



Major article

Effectiveness of the SYSTEM 1E Liquid Chemical Sterilant Processing System for reprocessing duodenoscopes



Gerald McDonnell PhD, Michele Ehrman BS*, Sara Kiess BS

STERIS Corporation, Mentor, OH

Key Words:

Sterilization
Semicritical device
GI endoscope reprocessing
Liquid chemical sterilization
Low-temperature sterilization

Background: A troubling number of health care-acquired infection outbreaks and transmission events, some involving highly resistant microbial pathogens and resulting in serious patient outcomes, have been traced to reusable, high-level disinfected duodenoscopes in the United States. The Food and Drug Administration (FDA) requested a study be conducted to verify liquid chemical sterilization efficacy of SYSTEM 1E® Liquid Chemical Sterilant Processing System (STERIS Corporation, Mentor, OH) with varied duodenoscope designs under especially arduous conditions. Here, we describe the system's performance under worst case SYSTEM 1E® processing conditions.

Methods: The test protocol challenged the system's performance by running a fractional cycle to evaluate reduction of recoverable test spores from heavily contaminated endoscopes, including all channels and each distal tip, under worst case SYSTEM 1E® processing conditions.

Results: All devices were successfully liquid chemically sterilized, showing greater than a 6 log₁₀ reduction of *Geobacillus stearothermophilus* spores at every inoculation site of each duodenoscope tested, in less than half the exposure time of the standard cycle.

Conclusions: The successful outcome of the additional efficacy testing reported here indicates that the SYSTEM 1E® is an effective low-temperature liquid chemical sterilization method for duodenoscopes and other critical and semicritical devices. It offers a fast, safe, convenient processing alternative while providing the assurance of a system expressly tested and cleared to achieve liquid chemical sterilization of specific validated duodenoscope models.

© 2016 Association for Professionals in Infection Control and Epidemiology, Inc. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

In recent years a troubling number of health care-acquired infection outbreaks and transmission events, some involving highly resistant microbial pathogens and resulting in serious patient outcomes, have been traced to reusable, high-level disinfected

duodenoscopes in the United States.^{1,2} These events have reportedly not been limited to 1 particular scope model, design, or manufacturer nor to a particular high-level disinfection modality, and no single lapse in recommended cleaning or reprocessing practices has been implicated as a single cause. Epidemiologic evidence around many of these outbreaks continues to be investigated.

In an ongoing effort to address the risks associated with the use of these devices, the Food and Drug Administration (FDA) convened a Gastroenterology-Urology Devices Advisory Panel Meeting during May 2015³ that sought to bring scientific and clinical knowledge to bear on this public health issue. The summary from that FDA meeting⁴ indicates that the majority of the panel believes it is necessary to reclassify duodenoscopes, based on the Spaulding Classification, from semicritical devices to critical medical devices. Accordingly, the majority support a move from acceptance of high-level disinfection for these devices toward sterilization as the reprocessing standard.

It is important to note that high-level disinfection had previously been considered an acceptable alternative when sterilization

* Address correspondence to Michele Ehrman, BS, STERIS Corporation, 5960 Heisley Road, Mentor, OH 44060.

E-mail address: michele_ehrman@steris.com (M. Ehrman).

Conflicts of Interest: This study was funded by the STERIS Corporation.

This study was conducted at the request of Food and Drug Administration to verify liquid chemical sterilization efficacy of SYSTEM 1E with varied duodenoscope designs under especially arduous conditions. The test protocol challenged the system's performance by running a fractional cycle to evaluate spore reduction in heavily contaminated endoscopes, including all channels and each distal tip, under worst case SYSTEM 1E processing conditions. The devices were not cleaned after they were inoculated; they were placed directly in the SYSTEM 1E for processing. The data resulting from the protocol demonstrated that all devices were successfully liquid chemically sterilized, showing greater than a 6 log₁₀ reduction of *Geobacillus stearothermophilus* spores at every inoculation site of each duodenoscope tested in less than half the exposure time of the standard cycle.

could not practically be achieved.⁵ This requirement for a higher standard of reprocessing in patient care is also reflected in the FDA's 2015 final guidance to industry, *Reprocessing Medical Devices in Health Care Settings: Validation Methods and Labeling*,⁶ which specifies that semicritical devices should be sterilized unless the device design prohibits sterilization.

