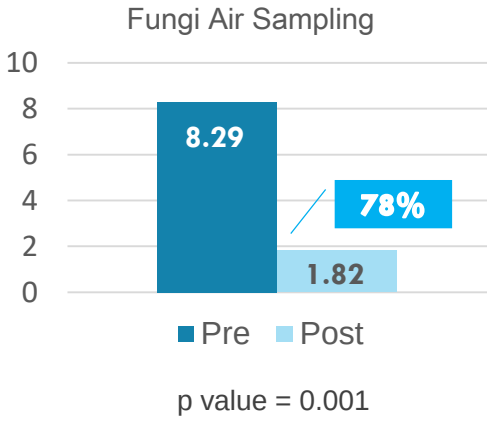


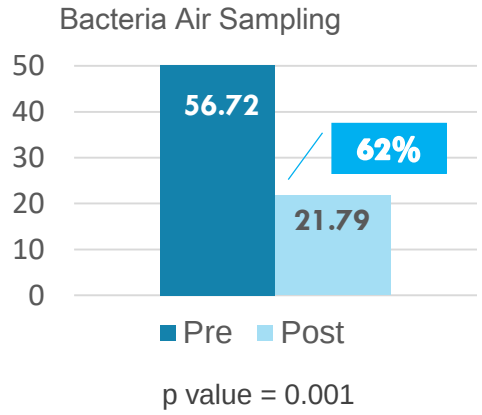




*Post-sampling period, no terminal cleaning took place.

Children’s Hospital, Pharmacy, Memphis, TN





Compounding IV Room	Pre CFUs	Post CFUs	% Decrease
Fungi Air Sampling	3.25	0	100%
Bacteria Air Sampling	1.25	0.125	92%

Guimera, Don et al. Effectiveness of a shielded ultraviolet C air disinfection system in an inpatient pharmacy of a tertiary care children's hospital, American Journal of Infection Control, August 2017

AIR: PUBLISHED DATA

Study Departments – Pharmacy, OR, ICU, Nursing Home, Outpatient Clinic

ARTICLE IN PRESS

American Journal of Infection Control ■■ (2017) ■■–■■

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Cleaning the air with ultraviolet

contact infections in a long-tern

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[b] American Green Technology, South Bend, IN

Key Words:
UV-C
air disinfection
HAI
infection prevention
airborne bacteria

BACKGROUND

Ultraviolet germicidal irradiation (UV-C) in vari

methods has been clearly demonstrated to reduce bacte

work published in 1877 showed that bacteria died w

to sunlight.[1] In 1924, Coblentz and Fulton published t

the germicidal effects of ultraviolet radiation.[2] Sharp, ir

onstrated the ultraviolet dosages needed to kill a variety

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Funding/support: The VidaShield units used in this study were pr

ican Green Technology, South Bend, IN.

Conflicts of interest: L.D.L. is employed by American Green Tec

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EMERGING TECHNOLOGIES

Surface and air: What impact does UV-C at the room level have on airborne and surface bacteria?

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Conflict of interest:

Dr. Lee is employed by VidaShield, which provided the UV-C products used in this study.

ABSTRACT

Background: Short-wave ultraviolet light (UV-C) is known to have the ability to render bacteria inert. We theorized that usin

level would not only lower the amount of bacteria circulating in the air, but also lessen the amount of bacteria found on surf

Methods: We set up field trials at three hospitals (Texas, Nevada, and Massachusetts) where we tested air and surface for ba

the room level, and then tested air and surface again.

Results: In all cases, airborne bacteria was reduced between 79 and 91% over pre-installation values. Most surfaces also sho

although we report one incident of an increase of 288%.

Conclusion: The data indicate that using active air UV-C technology at the room level reduces the bioburden in the air and

Hospitals should consider implementing active UV-C technology to improve air quality.

KEYWORDS

air disinfection, UV-C, airborne bacteria

INTRODUCTION

An early publication on the effectiveness of ultraviolet light on bacteria is from 1877, when two British scientists noticed that Pasteur's solution, when placed in lead-covered test tubes, grew innumerable bacteria, while the same solution in unshielded test tubes placed in sunlight, did not (1). Since then, many studies have demonstrated that UV rays are a powerful way to render bacteria inert, beginning with Coblentz in 1922 (2) and Sharp in 1939 (3).

It has been known for decades that many diseases, such as tuberculosis and influenza, are spread via airborne and/or droplet transmission. More recently, studies have shown that pathogens thought to be spread through direct contact can also become aerosolized. Roberts et al. demonstrated that Clostridium difficile (C. diff.) spores could be disseminated through the air (4) as did Best et al. (5). Li et al. reviewed 40 studies to show a strong association between building ventilation and the transmission of airborne disease (6). Eames et al. wrote similarly, but with a tighter focus on hospital acquired infection (HAI), including methicillin-resistant Staphylococcus aureus (MRSA) (7). Nazaroff's discussion of indoor bioaerosol dynamics lays out how the airflow in a space moves particulate matter, including microbes (8).

