

An Approach to Improving the Quality and Consistency of Flexible GI Endoscope Reprocessing

Grace Thornhill, Technical Service Specialist
Larry Talapa, Technical Service Specialist
Craig Wallace, Senior Technical Specialist

3M Infection Prevention Division
3M Center, Building 0275-04-E-01
St. Paul, MN 55144

ABSTRACT

Transmission of pathogens by inadequately reprocessed flexible endoscopes is well documented in scientific literature and is recognized as a significant patient risk. This paper outlines a comprehensive approach to improving the quality and consistency of flexible endoscope reprocessing including more detailed training and support for reprocessing staff, use of rapid cleanliness indicators for each endoscope, use of terminal sterilization by ethylene oxide as a replacement for High Level Disinfection (HLD), and use of microbial monitoring audits.

INTRODUCTION

Flexible endoscopes are highly sophisticated medical devices that have a wide range of diagnostic and therapeutic applications. Many of these applications are quite challenging, and require an endoscope with a complicated design comprised of long narrow lumens, intricate therapeutic or fiber optic devices, and complicated control mechanisms. The complex designs that enable the required performance also create significant challenges when it is time to reprocess the endoscope in preparation for the next case. The reprocessing procedure for flexible endoscopes is an intricate multi-step process that requires a significant amount of time and diligence that can vary by endoscope type and manufacturer. Independent assessments have demonstrated that important steps in these complex procedures may be performed incorrectly or not performed at all.⁽¹⁾

Multiple publications in the scientific literature have documented transmission of pathogenic organisms by various types of flexible endoscopes that were not adequately reprocessed between patients.^(2,3) Recently, these reports have included instances of transmission of multiple drug resistant organisms (MDROs) by contaminated duodenoscopes.⁽⁴⁻⁸⁾ Some duodenoscopes present a significant challenge to the cleaning and biocidal processes because of the small size and complexity of their elevator guide wire system.

This paper will propose steps that can be implemented using current, commercially available technology, to improve the quality and consistency of flexible endoscope cleaning procedures, and increase the margin of safety. Routine use of cleaning monitors based on detection of adenosine triphosphate

(ATP) from residual clinical soil can provide real time feedback on the adequacy of the manual cleaning process for each flexible endoscope. This real time feedback can indicate the need for additional cleaning, before the endoscope moves to the next stage in the process. Implementation of terminal sterilization of flexible endoscopes can provide an important, additional margin of safety over high level disinfection. Ethylene oxide sterilization has been utilized for reprocessing temperature sensitive medical devices for over 50 years, and has been utilized to resolve MDRO outbreaks from contaminated duodenoscopes.^(4,6)

OVERVIEW — FLEXIBLE ENDOSCOPE REPROCESSING

Current guidelines for reprocessing flexible gastrointestinal (GI) endoscopes focus on cleaning and high-level disinfection (HLD) as the standard of care. The various endoscopy focused organizations and associations have developed detailed guidance documents that describe a specific sequence of procedures deemed appropriate for endoscope reprocessing.⁽⁹⁻¹¹⁾

In the current guidelines, flexible GI endoscopes should first be thoroughly cleaned and then high-level disinfected or sterilized. Although there can be over 120 different steps involved in reprocessing a flexible GI endoscope, the process can be broken down into six main steps.⁽¹⁰⁾

1. Pre-cleaning at point of use
2. Leak Testing
3. Cleaning
4. High-level disinfection or sterilization
5. Drying with alcohol and forced air
6. Storage

It is very important to note that cleaning, and disinfection or sterilization are separate and distinct processes. Cleaning is the physical removal of clinical soil and bioburden whereas disinfection and sterilization are processes that are designed to kill microorganisms remaining after the cleaning step.⁽⁹⁾

Cleaning accomplishes several goals:⁽⁹⁾

- Minimizes soil transfer from one patient to another or between uses on the same patient
- Prevents accumulation of residual soil throughout the life of the product
- Allows for subsequent, successful disinfection or sterilization steps