The Gastroenterology-Urology Devices Advisory Panel discussed alternatives to high-level disinfection currently available for reprocessing duodenoscopes. The sterilization options mentioned included low-temperature sterilization modalities only, because current duodenoscope designs are unable to withstand high-temperature sterilization processes.

One option available is use of ethylene oxide (EO) for sterilization. EO is a time-honored sterilization method, but it requires lengthy processing and aeration time, and is associated with employee health and safety risks. To date, no EO processor in the United States has been cleared with a specific indication for sterilization of duodenoscopes. In addition, users report that endoscopes experience a shortened use life due to material degradation issues when processed repeatedly in EO. There is also a risk of patient and staff toxicity if these devices are not aerated correctly to remove gas residuals following the sterilization process. For these reasons, EO is a less frequently used option and is not readily available in many health care facilities.

Another low-temperature sterilization option is the use of liquid chemical sterilants. There are numerous liquid chemical sterilants cleared for device sterilization.⁷ However, the exposure time required to achieve sterilization for most of these formulations is far longer than practical; therefore, it is our understanding that these chemistries are commonly used for high-level disinfection only.

There is a single FDA-cleared alternative that provides liquid chemical sterilization within a 23-minute validated cycle. The SYSTEM 1E[®] Liquid Chemical Sterilant Processing System (STERIS Corporation, Mentor, OH) is the only system that is cleared in the United States specifically for liquid chemical sterilization of cleaned, immersible, reusable, heat-sensitive critical and semicritical medical devices, including flexible endoscopes such as duodenoscopes. The system uses S40[™] Sterilant Concentrate (STERIS Corporation, Mentor, OH), a peracetic acid-based chemistry, with every processing cycle. Following exposure to the sterilant, the devices are automatically rinsed to remove sterilant residuals. The rinse water is produced at the point of use from a potable water source through an extensive treatment process unique to SYSTEM 1E that removes or inactivates bacteria, viruses, protozoa, and fungi to ensure the device is safe for immediate patient use.

FDA noted in their executive summary for the Panel meeting that they have made recommendations to manufacturers of endoscope reprocessing systems to perform additional, rigorous testing with more robust reprocessing protocols to enhance the safety margin associated with duodenoscope use.⁴ STERIS therefore has recently conducted supplemental testing with SYSTEM 1E to challenge the process under extreme spore loading conditions, mimicking worst case clinical use, when processing duodenoscopes from 2 major manufacturers, including both closed and open elevator guide wire designs.

METHODS

Test devices

The objective was to perform triplicate test runs on a range of at least 3 duodenoscope models that included devices manufactured by more than a single manufacturer, and included at least 1 of each type of elevator wire channel design (ie, both open and

closed/sealed designs). The devices were selected based on their availability at the time of testing and included Olympus TJF-160F, Olympus TJF-Q180V (Olympus, Center Valley, PA), and Pentax ED-3490TK (Pentax Medical, Tokyo, Japan).

Test method development and validation

A test method was developed and validated to provide a defined, reproducible, high-titer inoculation of bacterial spores into each internal channel and at the distal tip of each device. Each manually cleaned duodenoscope was inspected before testing and was then inoculated with an aqueous *Geobacillus stearothermophilus* spore suspension containing 5% serum in 400 ppm AOAC International (Rockville, MD) hard water with a titer of 1.19×10^8 CFU/mL. All channels of each endoscope (biopsy, suction, air/water, air pipe if present, and elevator wire if present) were inoculated by flushing approximately 0.5 mL spore suspension through the port and through each channel. The distal tip was then placed into the liquid inoculum and the inoculum was suctioned up through the suction barb with a syringe. During inoculation, biopsy forceps were placed into the device biopsy channel to simulate clinical use. The distal tip of the endoscope was directly placed in the liquid inoculum for >30 seconds, and the elevator mechanism was set to the fully open position and then to the fully closed position at least three times with the biopsy forceps in place. The inoculated device was then allowed to dry >60 minutes.

To validate the inoculation procedure to provide a consistent recoverable spore burden on each device, the inoculation process described above was performed 3 times on each site of each device, and immediately harvested after the drying step as described below in the Sample recovery section. Mean recoverable test organisms achieved per site ranged from 7.0×10^6 - 1.9×10^8 .

