The Laryngoscope

The Effectiveness of Ultraviolet Smart D60 in Reducing Contamination of Flexible Fiberoptic Laryngoscopes

Uche C. Ezeh, MS; Efstratios Achlatis, MD; Tyler Crosby, MD; Paul E. Kwak, MD; Michael S. Phillips, MD; Milan R. Amin, MD

Objective: To compare the effectiveness of disinfection protocols utilizing a ultraviolet (UV) Smart D60 light system with Impelux™ technology with a standard Cidex *ortho*-phthalaldehyde (OPA) disinfection protocol for cleaning flexible fiberoptic laryngoscopes (FFLs).

Methods: Two hundred FFLs were tested for bacterial contamination after routine use, and another 200 FFLs were tested after disinfection with one of four methods: enzymatic detergent plus Cidex OPA (standard), enzymatic detergent plus UV Smart D60, microfiber cloth plus UV Smart D60, and nonsterile wipe plus UV Smart D60. Pre- and post-disinfection microbial burden levels and positive culture rates were compared using Kruskal-Wallis ANOVA and Fisher's two-sided exact, respectively.

Results: After routine use, approximately 56% (112/200) of FFLs were contaminated, with an average contamination level of 9,973.7 ± 70,136.3 CFU/mL. The standard reprocessing method showed no positive cultures. The enzymatic plus UV, microfiber plus UV, and nonsterile wipe plus UV methods yielded contamination rates of 4% (2/50), 6% (3/50), and 12% (6/50), respectively, with no significant differences among the treatment groups ($p > 0.05$). The pre-disinfection microbial burden levels decreased significantly after each disinfection technique ($p < 0.001$). The average microbial burden recovered after enzymatic plus UV, microfiber plus UV, and nonsterile wipe plus UV were 0.40 CFU/mL ± 2, 0.60 CFU/mL ± 2.4, and 12.2 CFU/mL ± 69.5, respectively, with no significant difference among the treatment groups ($p > 0.05$). *Micrococcus* species (53.8%) were most frequently isolated, and no high-concern organisms were recovered.

Conclusion: Disinfection protocols utilizing UV Smart D60 were as effective as the standard chemical disinfection protocol using Cidex OPA.

Key Words: UV disinfection, flexible fiberoptic laryngoscope, semi-critical device.

Level of Evidence: N/A

***Laryngoscope*, 00:1–8, 2023**

INTRODUCTION

Flexible laryngoscopy is a common procedure performed in otolaryngology ("ENT"). Flexible fiberoptic laryngoscopes (FFLs) are routinely exposed to the mucus membranes of the nasal cavity and pharynx potentially resulting in contamination by normal flora and pathogens. In a busy clinical practice, the same FFL may be used and reprocessed several times per day. Currently, there are no available national and international reprocessing guidelines specific to FFLs,[1] and there are gaps and variations in decontamination practices across ENT settings.[2–4] This may ultimately create a risk for iatrogenic infection.

Most published medical device-related outbreaks are linked to contaminated channeled devices[5]; there are few reports linking FFLs to infection.[1] Considering their site of use and simpler design, they retain lower microbial loads than channeled devices do after routine use.[6,7] However, a study published in 2019 revealed a gradual increase in the number of reports relating to contaminated ENT endoscopes.[8]

According to Spaulding's classification,[9] FFLs are semi-critical instruments, defined as those that contact mucous membranes and nonintact skin, which require high-level disinfection (HLD). Unlike sterilization, this process is not generally sporicidal.[7]

HLD is an important step in the prevention of transmission of infection. FFL reprocessing consists of other basic steps such as leak testing, manual pre-cleaning, rinsing, drying, and storage.[10] Endoscope reprocessing has become more complicated and less effective due to sophisticated endoscope design and advancement of knowledge regarding infection control.[11] Transmission of infection via endoscopy is rare, but when it occurs, it is typically related to inadequate reprocessing, noncompliance with recommended guidelines, and use of defective equipment.[5]

From the Department of Otolaryngology—Head and Neck Surgery (U.C.E., E.A., T.C., P.E.K., M.R.A.), NYU Langone Health, New York, New York, USA; Division of Infectious Disease, Department of Medicine (M.S. P.), NYU Grossman School of Medicine, New York, New York, USA.

Additional supporting information may be found in the online version of this article.

Editor's Note: This Manuscript was accepted for publication on June 21, 2023.

This manuscript was presented as a poster presentation at the 144th Annual Meeting of the American Laryngological Association on May 5–7, 2023 in Boston, Massachusetts.

The authors have no conflicts of interest to disclose.

Send correspondence to Milan R. Amin, Department of Otolaryngology—Head and Neck Surgery, NYU Langone Health, M.D.222 East 41st Street, 8th Floor, New York, NY 10017.