Disinfection and sterilization have one purpose, to kill microorganisms.⁽⁹⁾

PATHOGEN TRANSMISSIONS DUE TO FLEXIBLE ENDOSCOPE REPROCESSING CHALLENGES

There is a well-documented history of pathogen transmission due to improperly reprocessed endoscopes.^(2,3,10–13) The published assumption that GI endoscopic procedures have a very low (1 in 1.8 million) risk of pathogen transmission^(3,10,11) has been reexamined, and found to be “outdated, inaccurate, based on flawed methods and too low.”⁽¹⁴⁾ A study that used direct observation of the process has shown that flexible GI endoscopes were reprocessed correctly only 1.4% of the time when using the most common protocol, manual cleaning followed by HLD in an automated endoscope reprocessor (AER).⁽¹⁾ Inconsistent tracking of patient outcomes⁽¹⁰⁾, coupled with the lack of mandatory reporting of reprocessing lapses, means that the true incidence of endoscope associated infections (EAI) is unknown. There is little incentive for practitioners to publish reprocessing errors resulting in negative patient outcomes in peer-reviewed literature, giving the impression that the incidence of EAI is extremely low.⁽²⁾

A recent study looked at reprocessing lapses between January 2005 and June 2012 and found that over 30,500 people were exposed to contaminated endoscopes.⁽²⁾ During this time, there were documented transmissions of multi-drug resistant bacteria such as methicillin-resistant *Staphylococcus aureus* (MRSA), *E. coli* and *Klebsiella*. Other pathogens such as *Pseudomonas*, *Serratia* and *Proteus* as well as viruses such as Hepatitis B and HIV were also found to have been transmitted.

Over the past two years outbreaks of Carbapenem resistant *Enterobacteriaceae* (CRE) infections associated with Endoscopic Retrograde Cholangiopancreatography (ERCP) procedures performed with contaminated duodenoscopes have been reported in Florida, Illinois, Wisconsin, Washington, Pennsylvania and California. In 2013, the largest outbreak of NDM1- *E. coli* (CRE) was investigated at a tertiary hospital in Illinois.⁽⁴⁾ Thirty-nine case

patients were identified, with 35 being exposed to duodenoscopes. Microbial culture resulted in the recovery of both KPC and NDM-*E. coli* from duodenoscopes that had been reprocessed according to current guidelines, utilizing high level disinfection. Investigation revealed no lapses in reprocessing leading investigators to the conclusion that the duodenoscopes had the “potential to remain contaminated with pathogenic bacteria even after recommended reprocessing is performed.”⁽⁴⁾ Positive cultures were found to be associated with the elevator guide wire channel and the elevator mechanism. These features of the duodenoscope are extremely difficult to clean, so much so that the hospital changed from the recommended high-level disinfection procedures to terminal sterilization using ethylene oxide (EO) gas. After implementation of EO sterilization, no further infections with CRE were identified. Investigators also highlighted the fact that the only reason this outbreak was detected was because the laboratory serving the hospital was performing special screening for CRE bacteria.⁽⁴⁾

In 2013, a hospital in Seattle, WA found itself in a similar situation. Public health screening detected an outbreak of CRE bacteria (Amp-C *E. coli*) among patients who had undergone ERCP procedures.⁽⁵⁾ Similar to the Illinois outbreak investigation, no apparent lapses in reprocessing were found. Reprocessed duodenoscopes were cultured and 7% were found to be contaminated with gram-negative bacteria. In addition to the four separate strains of Amp-C *E. coli*, scopes were found to be positive for *Acinetobacter*, *Enterococcus*, *E. coli* and multi-drug resistant *Pseudomonas*. All pathogens were cultured from the difficult to clean elevator guide wire channel. When examined by the manufacturer, 7% of scopes were found to have occult mechanical defects (not detected by hospital personnel). The outbreak was controlled by quarantine of duodenoscopes until 48 hour cultures were negative for the presence of pathogens.⁽⁵⁾

In Wisconsin, an outbreak of NDM-*E. coli* was discovered when patients were exposed to the same duodenoscope. Attempts to culture the bacteria from the duodenoscope were unsuccessful, but the epidemiological evidence implicated the duodenoscope. Similar to the other CRE outbreaks discussed, no breaches in reprocessing protocol were found and the outbreak was controlled using ethylene oxide gas sterilization.⁽⁶⁾ Similar outbreak situations have been described for hospitals located in Florida and Pennsylvania.^(7,8)

INDUSTRY RESPONSE TO CRE OUTBREAKS

In response to the CRE outbreaks a number of recommendations and statements have been released to help healthcare facilities manage the increased risk posed by the difficulties in adequately reprocessing duodenoscopes, including statements from FDA, ASGE, SGNA and CDC and endoscope manufacturers.^(15–18)

The Food and Drug Administration (FDA) safety communication of February 19, 2015 addresses concerns around reprocessing duodenoscopes and states⁽¹⁹⁾ the complex design of duodenoscopes may impede proper reprocessing and that “meticulous cleaning of duodenoscopes prior to high-level disinfection should reduce risk of transmission of infection, but may not entirely eliminate it.”⁽¹⁹⁾ A number of recommendations were made to minimize the risk of pathogen transmission.