The standard recovery of low levels of organisms (10-100 CFU/device channel) was also validated for each test device. The validated efficiency of recovery ranged from 84%-101% for the duodenoscopes tested.

Test challenges

For each test cycle (three per device) the device was cleaned, inoculated, and dried as described above. The dried device was then placed in a SYSTEM 1E C1160E Universal Flexible Processing Tray. The appropriate SYSTEM 1E Quick Connect; that is, labeled specifically for processing that model of duodenoscope in that tray, was connected to the device according to its instructions for use. The elevator mechanism was placed in a position halfway between its extremes for processing in accordance with the device manufacturer's instructions for use. The SYSTEM 1E processing cycle was initiated under the following worst case test conditions: S40 Sterilant Concentrate represented its end-of-shelf-life concentration of peracetic acid, the pump output provided flow conditions representing the lowest flow rate that is likely to be experienced under normal operating conditions, the ultraviolet light system was set at or below its lowest acceptable intensity, and the system used incoming water at a temperature that would result in the shortest total contact time. The liquid chemical sterilization cycle was cancelled after 2.5 minutes of exposure to the sterilant use dilution, a time less than half of the full cycle exposure time of 6 minutes. Samples were immediately recovered from each inoculated site using a validated neutralization method as described below.

Sample recovery

Each test device was immediately harvested using 0.265% sodium thiosulfate in a procedure validated to achieve effective

Table 1
SYSTEM 1E[†] liquid chemical sterilization testing results of 3 trials each for 3 representative duodenoscopes

Test site	Mean recoverable spore load (control), log ₁₀ [‡]	Mean reduction (test), log ₁₀ [‡]
Olympus TJF-Q180V		
Distal end/elevator mechanism	>6	>6
Biopsy/suction channel	>7	>7
Air/water channel	>7	>7
Pentax ED-3490TK		
Distal end/elevator mechanism	>6	>6
Biopsy/suction channel	>8	>8
Air/water channel	>7	>7
Olympus TJF-160F		
Distal end/elevator mechanism	>6	>6
Biopsy/suction channel	>8	>8
Air/water channel	>7	>7
Elevator guide wire channel	>7	>7

*STERIS Corporation, Mentor, OH.

[†]Mean inoculum was established by inoculation of the test device in the same manner as for the test runs, in triplicate. The device was not liquid chemically sterilized between inoculation and harvest.

[‡]Mean log reduction is the difference between the mean recovered spore counts (control) and the recovery after liquid chemical sterilization (test) runs.

neutralization of the liquid chemical sterilant. A channel-opening brush was immersed into approximately 50 mL sterile sodium thiosulfate in a sterile specimen cup. The elevator mechanism was positioned in the lowered/closed position and vigorously brushed with the channel-opening brush.⁸ The brush was remoistened in the sodium thiosulfate, and the elevator mechanism was repositioned to the raised/opened position and vigorously brushed again with the channel-opening brush over the specimen cup containing the sterile sodium thiosulfate. The handle of the brush was cut off and the brush was immersed into the ~50 mL sterile sodium thiosulfate.

The biopsy/suction channel was flushed with 20 mL sterile sodium thiosulfate and air through the channel and out the distal tip into a sterile empty test tube. The air/water channel and, for Olympus devices, the air pipe channels were similarly harvested.

The Olympus TJF-160F is the only device tested that had an open elevator wire channel; for this device only the elevator wire channel was harvested using 10 mL sterile sodium thiosulfate and air by flushing from the elevator port and collection from the distal tip into a sterile empty test tube.

All harvested samples were filtered through 0.45 micron filters. Each filter was plated onto tryptic soy agar followed by incubation at 56°C ± 2°C for 7 days. Results were recorded (Table 1).

RESULTS

The recoverable inoculation levels (positive controls) in each test channel and distal tip were all in excess of 6 log₁₀, and ranged from 6.8–8.3 log₁₀ per site. Each channel of every duodenoscope tested as well as each distal end/elevator mechanism showed greater than a 6 log₁₀ reduction at an exposure time less than half of SYSTEM 1E's standard liquid chemical sterilization cycle. Positive and negative controls on all media performed as expected, meeting the acceptance criteria for the test controls.