Email: milan.amin@nyulangone.org

DOI: 10.1002/lary.30869

Currently, there are two conventional methods for disinfecting non-channeled ENT endoscopes: chemical immersion and automated endoscope reprocessors (AER).[12,13] Both processes utilize Food & Drug Administration (FDA)-cleared liquid chemical HLDs, including glutaraldehyde, *ortho*-phthalaldehyde (OPA), and peracetic acid. Several studies have shown that these agents are efficacious in disinfecting FFLs.[6,14–16] Unfortunately, liquid disinfectants have toxic side effect profiles, require lengthy immersion times, and may be incompatible with endoscope material.[17–19]

To address these challenges, new emerging methods (disposable sheaths and the Tristel Trio Wipe system (TTWS)) have begun to replace the traditional methods.[13] Recently, investigators had even begun exploring the utility of ultraviolet (UV) light as an HLD for FFLs. UV light technology is not new, but Rudhart et al. found a UV reprocessing machine (UV Smart D60) to be effective in reducing contamination of clinically used rigid laryngoscopes and FFLs.[20,21] The objective of our study was to compare the bactericidal efficacy of various cleaning methods utilizing UV Smart D60 to our clinic's standard reprocessing method using Cidex OPA. We hypothesized that UV light would be as effective as chemical methods for disinfecting FFLs, with the added benefits of being faster, safer, and more time- and resource-efficient.

MATERIAL AND METHODS

This study was performed at a single tertiary academic ENT outpatient clinic. Six non-channeled FFLs (Olympus ENF-VH; Olympus ENF-V3) were used during this study. All endoscopic procedures were performed by a fellow and two laryngologists. This study was exempt from review by the New York University (NYU) Langone Health Institutional Review Board (IRB) as it involved only microbiological sampling and did not involve the collection of any human data or harm to any patients.

Sample Processing and Bacterial Culturing

During the sampling, cleaning, and disinfection processes, gloves were worn by researchers and reprocessing personnel. The investigators employed several sterile techniques to avoid contamination.

For the microbiological investigation, samples were collected immediately after clinical use and following HLD with Cidex OPA or UV Smart D60 (Fig. 1). The distal tip of each FFL was immersed in a 9 mL Butterfield's Phosphate Buffer (pH: 7.2) tube. The tubes were vortexed at medium speed for 2 min (Fig. 2).

Samples were sent for quantitative aerobic plate culture at EMSL Analytical, Inc. (New Jersey), a laboratory certified by the New York State Department of Health, to perform microbiological studies on environmental specimens. The pre- and post-disinfection samples were cultured on blood agar plates. If growth was detected, the number of colonies was counted and reported as colony-forming units per mL (CFU/mL). Effective disinfection was defined as a bacterial count of <10 CFU/mL, considering that this was the lowest detection threshold of

Fig. 1. Arrangement of a flexible fiberoptic laryngoscope (FFL) inside the ultraviolet (UV) Smart D60 light unit. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

EMSL Analytical, Inc. (New Jersey) assays. For the post-samples, positive cultures were gram-stained using standard protocols, and bacterial identification was performed.

The chemical disinfection and UV reprocessing protocols are outlined in Table I. Chemical disinfection was performed by one healthcare worker throughout the study period.

Following experimental decontamination, all UV reprocessed FFLs were decontaminated according to our clinic's reprocessing method using enzymatic detergent for pre-cleaning and Cidex OPA for HLD.

Statistical Analysis

Descriptive analysis was reported as mean ± standard deviation (SD). For statistical analysis, CFUs were log-transformed (mean log $(x+1)_{10}$) to

TABLE I.
An Outline of Each Decontamination Workflow.

Disinfection Arm	Methods
1. Enzymatic detergent + Cidex OPA (standard method)	FFLs were placed in MaxiZyme Dual Enzymatic Detergent solution (Hardy Diagnostics) and cleaned with a Metrex MetriSponge (30 s). Instruments were then rinsed with tap water (30 s) and subsequently immersed in CIDEX™ OPA Solution (ASP) (12 min) at room temperature (20°C). After completing chemical immersion, the instruments were rinsed with tap water (30 s) and wiped with a 70% isopropyl alcohol-soaked gauze. **Approximate total time**: 13.5 min
2. Enzymatic detergent + UV Smart D60	FFLs were placed in MaxiZyme Dual Enzymatic Detergent solution (Hardy Diagnostics) and cleaned with a Metrex MetriSponge (30 s). Instruments were rinsed with tap water (30 s) and were placed in the UV Smart D60 machine for HLD (60 s). **Approximate total time**: 2 min
3. Microfiber cloth + UV Smart D60	FFLs were wiped 3 times with a Vileda MicroOne Microfiber cloth impregnated with sterile water followed by a wipe 1 time with a dry Vileda microcloth (30 s). Instruments were placed in the UV Smart D60 machine for HLD (60 s). **Approximate total time**: 1.5 min
4. Nonsterile wipe + UV Smart D60	FFLs were wiped once with Fisherbrand Clean-Wipes™ impregnated with sterile water (30 s). Instruments were placed in the UV Smart D60 machine for HLD (60 s). **Approximate total time**: 1.5 min

