

ORIGINAL COMMUNICATION

UV-C Irradiation Reduces the Experimentally Induced Bacterial Load on the Surface of a Human Cadaver: An Additional Option for the Preservation of Cadavers in Anatomy

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Safety is a major issue in the embalming procedures of human cadavers. Reduced application of formaldehyde is often recommended. The aim of this study was to investigate the potency of ultraviolet light (UV-C irradiation) on the bacterial load on the surface of a conserved human cadaver. To test UV-C irradiation, the cadaver was laid out in the dissection hall and, after preparation of the muscles, was covered with linen sheets moistened with water. Swabs of the surface and microbiological analysis revealed sporadic bacterial colonies. The surface area was then spiked with bacteria and irradiated by a UV lamp for 15 or 60 min. Half of the area was covered by aluminum foil to serve as a control. After exposition, swabs were taken and analyzed. The exposition had reduced the number of colonies to one third (15 min exposition) and to one tenth (60 min exposition) of the control area. Thus, UV-C irradiation could be used in the preservation of cadavers without chemical pollution of the environment and without any risk for the employees. *Clin. Anat.* 33:113–116, 2020. © 2019 Wiley Periodicals, Inc.

Key words: ultraviolet light; UV-C; human cadaver; bacterial; saving of fixative

INTRODUCTION

In the past, environmental and safety issues have been a major topic in the discussion of embalming procedures applied to human cadavers (Mercer, 1992). This year a paper by Waschke et al. (2019) was presented by the Society of Anatomists (Anatomische Gesellschaft) as a consensus publication. Waschke et al.'s (2019) publication contained recommendations for a reduction in the amount of formaldehyde used by anatomical institutes in the embalming of human cadavers, especially in solutions for body perfusion and immersion tanks. The recommendation was to reduce the concentration of formaldehyde to 2% or less. Also for the preservation of the cadavers in the dissection hall, 2% phenoxy-ethanol was recommended. Due to the fact that it is odorless, phenoxy-ethanol is pleasant to use; however, it remains a source of dangerous emission. This study tests an effective, nontoxic and inexpensive option, which not only reduces the

concentration of fixatives but also controls bacterial contamination of cadavers.

METHODS

Preservation

The experiment was conducted on a male cadaver, 77 years old at the time of death. The cadaver had been preserved for 2 years prior to the experiment.

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Received 25 June 2019; Revised 19 August 2019; Accepted 14 September 2019

Published online 9 October 2019 in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/ca.23481

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Solution A was used for intra-arterial instillation and Solution B was used for the immersion tank (Table 1). Some months before the experiment, a dissection had been performed and the body had been covered with a linen sheet moistened with 1.5% phenoxy-ethanol. Two weeks prior to the experiment, the linen sheet was replaced by a sheet moistened with water. This was necessary as probes from body surfaces covered with phenoxy-ethanol-soaked sheet had yielded no, or only sporadic, colonies at commencement of sampling, which was several days prior to the commencement of the experiment.

Ultraviolet Irradiation Device

As shown in Figure 1, a commercial and industrial UV lamp emitting ultraviolet irradiation C (253.7 nm wave length, UV 72W, UVECO GmbH, Bruckmühl, Germany) was adapted for use at anatomical tables. The lamp was fixed using tension belts, which permitted easy transfer from table to table and adjustment in height. A 360° motion detector was connected in an inverse mode to avoid any risk for staff and students. The lamp switched off automatically if anybody approached within a radius of 10 m. The setting of exposure is presented in Figure 2.

Experimentally Induced Bacterial Load

Aliquots (100 μ l) of an *Escherichia coli* DSM 1103 McFarland 0.5 solution diluted in Dulbecco's Modified Eagle's medium to the colony forming units (CFU) rates indicated were placed with an eSwab tip on 25 cm² areas on a leg muscle of the cadaver (high inoculum: 7×10^5 CFU, low inoculum: 7×10^3 CFU). Spiked areas were either covered with aluminum foil or left exposed.