- Reprocessing facilities are encouraged to strictly follow all manufacturer instructions for use and should report any reprocessing problems to the FDA and the manufacturer.
- Meticulous manual cleaning is emphasized.
- A comprehensive quality control program should be in place. It should include written procedures for monitoring training and adherence to reprocessing procedures. It should also include documentation of equipment, tests, process and quality monitors used during reprocessing.
- The Multi-Society Guidelines on Reprocessing Flexible GI Endoscopes⁽¹⁰⁾ should be followed, along with manufacturer instructions for use.
- Quarantine duodenoscopes suspected of being associated with patient infection until they have been shown to be free of pathogens.

The CDC has issued an interim guidance on microbial surveillance of duodenoscopes with the goal of assessing the adequacy of reprocessing, however, it does not recommend a particular frequency for microbial surveillance.⁽¹⁵⁾ The interim guidance emphasizes that special attention needs to be placed on manual cleaning and drying. A detailed procedure for culturing duodenoscopes after completion of reprocessing is outlined and CDC states that the sensitivity of the recommended culture methods have not been evaluated and false negative results are a possibility.⁽¹⁵⁾

ASGE has also issued an interim guidance that has more specific recommendations on what procedures to implement based on several different clinical situations.⁽¹⁶⁾ These procedures emphasize that the elevator guide wire channel and elevator mechanism should be manually cleaned even if an AER is used. Microbial surveillance frequency recommendations are based on risk assessment and range from culturing every scope in the event that a scope has been found to transmit infections to a one-time surveillance culture of the entire endoscope inventory. Terminal sterilization using ethylene oxide gas was proposed as an alternative to microbial surveillance.⁽¹⁶⁾

MONITORING THE CLEANING PROCESS

An effective quality control program is required to support proper execution of the reprocessing steps. For example, when reprocessing reusable medical devices using steam sterilization,

39% of the steps are documented as part of a quality assurance program. In contrast, when reprocessing flexible GI endoscopes, only 8% of steps are documented.⁽²⁰⁾ Flexible GI endoscope reprocessing has a very narrow margin of safety. “Any slight deviation from the recommended reprocessing protocol can lead to the survival of microorganisms and an increased risk of infection.”⁽²¹⁾ The lack of consistent and comprehensive quality control for flexible GI endoscopes is a problem that is reflected in the current rate of reprocessing lapses.⁽²⁾

“The first and most important step in the prevention of transmission of infection by an endoscope is manual cleaning of the endoscope with detergent solution and brushes.”⁽²²⁾ This statement made by ASGE highlights that the correct performance of manual cleaning is critical to the success of the overall process and implies that it should have the same level of quality control as the high-level disinfection or sterilization processes. While some quality control measures are routinely performed for the high-level disinfection step in endoscope reprocessing, effective QC measures are not commonly implemented to verify effective manual cleaning.⁽¹²⁾ The current standard of care for assessing cleaning effectiveness is visual inspection which is unable to detect residual clinical soil or bioburden in the endoscope lumen or within the elevator channel mechanism.

There are a variety of commercially available, rapid-indicator products well suited to integration into a quality control system in that they are designed to provide an objective assessment of the cleanliness of endoscopes in real-time and can therefore facilitate early detection of reprocessing problems.^(12,20,23-26)

One of the more useful cleanliness markers is adenosine triphosphate (ATP), a molecule that is universally present in all living organisms, and is therefore present in clinically relevant soils (tissue, cells, excretions, secretions, body fluids and all microbes). Over the past 10 years, there have been numerous publications documenting that the use of ATP has been effective in detection of endoscopes that have not been cleaned properly. In 2013, an abstract was presented at the APIC national conference describing how ATP can be used to detect failures in manual cleaning of flexible GI endoscopes. This study demonstrated that duodenoscopes had the highest failure rate at 30% followed by a 24% and 3% failure rate for gastroscopes and colonoscopes respectively.⁽²⁰⁾ The high failure rate seen for duodenoscopes is consistent with the current problems seen in outbreaks of CRE due to contaminated duodenoscopes used in ERCP procedures. A recent 2014 publication showed that when ATP was used to monitor the manual cleaning of numerous types of GI endoscopes (colonoscopes, gastroscopes, and duodenoscopes), 41% of the endoscope internal channels did not meet the ATP benchmark for cleanliness. A paper published by Alfa *et al.* showed that 20% of duodenoscopes tested did not meet the ATP benchmark for cleanliness.^(27,28) A 2004 study used ATP monitoring to verify the

presence of persistent biofilm in older endoscopes.⁽²⁴⁾ These studies show that ATP monitoring is effective in the detection of flexible GI endoscopes that have not been properly manually cleaned. ATP monitoring meets the current standards for an effective cleaning monitor which is the “use of a quantitative test capable of measuring levels of clinically relevant soil to meet a related, predetermined cleaning test point.”⁽²⁹⁾