OPA = *ortho*-phthalaldehyde; UV = ultraviolet.

stabilize the variance. Differences in the amount of microbial burden found before and after disinfection were compared using the Kruskal–Wallis analysis of variance (ANOVA); Dunn's test was performed to delineate significant pairwise comparisons. Data was also categorized as positive (≥10 CFU) and negative cultures (<10 CFU) and

Fig. 2. Sample collection from the flexible fiberoptic laryngoscope (FFL) distal tip surface using vortex and collection tube. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

compared using a two-sided Fisher's exact test with Bonferroni correction. SPSS IBM v28 was used for analysis and $p < 0.05$ was statistically significant.

A post-hoc power analysis was conducted to determine the study's statistical power. The Kruskal-Wallis test's post-hoc power analysis, with an effect size of 0.25, an alpha level of 0.05, and a total sample size of 200 FFLs (with 50 in each treatment group), indicated power of

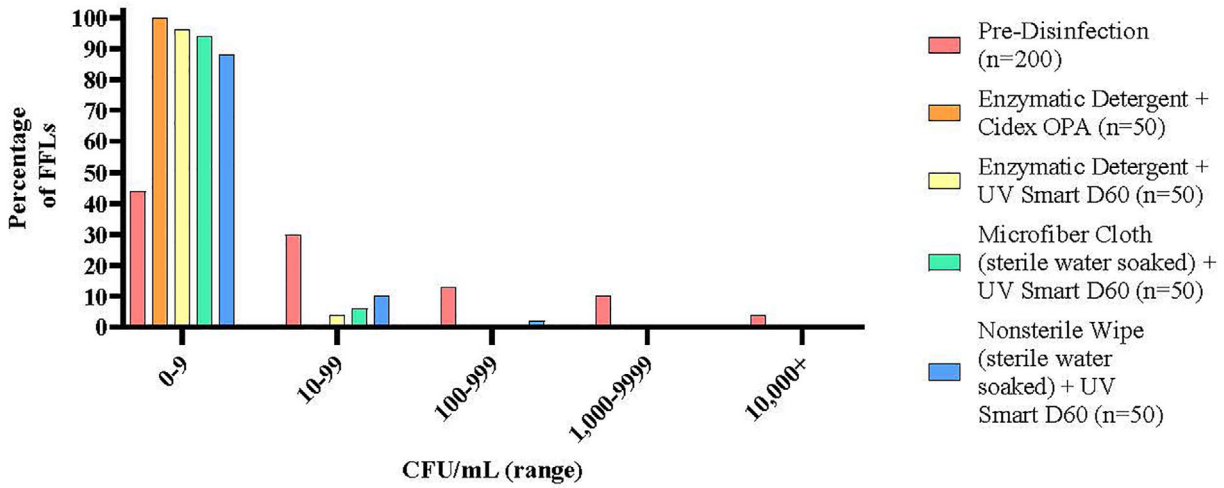

Fig. 3. Distribution of microbial burden after clinical use and after high-level disinfection (HLD). [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

90%. Similarly, the post-hoc analysis for the fisher's exact test revealed a power exceeding 90%. These tests confirmed that the study possessed sufficient statistical power to detect significant differences in proportions (Fisher's exact test) and mean values (Kruskal–Wallis ANOVA).

RESULTS

Bacterial Contamination of Flexible Fiberoptic Laryngoscope After Routine Use

A total of 200 FFLs were sampled after clinical use, of which 112 of them had bacterial growth (56%). The mean microbial load recovered from the distal tips of FFLs after clinical use was 9,973.7 CFU/mL ± 70,136.3 (range: <10 to 570,000 CFU/mL). Figure 3 shows that 30% of FFLs were contaminated with 10–99 CFU/mL, 13% between 100 and 999, 10% between 1000 and 9999, and 4% greater than 10,000.

Bacterial Contamination Recovered After Disinfection

There was no microbial burden found on FFLs after standard reprocessing (enzymatic + Cidex OPA). There was a mean of 0.40 CFU/mL ± 2 (range: 10 CFU) recovered after enzymatic + UV Smart D60, 0.60 CFU/mL ± 2.4 (range: 10) recovered after microfiber cloth + UV Smart D60, and 12.2 CFU/mL ± 69.5 (range: 10–490) after nonsterile wipe + UV Smart D60. Kruskal-Wallis ANOVA was conducted, and the results showed that there was a statistically significant reduction in the amount of contamination found after each disinfection protocol compared to before reprocessing ($p < 0.001$), but that there was no significant difference in the amount of microbial burden recovered between each method ($p > 0.05$) (Table II).