Exposure to Ultraviolet Radiation

The spiked areas were subsequently exposed to UV-C for 15 and 60 min. During irradiation the body was not covered with water-moistened linen sheets.

TABLE 1. Solution A (Instillation) and B (Immersion Tank) for Conservation of Human Cadavers

Compounds	Solution A	Solution B
Water (l)	39	923
Formaldehyde 39% (l)	3	77
Sorbitol (l)	12	
Lysoformin ^{®a} (l)	2.7	
Calciumchloride (kg)	0.6	
Choralhydrate (kg)	3	
Thymol (g)	12	
Natriumchloride (kg)	2.4	
Formaldehyde concentration (%) (as measured using gas chromatography)	Approx. 5	Approx. 3

^aLysoform, Berlin, Germany.



Fig. 1. An ultraviolet lamp mounted above a dissection table. Also visible is the motion detector that prevents irradiation of any person nearby.

Sampling of Bacteria on Body Surfaces

After exposition, the areas were probed with a fresh eSwab tip, prewetted with Amies transport medium,



Fig. 2. Two areas of skeletal muscle comparable in size were labeled and one was covered using aluminum foil. Swabs were taken from both areas after UV-C irradiation. [Color figure can be viewed at wileyonlinelibrary.com]

the tip was then placed into the transport tube of this system. Recovered bacteria were detached from the tip by vortexing the tube for 5 sec and 100 μ l of the transport medium were subsequently streaked onto blood agar plates. Colonies formed on the plates were counted after 18 hr of incubation at 37°C. Exposition was also performed for 6 hr in order to examine the effects of long exposure.

Specimen Identification

Vegetation on conserved cadavers were sampled with eSwab systems (Copan, Murrieta, CA) and plated onto sheep blood agar plates. Plates were cultured for 48 hr at room temperature and 37°C, respectively, and colonies were analyzed by matrix-assisted laser desorption ionization-time of flight-mass spectrometry (MALDI-TOF-MS) and subsequently compared with the Biotyper 3.0 database (Bruker Daltonik GmbH, Bremen, Germany) for species determination.

RESULTS

As shown in Figure 3, the number of bacterial colonies (CFU) on blood agar plates after 60 min of exposition to UV light was markedly reduced. In the transport medium of swabs from the foil-covered area with high inoculum, 466 colonies were detected. In the medium from the noncovered area, only 41 colonies were found. This is a one-tenth reduction in comparison to the covered, nonexposed area. In the medium of the foil-covered area with low inoculum, six colonies were

observed versus zero colonies after UV-C exposition. In the trial with an exposure time of 15 min, the reduction was about one third as compared to the nonexposed area (934 vs. 364 CFU and 148 vs. 42 CFU, respectively). No changes in color or rigidity of the tissue were observed after a long exposure time of 6 hr.

An additional—nonexperiment related—observation was made. Another cadaver developed spotty and confluent colonies on some parts of the muscle and organ surfaces despite being covered with a phenoxy-ethanol-soaked linen sheet. Mechanical cleaning and washing with Lysoformin (Table 1) was effective, but only for a few weeks. A microbiological analysis detected no bacteria in probes of these smears. Using matrix-assisted laser desorption—time of flight mass spectrometry, the fungus, *Candida famata* (sive *Candida flareri*, *Debaryomyces hansenii*), was identified (identification score 2.2). This fungus belongs to the flavinogenic yeasts, has a high osmo-tolerance (Dmytruk and Sibirny, 2012), and is specialized to moist and cold environments as described by Desnos-Ollivier et al. (2008). A 60-min UV-C irradiation led to a “melting” of the colonies and smears. In order to prevent loss of the body, it was transferred for 6 weeks to an immersion tank containing water with 5% formaldehyde. The fungus had not reappeared since the body was returned to the dissection table 2 months later.