TERMINAL STERILIZATION BY ETHYLENE OXIDE

The most common biocidal practice used for duodenoscopes and flexible endoscopes is high level disinfection (HLD) using a liquid chemical disinfecting agent; however, terminal sterilization is validated and even recommended for many types of endoscopes. Faster device reprocessing time is the primary reason HLD is a more common method than terminal sterilization, even though there is a trade-off in margin of safety. A more careful comparison of HLD versus sterilization will support the premise that sterilization of duodenoscopes can provide a greater margin of safety and should be considered.

Disinfection is defined as a “process that kills pathogenic and other microorganisms by physical or chemical means. Disinfection destroys most recognized pathogenic microorganisms but not necessarily all microbial forms, such as bacterial spores.”⁽³⁰⁾ Performance requirements for high level disinfecting chemicals and processes are defined by the United States Food and Drug Administration (FDA).⁽³¹⁾ The disinfectants must demonstrate the ability to kill 6 logs (1×10^6 or 1,000,000 organisms) of various test organisms under the specified use conditions, including exposure time, defined by the manufacturer.

Sterilization is defined as “a validated process used to render product free from viable microorganisms.”⁽³²⁾ Sterilization processes are required to kill all types of microorganisms *including* bacterial spores, and are actually tested and validated using bacterial spores. This validation process, commonly referred to as the “overkill” process, is performed by determining the amount of exposure time required to kill 6 logs of bacterial spores, then this exposure time is doubled to the equivalent of 12 logs of kill (1,000,000,000,000 spores) to provide a large margin of safety. High level disinfection processes are required to kill 6 logs of less resistant test organisms, while sterilization process exposure times are designed to kill 12 logs of bacterial spores. Mathematically, the level of assurance in margin of safety of sterilization is twice that of high level disinfection. This is part of the rationale for the statements in Association for the Advancement of Medical Instrumentation (AAMI) standards and FDA guidance documents that “Disinfection processes do not ensure the margin of safety associated with sterilization processes.”^(30,31)

Ethylene oxide gas is often used for sterilization of flexible endoscopes. It is a non-oxidative low temperature process that has been tested and found to be compatible with a range of medical device materials⁽³³⁾, and “can sterilize heat or moisture-sensitive medical equipment without deleterious effects on the material used in the medical devices.”⁽³⁴⁾ Ethylene oxide sterilization is well characterized and understood, and has been used in health care facilities for over 50 years.^(34,35) The requirements for safe and effective reprocessing of medical devices in health care facilities using ethylene oxide are well documented in industry standards.^(36,37)

There is support in the scientific literature for use of ethylene oxide sterilization to increase the margin of safety in duodenoscope reprocessing. Ethylene oxide sterilization was used as part of the resolution of recent outbreaks of CRE associated with the use of duodenoscopes.^(4,6,7) Foliente *et al.* was able to demonstrate that ethylene oxide sterilization was able to eliminate all organisms from duodenoscopes in simulated use testing, while several methods of high level disinfection were not.⁽³⁸⁾

Ethylene oxide sterilization processes in health care facilities have an established and rigorous quality control testing program that includes both tests of the sterilization equipment, as well as physical, chemical and biological monitoring of every load and cycle.⁽³⁶⁾

MICROBIAL SURVEILLANCE

In response to the outbreaks, a number of recommendations and statements have been released to help healthcare facilities manage the increased risk posed by the difficulties in adequately reprocessing duodenoscopes. One of the recommended actions is to implement a program of culturing endoscopes to test for viable organisms or pathogens after reprocessing or before patient use. While some useful information would be provided by this type of testing, this method has technical and practical limitations that must be understood.

The CDC has recommended that duodenoscopes undergo microbial surveillance so that the efficacy of reprocessing can be determined.⁽¹⁵⁾ The recommended procedures use traditional plate and broth culture techniques as well as techniques for selective and differential growth of gram-negative bacteria. Each of these techniques has limitations that should be understood.