Our findings showed the following bacterial rates: enzymatic + UV Smart D60 (4%), microfiber cloth + UV Smart D60 (6%), and nonsterile wipe + UV Smart D60 (12%) (Table III). The results of Fisher's exact test revealed a significant difference in contamination rates before disinfection compared to those after each disinfection method ($p < 0.001$). However, no significant differences were observed when the contamination rates between each disinfection method were compared ($p > 0.05$). The pairwise comparison of bacterial culture rates are presented in Supplementary Table 1.

TABLE III.
Positive Bacterial Culture Rates Pre- and Post-Disinfection.

Disinfection Protocol	Proportion of Positive Cultures	Contamination Rates (%)
Pre-disinfection	112/200	56*
1. Enzymatic detergent + Cidex OPA	0/50	0†
2. Enzymatic detergent + UV Smart D60	2/50	4†
3. Microfiber cloth + UV Smart D60	3/50	6†
4. Nonsterile wipe + UV Smart D60	6/50	12†

*Proportions did significantly differ from each other ($p < 0.001$).
†Proportions did not significantly differ from each other ($p > 0.05$).
OPA = *ortho*-phthalaldehyde.

Microorganisms Cultured

The microorganisms isolated are summarized in Table IV. A total of thirteen bacteria were recovered on eleven FFLs, none of which were of high concern (i.e., *Escherichia coli, Klebsiella pneumoniae, Staphylococcus aureus*),[22] and most were found at low amounts (Table V). The most frequent organism isolated was *Micrococcus* sp. (53.8%), a non-pathogenic spore-forming bacteria found in the environment and on the skin. One FFL in the nonsterile wipe plus UV disinfection treatment arm grew more than one bacterial strain (gram-negative rod, *Kytococcus schroeteri*, *Micrococcus luteus*).

TABLE II.
Pairwise Comparison of the Mean Log Colony-Forming Unit (CFU) of Each Disinfection Arm (Dunn's Test).

Bacterial Organisms	Test Statistic	Standard. Test Statistic	Standard. Error	*p*-Value
Pre-disinfection versus Arm 1	−113.707	−7.614	14.934	<0.001
Pre-disinfection versus Arm 2	−107.547	−7.201	14.934	<0.001
Pre-disinfection versus Arm 3	−104.467	−6.995	14.034	<0.001
Pre-disinfection versus Arm 4	−91.937	−6.156	14.934	<0.001
Arm 1 versus2	−6.160	−0.326	18.890	0.744
Arm 1 versus 3	−9.240	−0.489	18.890	0.625
Arm 1 versus 4	−21.770	−1.152	18.890	0.249
Arm 2 versus 3	−3.080	−0.163	18.890	0.870
Arm 2 versus 4	−15.610	−0.826	18.890	0.409
Arm 3 versus 4	−12.530	−0.663	18.890	0.507

1 = Enzymatic detergent + Cidex OPA (ortho-phthalaldehyde); 2 = Enzymatic detergent + UV Smart D60; 3 = Microfiber cloth + UV Smart D60; 4 = Nonsterile wipe + UV Smart D60.

TABLE IV.
Profile of Bacterial Isolates Recovered After Each Disinfection Process.

Disinfection Processes	Positive Cultures ($n = 50$ FFL)	Microorganism Isolated (CFU/mL)
1. Enzymatic detergent + Cidex OPA	0	—
2. Enzymatic detergent + UV Smart D60	2	*Staphylococcus epidermidis* (10); *Staphylococcus warneri* (10)
3. Microfiber cloth + UV Smart D60	3	*Micrococcus luteus* (10); *Micrococcus luteus* (10); *Dermacoccus nishinomiyaensis* (10)
4. Nonsterile wipes + UV Smart D60	6	*Staphylococcus capitis* (20); *Micrococcus luteus* (10); *Micrococcus luteus* (40); *Bacillus sp*. (10); *Bacillus simplex* (10); *Gram-negative rod†, *Kytococcus schroeteri**, *Micrococcus luteus** (490)

*Isolates found on the same FFL.
†Not specified.
OPA = *ortho*-phthalaldehyde; UV = ultraviolet.

DISCUSSION

FFLs are indispensable instruments used in ENT practice, and their potential role in infection transmission has been a growing concern. They must be rigorously cleaned and disinfected between each patient encounter, but the fast-pace and demanding nature of ENT clinical practice makes adequate reprocessing particularly challenging.[13] The ideal disinfection system for FFLs should be standardized, fast, and less hazardous, with a minimal risk of endoscope contamination and damage.[13]

We report the results of the first prospective study to evaluate and compare the bactericidal efficacy of UV light disinfection protocols with one using Cidex OPA solution. We found no significant difference between these methods in terms of the amount of residual microbial burden recovered or proportion of positive cultures. In addition, microbiological analysis showed no high-concern pathogens (i.e., *E. coli, Pseudomonas, S. aureus*) in any of the positive cultures post-decontamination. Overall, our study shows that disinfection processes utilizing UV light systems are non-inferior to one using Cidex OPA.