DISCUSSION

In early 2015, FDA approached endoscope manufacturers and manufacturers of automated endoscope reprocessors with requests to perform specially designed, challenging protocols for testing duodenoscope reprocessing systems to establish greater confidence in their safe and effective use. These requests applied to

reprocessing systems already cleared by FDA and currently in use in US health care facilities. Following discussion and subsequent agreement on the protocol with FDA, STERIS agreed to design, validate, and execute a suitable test protocol for the SYSTEM 1E Liquid Chemical Sterilant Processing System based on FDA's proposed test model, using a range of duodenoscopes. The outcome of that testing for 3 test trials on each of 3 duodenoscopes representing varied designs is reported here. A limitation of this work is that only 3 repetitions of the test were performed on 3 endoscope models. To provide more data, additional testing was performed and will be reported at a later date. A further limitation of the study is that it did not evaluate clinically soiled, manually cleaned duodenoscopes under the actual intended use conditions of SYSTEM 1E Liquid Chemical Sterilant Processing System.

The data demonstrate that the SYSTEM 1E Liquid Chemical Sterilant Processing System reliably achieves liquid chemical sterilization of heavily contaminated duodenoscopes of varied designs under conditions purposefully made more challenging than those normally encountered in the clinical setting, while more accurately reflecting certain conditions that may arise from clinical use. It is important to note that this testing was conducted under conditions that do not reflect the cleared instructions for use nor the standard cycle of the SYSTEM 1E processor, but were designed to show the efficacy of the process under particular, rigorous test conditions.

Each validation test run was performed with large numbers of *Geobacillus stearothermophilus* spores as the worst-case challenge to peracetic acid-based liquid chemical disinfectants and sterilants (also steam sterilization), inoculated into areas of the devices that are most challenging for the sterilant to penetrate, including the length of every internal channel and the crevices around the forceps elevator wire at the distal tip. Placement of an instrument into the working channel, its repeated manipulation during inoculation, and a secondary channel inoculation via suctioning from the distal tip up through the port of the duodenoscope ensured that a heavy burden of spores would be recoverable from each of the sites, and would represent a clinical soiling condition considered especially challenging for the intricate distal tip design of the duodenoscopes. Test organism spores were concentrated in the aqueous inoculum to more than 1 × 10⁸ CFU/mL, a titer targeted to achieve a load of approximately 1 × 10⁷ spores (in the presence of organic and inorganic soil) on each distal tip site and in every internal channel of every duodenoscope using the validated inoculation procedure. The total burden of most-difficult-to-kill-spores on each endoscope was therefore more than 10 times the load of ≥1 × 10⁶ spores per device that is normally used for simulated use testing in accord with recommendations of Guidance for Industry and FDA reviewers in *Content and Format of Premarket Notification [510(k)] Submissions for Liquid Chemical Sterilants/High Level Disinfectants* (January 3, 2000). Research previously published⁹ identified the microbial load on a cleaned device before reprocessing as typically 2 log₁₀ CFU/cm² (which represents 3.2–5.3 log₁₀ CFU/endoscope channel). Therefore, the microbial load used to challenge the duodenoscopes in the tests reported here is much greater than what would be experienced during normal use of the system with a properly cleaned device. Natural soil loads on clinically used devices before manual cleaning differ in type and quantity from the test organisms used in this study; however, as noted previously, only cleaned devices fall within the intended use of SYSTEM 1E.

The protocol included use of 5% serum in extremely hard water (400 ppm), a medium typically used in this type of testing to represent potential organic and inorganic residues that could remain in these hard-to-reach areas of the endoscope following cleaning. After each inoculation, the endoscope was allowed to dry for at least an hour. Despite this standard organic and inorganic load in the inoculum, it should be emphasized that this processing system is

designed and labeled to liquid chemically sterilize only critical and semicritical devices that are thoroughly cleaned; that is, SYSTEM 1E is not intended to clean soiled devices.

The cycles were run under worst-case conditions to achieve liquid chemical sterilization, including exposure time, liquid circulation pump rate, and water temperature. In addition, the S40 Sterilant Concentrate used represented the lowest usable (end of shelf life) peracetic acid concentration. The simulated use processing cycles performed were interrupted after 2.5 minutes of sterilant exposure, which is less than half the exposure time of the standard (6.0 minutes) SYSTEM 1E liquid chemical sterilization cycle. These parameters ensured that testing would validate SYSTEM 1E's performance with a wide margin of safety between the laboratory setting and real-world use.