The CDC recommends that organisms of lower-concern be at levels of <10 CFU when enumerated using an aerobic plate count method. The plate count method is unreliable and shows considerable variability as these low levels of bacteria (<10 CFU) are below the typical detection level of plate count technology. Valid plate counts occur when colonies are within a countable

range which is 25–250 CFU per plate.^(39–41) It should be noted that culturing the duodenoscopes implicated in the Milwaukee outbreak did not recover any CRE organisms.

The organisms present in an endoscope may be growing as part of a biofilm. By definition they are difficult to culture, slow-growing and are isolated using special sample preparation techniques not employed by most clinical labs.^(42,43)

Microbial culture does have a place in assessing the efficacy of flexible endoscope reprocessing. However, the limitations should be well understood if only to avoid the high incidence of false negative results.^(39,40,41) Other monitoring methods should be considered in addition to microbial surveillance.

A RECOMMENDATION FOR AN IMPROVED QUALITY CONTROL SYSTEM FOR FLEXIBLE ENDOSCOPE REPROCESSING

There is substantial evidence from documented reprocessing lapses, transmissions and outbreaks that the quality and effectiveness of the reprocessing of flexible endoscopes is inconsistent. The best path to improve consistency is to (1) improve training on the proper endoscope cleaning procedures, (2) increase the amount of available cleaning verification information on the effectiveness of the critical cleaning steps, (3) increase the margin of safety by moving to ethylene oxide sterilization instead of high level disinfection, and (4) utilize microbial surveillance as an additional audit tool.

It is clear from the documented instances of reprocessing errors that improved staff training and vigilance in completing all cleaning steps as described by the manufacturers and industry guidelines is a critical element to improving the consistency of endoscope reprocessing. Educating everyone involved with flexible endoscopes, including the physicians, on the complexity and diligence required for proper reprocessing will help create a supportive environment for the endoscopes reprocessing staff. However, training should be coupled with an effective quality control program that can collect data from the various process steps to verify they were performed correctly.

Use of rapid cleanliness monitors such as ATP based systems on each endoscope after cleaning will assist the reprocessing staff by providing real time feedback on the effectiveness of the process, in time for the staff to address any cleaning quality issues before the endoscope is moved to the next step in the process. These systems can provide quantitative data that can be recorded and analyzed to measure trends and identify opportunities for improvement in the process. Testing each endoscope will assure an equivalent level of care for all patients,

and provide the facility with records of results for each endoscope should there be any downstream patient issues associated with the use of that endoscope.

Microbial surveillance should be used as an audit tool, at appropriate test intervals defined by the facility. The test limitations of sensitivity and time required to get test results make this process better suited to quality control audits as it is impractical as a routine monitoring tool.

Moving the standard of care from high level disinfection to terminal sterilization using ethylene oxide will provide an increased margin of safety over high level disinfection. The impact of longer reprocessing times for sterilization can be minimized with a combination of solutions that could include optimized patient scheduling, purchase of additional devices, and efficient use of available EO sterilization equipment. Ethylene oxide sterilization processes have quality control testing requirements for each sterilization cycle defined in industry standards. The results of the physical, chemical, and biological monitoring for each sterilization load can be kept with the reprocessing records for all endoscopes contained in that load, once again providing assurance of an effective cycle and a record that each endoscope was properly processed.

REFERENCES

1. Ofstead CL, Wetzler HP, Snyder AK, Horton RA. 2010. Endoscope reprocessing methods: a prospective study on the impact of human factors and automation. *Gastroenterol Nurs* 33(4): 304–311.
2. Alexandra M. Dirlam-Langlay, Cori L. Ofstead, Natalie J. Mueller, Pritish K. Tosh, Todd H. Baron, Harry P. Wetzler. 2013. Reported gastrointestinal endoscope reprocessing lapses: The tip of the iceberg *American Journal of Infection Control*, 41(12)
3. American Society for Gastrointestinal Endoscopy (ASGE). (2001). Transmission of infection by gastrointestinal endoscopy. *Gastrointestinal Endoscopy*, 54(6), 824–828.
4. Lauren Epstein, Jennifer C. Hunter, M. Allison Arwady, Victoria Tsai, Linda Stein, Marguerite Gribogiannis, Mabel Frias, Alice Y. Guh, Alison S. Laufer, Stephanie Black, Massimo Pacilli, Heather Moulton-Meissner, J. Kamile Rasheed, Johannetsy J. Avillan, Brandon Kitchel, Brandi M. Limbago, Duncan MacCannell, David Lonsway, Judith Noble-Wang, Judith Conway, Craig Conover, Michael Vernon, Alexander J. Kallen. 2014. NewDelhi Metallo- β -Lactamase—Producing Carbapenem-Resistant *Escherichia coli* Associated With Exposure to Duodenoscopes. *JAMA*. 312(14) pp.1447–1455.