UV-C technology has been frequently used in healthcare settings for decontamination purposes.[23,24] It has recently emerged as a new technique for disinfecting semi-critical devices, with the literature primarily discussing its use in endocavitary probes.[25–27] Only one previous study evaluated the microbiological efficacy of UV light in disinfecting FFLs. Rudhart et al.[21] conducted a study in 2021 in which 50 FFLs were cleaned with nonsterile wipes impregnated with sterile water and irradiated with UV Smart D60. Their results showed positive cultures in 11 of the 50 instruments (14%). A similar rate was achieved in our study using a similar process (12%). However, we found a lower contamination rate when using enzymatic detergent (4%) or microfiber cloth (6%) in conjunction with UV Smart D60. Although there was no statistically significant difference between these rates, these findings suggest that non-sterile wipes impregnated with sterile water may not be able to adequately disinfect FFLs before irradiation.

In our study, instruments assigned to the Cidex OPA reprocessing arm showed no positive bacterial growth, which is in accordance with previous studies that used chemical disinfectants. Abramson et al.[6] reported a 1.7% positive culture rate after immersing 60 rigid laryngoscopes and FFLs in Cidex OPA for 5 min; no organisms were recovered after a 10-minute exposure. Bhattacharyya and Kepnes[14] reported a 2.1% positive culture rate (1/48) after cleaning FFLs with enzymatic detergent for 5 min and soaking in Cidex OPA solution for 20 min. There was one positive fungal culture, but no bacterial growth. Chang et al.[15] contaminated FFLs in vitro with *S. aureus* and *C. albicans* and compared the efficacy of various disinfection techniques, with some involving immersion in Cidex OPA. Their study did not recover any bacterial isolates from the FFLs after chemical disinfection. An in vivo study by Liming et al.[16] compared several disinfection techniques and they achieved similar results.

TABLE V.
Frequency of Bacterial Organisms ($n = 13$).

Bacterial Organisms	Species	Source	Frequency, *n* (%)
Micrococcus luteus	*Micrococcus*	Environmental, skin	7 (53.8)
Kytococcus schroeteri (*Micrococcus* sp.)			
Dermacoccus nishinomiyaensis (also known as *Micrococcus nishinomiyaensis*)			
Staphylococcus epidermidis	Coagulase-negative Staphylococci	Skin	3 (23.1)
Staphylococcus warneri			
Staphylococcus capitis			
Bacillus sp., not specified	*Bacillus*	Environmental	2 (15.4)
Bacillus simplex			
Gram-negative rod, not specified	—	—	1 (7.7)

sp = Species.

Although chemical disinfectant protocols have been proven to be very effective in decontaminating FFLs, they are hazardous, require extensive monitoring to ensure compliance with manufacturer and regulatory requirements, have lengthy processing times, and may be potentially incompatible with endoscope material.[19,28,29] The advent of AERs has helped reduce the exposure of patients and healthcare workers to these hazardous chemicals and has automated a process that is prone to operator error. Liming et al. demonstrated that the Medivator AER was as effective as Cidex OPA at disinfecting FFLs.[16] However, chemical disinfectants are commonly used in conjunction with AERs, which have long processing cycles and have been previously linked to infection outbreaks.[5]

In the field of ENT, there have been other emerging techniques, including disposable sheaths and TTWS.[12,13] Disposable sheaths can easily be applied and removed from FFLs. Alvarado et al. found no bacterial growth on 100 nasopharyngoscopes after enzymatic cleaning and disinfection with 70% ethanol.[30] Although the use of endoscope sheaths allows for a quicker turnover of instruments, a drawback of this approach is their susceptibility to perforation. The Centers for Disease Control and Prevention (CDC) still recommends instruments with mucosal contact undergo HLD between every use despite being covered with a sheath.[7] TTWS has also become a popular choice in ENT clinics.[31] Hitchcock et al.[32] compared the efficacy of TTWS and Cidex OPA solution in conjunction with AER and PeraSafe chemical immersion in decontaminating flexible nasoendoscopes. The results of their study revealed no bacterial growth after TTWS, one positive culture after PeraSafe immersion, and 3 after Cidex OPA with AER. Furthermore, they demonstrated that disinfection with TTWS had the fastest turnaround time compared with the other two methods and was more user-friendly and cost-efficient.[32] The primary drawback of this approach is its reliance on mechanical action; consequently, the efficacy of disinfection is highly operator-dependent and more susceptible to human error than the synergistic action of manual cleaning and automated HLD.