DISCUSSION AND CONCLUSION

All cadavers in anatomy are primary contaminated with bacteria and fungi. After preservation with bactericidal fixatives, secondary contamination occurs during the dissection, caused by dissectors and others. The growth of bacteria and fungi is prevented by using linen sheets that have been moistened with solutions containing bactericidal substances such as phenoxy-ethanol. All antimicrobial fixatives in tissues, fluids, and the air are more or less harmful to humans. Various approaches toward a reduction of harmful effects have been tested. One method was the extraction or exchange of room air containing formaldehyde. Since then, dissection tables have become available that can be docked to extraction units and that withdraw formaldehyde-contaminated air from the bodies by suction. Another method is the chemical neutralization of formaldehyde after the preservation procedure (e.g., Infutrace™, American Bio-Safety, Rocklin, CA). An obvious approach is the reduction of fixatives or their concentration. However, at a certain point the reduction of fixatives in the preservation and maintenance of cadavers in medicine and veterinary medicine leads to problems with bacteria (e.g., staphylococci) and fungi (e.g., *Candida famata*). The search for alternatives to chemicals drew our attention to UV-C irradiation. UV-C exposure is widely used in industry and cell culture labs for the elimination of bacteria and fungi. As the effect of UV-C irradiation is physical destruction, no resistances develop and no environmental contamination occurs. Thus, the effect established in this short study has strengthened the prospects for a possible effective application of UV-C irradiation in the preservation of cadavers in the anatomical field. There are limitations and

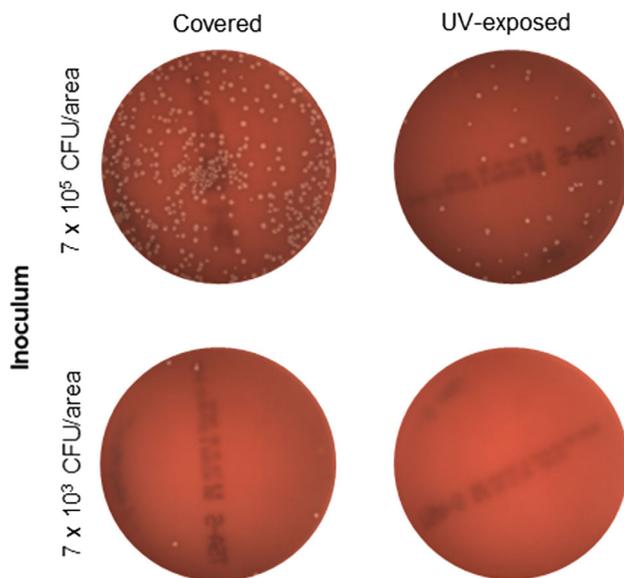


Fig. 3. Representative images of the incubated blood agar plates with smears of transport medium are shown. Samples were taken from areas with and without UV exposition and from two inocula as indicated. [Color figure can be viewed at wileyonlinelibrary.com]

problems: Only the surface can be exposed to the UV light, it is doubtful whether UV light can be used for a situs, and it is also not fully clear which exposure times and intervals are necessary in order to maintain sufficient antimicrobial protection of the cadavers. The authors recommend UV-C irradiation exposure for 60 min once a week while constant work is being performed on the bodies. If no, or only occasional, work is being carried out, then 60 min of exposure once per month is sufficient, provided that the linen sheets covering the cadavers are moistened with at least 1% phenoxy-ethanol.

Altogether, UV-C irradiation might be a simple, effective, and an environmentally sound complementary tool in the maintenance of human cadavers in anatomy.

ACKNOWLEDGMENTS

The authors thank Christoph Neuhardt for the UV lamp construction, Irina Scheck and Ronald Dollwett for the preparation of the human cadavers. The authors also wish to thank Helga Meyer and Barbara Michahelles-Horzella for their excellent work in the body donation group and Ann Söther for polishing the language.

ABBREVIATIONS

CFU colony forming units
UV-C ultraviolet light C

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