Knowing that disease could be spread through the air, and that short-wave ultraviolet (UV-C) can render pathogens inert, it is logical that the medical community would turn to UV-C to reduce the amount of bacteria circulating in the air. Bolton and Cotton discussed how UV disinfection worksin general (9) and Boyce discussed specific technologies for using UV-C in hospitals (10). Rutala et al. studied ho

eliminate bacteria (11).

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from surfaces (14). Our study

of using UV-C at the room le

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surface bacteria.

METHODS

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in Massachusetts (Hospital A

in Texas (Hospital B), and an

(Hospital C). In each case, th

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Major Article

Effect of a shielded continuous ultraviolet-C air disinfection device on reduction of air and surface microbial contamination in a pediatric oncology outpatient care unit

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Key Words:
air disinfection
ultraviolet-C
pediatric oncology

Background: For a clean hospital environment, we evaluated whether ultraviolet-C (UV-C) air disinfection reduces airborne and surface microbial contamination in an outpatient pediatric oncology center.

Methods: A pre- and post-intervention study compared 6 test locations, where continuous shielded UV-C air disinfection devices were installed, with 10 control locations without UV-C. Pre- and post-intervention air and surface samples were collected for bacterial and fungal cultures. Percent changes in colony forming unit (CFU) counts in the test and control locations were compared.

Results: Mean bacterial CFU count per cubic meter air and per surface contact plates decreased by 27% ($P = .219$) and 37% ($P < .01$), respectively, in test locations compared to 40% ($P = .054$) and 10% ($P = .006$) reductions in control locations. Mean fungal CFU count per cubic meter air and per surface contact plates increased by 14% ($P = .156$) and 19% ($P = .048$), respectively, in test locations compared to 24% ($P = .409$) and 2% ($P = .34$) increases in control locations.

Conclusions: There were no consistent statistically significant differences in the air and surface culture results between test locations where UV-C devices were installed and control locations. The effectiveness of UV-C air disinfection in reducing air and surface microbial contamination in outpatient clinical areas where immunocompromised children are encountered was not proven.

BACKGROUND

The hospital environment plays an important role in the transmission of health care–associated infections (HAIs) caused by airborne pathogens or surface contamination.[1,2] For this reason, the Centers for Disease Control and Prevention provided recommendations for environmental disinfection and control to prevent HAIs.[3] Maintaining a clean protective environment is especially important in immunocompromised patient care areas. Pediatric oncology patients are at an increased risk for acquisition of infections, not only in the inpatient care settings but also in outpatient settings, where most health care delivery including chemotherapy infusions occurs. To protect immunocompromised patients, our pediatric oncology center has actively sought ways to reduce the burden of pathogens, including airborne transmission of infections.[4]

The effectiveness of germicidal ultraviolet-C (UV-C) light irradiation has been demonstrated for the disinfection of water and air-handling systems, in the food industry, and for laboratory disinfection, among other uses.[5–11] Over the past decades, UV-C light technology has been increasingly used in health care settings as a tool to prevent infection by disinfecting the hospital environment, including surfaces, water, and air. Recent studies demonstrated the effectiveness of UV-C light in environmental disinfection and a reduction in the acquisition

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Conflicts of interest: L.D.L. was formerly employed by American Green Technology (South Bend, IN), the manufacturer of the VidaShield technology. The other authors have no conflicts of interest to disclose.

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EMERGING TECHNOLOGIES

UV-C light and infection rate in a long term care ventilator unit

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ABSTRACT

bedded rooms, such as in our study, where empty patient rooms are uncommon.

Rooms treated with mobile UV-C emitters do show reduced bacterial surface colony counts, (5) but use of the emitter depends on initial cost, its availability, the allotted time between patients, the need for staff initiative, and an unoccupied space. Our study was designed to determine if the use of continuous, shielded UV-C lights that treat and recirculate patient room air could have an impact on infection rates. A long-term care ventilator unit was chosen because it is an environment with comparatively high infection rates, particularly MDRO and *C. difficile*.

Many of the common HAIs, such as *C. difficile* and MRSA, are considered contact transmissible. However, Best et al. reported that air and sample cultures were positive for *C. difficile* in 60% of hospital rooms where patients had symptomatic *C. difficile* infections. In other words, *C. difficile* can be suspended in air, and from there can settle onto surfaces (6). Surface bound bacteria may become intermittently airborne when surfaces are agitated. The frequent movement of bed sheets would be an example, as Shiomori et al. demonstrated (7). We wondered what impact cleaning the air with UV-C might have on HAIs, including those generally considered to be contact transmissible.

y American Green Technology, South Bend, IN. Manuscript preparation support was done by Diane Laux acted by Eventa LLC to perform the study. Ms. Finley and Ms. Brown have no conflicts of interest to report.

THANK YOU!

ANY QUESTIONS?

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