FFLs typically retain a lower amount of contamination, with estimates being around 3000–5000 CFU.[6] Before disinfection, we recovered a mean bacterial load of 9,973.7 CFU/mL (range: <10 to 570,000), with 44% (88/200) of FFLs found to be sterile (<10 CFU) after procedural use. This is in accordance with a study conducted by Nystrom et al., in which 62% of the surgical devices, including ENT instruments, had <10 organisms after use.[33] Compared to devices used in gastroenterology and pulmonary, FFLs are briefly passed into the upper aerodigestive tract via the nares or oral cavity and may not be exposed to the same amount of microbial burden found in the colon or lower respiratory tract. Additionally, FFLs are non-channeled devices and have fewer accessories and compartments for microorganisms to hide. Our results confirm the notion that FFLs, by virtue of their design and site of use, carry less microbial burden than channeled endoscopes but may still pose a risk for infection transmission if they are inadequately decontaminated.

Micrococcus spp., coagulase-negative staphylococci, and *Bacillus* spp. were the most common strains isolated after disinfection. These microorganisms rarely cause significant infections and were found in low amounts, most likely from skin or environmental sources. These results may be explained by improper hand hygiene, inadequate maintenance of aseptic conditions, use of non-sterile gloves, or mishandling of instruments during sample collection. HLD is effective in killing all forms of microorganisms, except for a large number of bacterial spores. The absence of bacterial spores after pre-cleaning with enzymatic detergent and HLD with either Cidex OPA or UV Smart D60 suggests that these two methods may be more sporicidal than those involving sterile-water pre-cleaning.

Our results also showed no recovery of any high-concern organisms, which is clinically relevant considering that these pathogens have been linked to outbreaks of endoscopy-related infections and are susceptible to developing multidrug resistance.[34] Although the isolates we recovered had low pathogenicity, vulnerable populations (ie. elderly, immunocompromised) may still be at risk of serious infection. Further refinement of our UV disinfection protocols and stricter adherence to aseptic techniques would help minimize contamination.

By minimizing the resources required for disinfection, UV Smart D60 may help eliminate the need to purchase additional endoscope equipment, which is often necessary due to long processing times and rapid instrument turnover. Although our study did not assess cost-efficacy, a recent group performed a cost analysis of four disinfection methods (UV-Smart D60 vs. Cidex OPA vs. TTWS vs. Revital-Ox (hydrogen peroxide solution)) and found UV-Smart D60 to have the shortest amount of labor time and to be the most cost-effective disinfection method for large-volume ENT clinics.[35] Our study team found the device easy to use and safe, which will increase compliance with FFL disinfection in patient care settings and enhance patient safety.

Our study has some limitations. One of the shortcomings of our study is the lack of investigation into the efficacy of UV Smart D60 in eliminating fungal, mycobacterial, and viral growth from FFLs. Previous investigators have demonstrated the efficacy of UV light against HPV on endocavitary probes.[36] Future investigations should consider studying UV Smart D60's efficacy in eliminating other microorganisms. Culturing bacteria before disinfection and comparing them with post-disinfection organisms would have provided valuable insights into our study. However, due to cost limitations, we only cultured bacteria after the disinfection process. In a previous study by Rudhart et al., they cultured organisms before disinfection with UV Smart D60 and commonly isolated non-pathogenic organisms (such as coagulase-negative Staphylococci); few isolates were pathogenic bacteria.[12] This again underscores the significance of effective disinfection practices. Our study was conducted in a non-hospital setting. We recognize that hospitals and hospital-based clinics may be subject to different standards set by the Joint Commission, which could impede the widespread adoption of UV light as an HLD in ENT settings. Additionally, it is important to note that our study specifically compared the efficacy of UV

disinfection protocols to a Cidex OPA protocol. Different ENT clinics may utilize alternative chemical disinfectants, which would restrict the generalizability of our findings. In the United States, there is only one validated sampling and culturing surveillance protocol, which is proposed by the CDC,[22] and it only applies to channeled instruments. Without a consensus guideline for non-channeled endoscopes, we do not know what the acceptable microbial burden threshold should be for organisms of low-to-moderate concern. We understand that the presence of any contamination following UV protocols, as opposed to none after following the standard reprocessing guidelines for endoscope disinfection, may raise concerns, particularly for vulnerable populations. Although we found no statistically significant differences between our treatment methods, repeat studies may help reinforce our conclusions.

CONCLUSION

Chemical disinfection of FFLs results in substantial workload demands, purchasing expenses, and health and safety risks. Our results showed that our decontamination protocols with UV Smart D60 were as effective in removing contamination from FFLs as our traditional method of using Cidex OPA. Although chemical agents may continue to be used, the use of UV-light systems can ultimately help make FFL decontamination simpler, safer, and less time- and resource-intensive.

ACKNOWLEDGMENTS

We are grateful to Erika Mero for her assistance with standard reprocessing. We thank Michele Santacatterina and Yan Zhang for their guidance and assistance with statistical analysis.

Role of sponsors: The sponsors had no role in the design and conduct of the study, in the collection, analysis, and interpretation.