The use of these test conditions for the studies was proposed by STERIS and accepted by the FDA. This testing is considered supplemental because it was performed to satisfy a specific FDA request, yet does not replace the range of data submitted as the basis for SYSTEM 1E's original 2010 premarket clearance. That work included simulated use testing of devices under static conditions; that is, tested outside the S1E Processor, to minimize the natural effect of wash-off associated with circulation of processing fluids in the automated system, a potential complication of device testing within all liquid chemical processors. It should be noted that in the current testing, some of the inoculated spore load (percentage not known) may have been physically removed by the circulation of the peracetic acid-based solution around and through the duodenoscope during the 2.5-minute exposure time. Despite this testing limitation, in real-world use SYSTEM 1E's tendency to wash away surface residues with its oxidative sterilant use-dilution is generally considered a beneficial feature.

CONCLUSIONS

The SYSTEM 1E Liquid Chemical Sterilant Processing System was validated to achieve more than 6 logs of spore reduction in each internal channel and at the complex distal tip for varied duodenoscope types, in less than half the exposure time normally provided and in the presence of the worst-case parameters of SYSTEM 1E processing. The successful outcome of the additional efficacy testing reported here indicates that the SYSTEM 1E Liquid Chemical Sterilant Processing System is an effective low-temperature liquid chemical sterilization method for duodenoscopes and other

critical devices. It offers a fast, safe, convenient reprocessing method with the assurance of a system expressly tested and cleared to achieve liquid chemical sterilization of specific validated duodenoscope models.

Acknowledgments

The authors thank the STERIS Corporation for supporting this project.

References

1. Epstein L, Hunter JC, Arwady MA, Tsai V, Stein L, Gribogiannis M, et al. New Delhi metallo- β -lactamase-producing carbapenem-resistant *Escherichia coli* associated with exposure to duodenoscopes. *JAMA* 2014;312:1447-55.
2. Centers for Disease Control and Prevention. Notes from the Field: New Delhi Metallo- β -Lactamase-Producing *Escherichia coli* Associated with Endoscopic Retrograde Cholangiopancreatography—Illinois, 2013. Available from: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6251a4.htm?s_cid=mm6251a4_w. Accessed September 25, 2015.
3. Food and Drug Administration. Medical Devices Advisory Committee; Gastroenterology-Urology Devices Panel. Available from: <http://www.fda.gov/AdvisoryCommittees/CommitteesMeetingMaterials/MedicalDevices/MedicalDevicesAdvisoryCommittee/Gastroenterology-UrologyDevicesPanel/ucm445590>. Accessed October 21, 2015.
4. Food and Drug Administration. Brief Summary of the Gastroenterology and Urology Devices Panel Meeting, May 14-15 2015. Available from: <http://www.fda.gov/downloads/AdvisoryCommittees/CommitteesMeetingMaterials/MedicalDevices/MedicalDevicesAdvisoryCommittee/Gastroenterology-UrologyDevicesPanel/UCM447407.pdf>. Accessed October 5, 2015.
5. Centers for Disease Control and Prevention. Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008. Available from: http://www.cdc.gov/hicpac/pdf/guidelines/Disinfection_Nov_2008.pdf. Accessed October 5, 2015.
6. Food and Drug Administration. Reprocessing Medical Devices in Health Care Settings: Validation Methods and Labeling Guidance for Industry and Food and Drug Administration Staff, March 17, 2015. Available from: <http://www.fda.gov/ucm/groups/fdagov-public/@fdagov-meddev-gen/documents/document/ucm253010.pdf>. Accessed September 27, 2015.
7. Food and Drug Administration. FDA-Cleared Sterilants and High Level Disinfectants with General Claims for Processing Reusable Medical and Dental Devices—March 2015. Available from: <http://www.fda.gov/medicaldevices/deviceregulationandguidance/reprocessingofreusablemedicaldevices/ucm437347.htm>. Accessed September 27, 2015.
8. Center for Disease Control and Prevention. Interim Protocol for Healthcare Facilities Regarding Surveillance for Bacterial Contamination of Duodenoscopes after Reprocessing. Available from: www.cdc.gov/hai/organisms/cre/cre-duodenoscope-surveillance-protocol.html. Accessed September 27, 2015.
9. Alfa M, Degagne P, Olson N. Worst-case soiling levels for patient-used flexible endoscopes before and after cleaning. *Am J Infect Control* 1999;27:392-401.