FUNDING INFORMATION

UV Smart Technologies supported this study by providing our research study team with a proprietary UV Smart D60 machine and funding for cleaning materials for conducting UV disinfection experiments of data, or in the preparation of the manuscript, review, or approval of the manuscript.

BIBLIOGRAPHY

1. Muscarella LF. Prevention of disease transmission during flexible laryngoscopy. *Am J Infect Control*. 2007;35(8):536-544. https://doi.org/10.1016/j.ajic.2006.09.010.
2. Banfield GK, Hinton AE. A national survey of disinfection techniques for flexible nasendoscopes in UK ENT out-patient departments. *J Laryngol Otol*. 2000;114(3):202-204. https://doi.org/10.1258/0022215001905337.
3. Lubbe DE, Fagan JJ. South African survey on disinfection techniques for the flexible nasopharyngoscope. *J Laryngol Otol*. 2003;117(10):811-814. https://doi.org/10.1258/002221503770716269.
4. Chandran D, Lomas J, Anderson J, Green M, McKenzie JL, Grigg R. A state-wide survey of disinfection techniques for nasendoscopies in Queensland ENT out-patient departments. *Aust J Otolaryngol*. 2018;1:28. https://doi.org/10.21037/ajo.2018.10.02.
5. Kenters N, Huijskens E, Meier C, Voss A. Infectious diseases linked to cross-contamination of flexible endoscopes. *Endosc Int Open*. 2015;03(04):E259-E265. https://doi.org/10.1055/s-0034-1392099.
6. Abramson AL, Gilberto E, Mullooly V, France K, Alperstein P, Isenberg HD. Microbial adherence to and disinfection of laryngoscopes used in office practice. *Laryngoscope*. 1993;103(5):503-508. https://doi.org/10.1288/00005537-199305000-00004.
7. Rutala WA. *Guideline for Disinfection and Sterilization in Healthcare Facilities*. Centers for Disease Control and Prevention (CDC); 2008:163.
8. Jiang R, Kasle DA, Alzahrani F, Kohli N, Lerner MZ. A manufacturer and user facility device experience analysis of upper aerodigestive endoscopy contamination: is flexible laryngoscopy different? *Laryngoscope*. 2021;131(3):598-605. https://doi.org/10.1002/lary.28826.
9. Spaulding EH. The role of chemical disinfection in the prevention of nosocomial infections. *Proceedings of the International Conference on Nosocomial Infections, vol. 1970. American Hospital Association Chicago*; 1971:254-274.
10. Rutala WA, Weber DJ. Reprocessing endoscopes: United States perspective. *J Hosp Infect*. 2004;56:27-39. https://doi.org/10.1016/j.jhin.2003.12.035.
11. Omidbakhsh N, Manohar S, Vu R, Nowruzi K. Flexible gastrointestinal endoscope processing challenges, current issues and future perspectives. *J Hosp Infect*. 2021;110:133-138. https://doi.org/10.1016/j.jhin.2021.01.021.
12. Collins WO. A review of reprocessing techniques of flexible nasopharyngoscopes. *Otolaryngol Head Neck Surg*. 2009;141(3):307-310. https://doi.org/10.1016/j.otohns.2009.05.027.
13. Cavaliere M, Iemma M. Guidelines for reprocessing non-lumened, heat-sensitive ENT endoscopes. In: Amornyotin S, ed. *Endoscopy—Innovative Uses and Emerging Technologies*. InTech; 2015. https://doi.org/10.5772/61219.
14. Bhattacharyya N, Kepnes LJ. The effectiveness of immersion disinfection for flexible fiberoptic laryngoscopes. *Otolaryngol Head Neck Surg*. 2004;130(6):681-685. https://doi.org/10.1016/j.otohns.2003.11.004.
15. Chang D. Disinfection of flexible fiberoptic laryngoscopes after In vitro contamination with *Staphylococcus aureus* and *Candida albicans*. *Arch Otolaryngol Head Neck Surg*. 2012;138(2):119-121. https://doi.org/10.1001/archoto.2011.1204.
16. Liming B, Funnell I, Jones A, Demons S, Marshall K, Harsha W. An evaluation of varying protocols for high-level disinfection of flexible fiberoptic laryngoscopes: high-level disinfection of FFLs. *Laryngoscope*. 2014;124(11):2498-2501. https://doi.org/10.1002/lary.24665.
17. Sokol WN. Nine episodes of anaphylaxis following cystoscopy caused by Cidex OPA (ortho-phthalaldehyde) high-level disinfectant in 4 patients after cytoscopy. *J Allergy Clin Immunol*. 2004;114(2):392-397. https://doi.org/10.1016/j.jaci.2004.04.031.
18. Takigawa T, Endo Y. Effects of glutaraldehyde exposure on human health. *J Occup Health*. 2006;48(2):75-87. https://doi.org/10.1539/joh.48.75.
19. Atiyeh K, Chitkara A, Achlatis S, Branski RC, Amin MR. Allergic reaction to ortho-phthalaldehyde following flexible laryngoscopy. *Laryngoscope*. 2015;125(10):2349-2352. https://doi.org/10.1002/lary.25421.
20. Rudhart SA, Günther F, Dapper L, et al. UV light-based decontamination: an effective and fast way for disinfection of endoscopes in otorhinolaryngology? *Eur Arch Otorhinolaryngol*. 2020;277(8):2363-2369. https://doi.org/10.1007/s00405-020-05978-w.
21. Rudhart SA, Günther F, Dapper L, et al. UV light-based reprocessing of flexible endoscopes without working channel in oto-rhino-laryngology: an effective method? *Eur Arch Otorhinolaryngol*. 2021;278(10):4075-4080. https://doi.org/10.1007/s00405-021-06737-1.
22. Duodenoscope-Surveillance-Sampling-and-Culturing-Protocols US Food and Drug Administration website. 2018 Accessed November 1, 2022. https://www.fda.gov/media/111081/download.
23. Nerandzic MM, Cadnum JL, Pultz MJ, Donskey CJ. Evaluation of an automated ultraviolet radiation device for decontamination of Clostridium difficile and other healthcare-associated pathogens in hospital rooms. *BMC Infect Dis*. 2010;10(1):197. https://doi.org/10.1186/1471-2334-10-197.
24. Rutala WA, Gergen MF, Weber DJ. Room decontamination with UV radiation. *Infect Control Hosp Epidemiol*. 2010;31(10):1025-1029. https://doi.org/10.1086/656244.
25. Kac G, Gueneret M, Rodi A, et al. Evaluation of a new disinfection procedure for ultrasound probes using ultraviolet light. *J Hosp Infect*. 2007;65(2):163-168. https://doi.org/10.1016/j.jhin.2006.10.008.
26. Kac G, Podglajen I, Si-Mohamed A, Rodi A, Grataloup C, Meyer G. Evaluation of ultraviolet C for disinfection of endocavitary ultrasound transducers persistently contaminated despite probe covers. *Infect Control Hosp Epidemiol*. 2010;31(2):165-170. https://doi.org/10.1086/649794.
27. Bloc S, Mercadal L, Garnier T, et al. Evaluation of a new disinfection method for ultrasound probes used for regional anesthesia: ultraviolet C light. *J Ultrasound Med*. 2011;30(6):785-788. https://doi.org/10.7863/jum.2011.30.6.785.
28. Cowan RE, Manning AP, Ayliffe GA, et al. Aldehyde disinfectants and health in endoscopy units. *Gut* British Society of Gastroenterology Endoscopy Committee. 1993;34(11):1641-1645. https://doi.org/10.1136/gut.34.11.1641.
29. Fujita H, Sawada Y, Ogawa M, Endo Y. Health hazards from exposure to ortho-phthalaldehyde, a disinfectant for endoscopes, and preventative measures for health care workers. *SanEiShi*. 2007;49(1):1-8. https://doi.org/10.1539/sangyoeisei.49.1.
30. Alvarado CJ, Anderson AG, Maki DG. Microbiologic assessment of disposable sterile endoscopic sheaths to replace high-level disinfection in reprocessing:

a prospective clinical trial with nasopharygoscopes. *Am J Infect Control*. 2009;37(5):408-413. https://doi.org/10.1016/j.ajic.2009.04.276.
31. Swift AC. *Guidance on the Decontamination and Sterilization of Rigid and Flexible Endoscopes*. 2010.
32. Hitchcock B, Moynan S, Frampton C, Reuther R, Gilling P, Rowe F. A randomised, single-blind comparison of high-level disinfectants for flexible nasendoscopes. *J Laryngol Otol*. 2016;130(11):983-989. https://doi.org/10.1017/S0022215116008860.
33. Nystrom B. Disinfection of surgical instruments. *J Hosp Infect*. 1981;2:363-368. https://doi.org/10.1016/0195-6701(81)90069-4.
34. Gaynes R, Edwards JR. National Nosocomial Infections Surveillance System. Overview of nosocomial infections caused by gram-negative bacilli. *Clin Infect Dis*. 2005;41(6):848-854. https://doi.org/10.1086/432803.
35. Biadsee A, Crosby L, Chow W, Sowerby LJ. Cost minimization analysis of nasopharyngoscope reprocessing in community practice. *J Otolaryngol Head Neck Surg*. 2023;52(1):8. https://doi.org/10.1186/s40463-022-00610-9.
36. Meyers C, Milici J, Robison R. UVC radiation as an effective disinfectant method to inactivate human papillomaviruses. Liu X, ed. *PLoS One*. 2017;12(10):e0187377. https://doi.org/10.1371/journal.pone.0187377.