5. Kristen A. Wendorf, Meagan Kay, Christopher Baliga, Scott J. Weissman, Michael Gluck, Punam Verma, Marisa D'Angeli, Jennifer Swoveland, Mi-Gyeong Kang, Kaye Eckmann, Andrew S. Ross and Jeffrey Duchin. 2015 Endoscopic Retrograde Cholangiopancreatography—Associated AmpC *Escherichia coli* Outbreak. *Infection Control & Hospital Epidemiology*. Available on CJO 2015 doi:10.1017/ice.2015.66.
6. Zachary L. Smith, Young S. Oh, Kia Saeian, Charles E. Edmiston Jr, Abdul H. Khan, Benson T. Massey, Kulwinder S. Dua, . 2015. Transmission of carbapenem-resistant Enterobacteriaceae during ERCP: time to revisit the current reprocessing guidelines. *Gastrointestinal Endoscopy* 81(4) pp.1041–1045.
7. Sheila McCool. 2014. High Level Disinfection Failure in Gastrointestinal Scopes with Elevator channels—Is it time to switch to Ethylene oxide (ETO) Sterilization? Abstract. ID Week. Oct. 7–11, 2014. San Diego, CA.
8. Alrabaa SF, Nguyen P, Sanderson R, *et al.* 2013. Early identification and control of carbapenemase-producing *Klebsiella pneumoniae*, originating from contaminated endoscopic equipment. *Am J Infect Control* 41(6):562–564.
9. FDA. Reprocessing Medical Devices in Health Care Settings: Validation Methods and Labeling. Guidance for Industry and Food and Drug Administration Staff. March 17, 2015. <http://www.fda.gov/downloads/medicaldevices/deviceregulationandguidance/guidancedocuments/ucm253010.pdf>
10. Petersen BT., Chennat J., Cohen J. *et al.* 2011. Multi-society guideline on reprocessing flexible GI endoscopes. *Infect Control Hosp Epidemiol* 32(6):527–537.
11. Society of Gastroenterology Nurses and Associates (SGNA). Standards of Infection Control in Reprocessing of Flexible Gastrointestinal Endoscopes. Chicago: SGNA, 2012:1–23.
12. Michelle J. Alfa. 2013. Monitoring and improving the effectiveness of cleaning medical and surgical devices. *American Journal of Infection Control* 41. S56–S59.
13. Muscarella, L. F. 2014. Risk of transmission of carbapenem-resistant Enterobacteriaceae and related “superbugs” during gastrointestinal endoscopy. *World J Gastrointest Endosc.* 6(10): 457–474.
14. Ofstead, Cori, L., Alexandra M. Dirlam Langlay, Natalie J. Mueller MPH, Pritish K. Tosh, Harry P. Wetzler. 2013. Re-evaluating endoscopy-associated risk estimates and their implications. *American Journal of Infection Control.* 41 p734–6.
15. CDC Interim Duodenoscope Surveillance Protocol. March 2015. <http://www.cdc.gov/hai/organisms/cre/cre-duodenoscope-surveillance-protocol.html>
16. American Society for Gastrointestinal Endoscopy (ASGE). March 17, 2015. Interim Guidance. Transmission of CRE bacteria through Endoscopic Retrograde Cholangiopancreatography (ERCP). http://www.asge.org/uploadedFiles/Publications_and_Products/ASGE_InterimGuidance_CRE_03172015.pdf
17. Society of Gastroenterology Nurses and Associates. Infection Prevention Web page. <http://www.sgna.org/Issues/InfectionPrevention/SGNAResources.aspx>
18. Olympus Customer Resources: <http://medical.olympusamerica.com/duodenoscope>
19. FDA Safety Communication Design of Endoscopic Retrograde Cholangiopancreatography (ERCP) Duodenoscopes May Impede Effective Cleaning. March 2015. <http://www.fda.gov/medicaldevices/safety/alertsandnotices/ucm434871.htm>
20. Bommarito, M., Thornhill, G., Morse, D. 2013. A Multi-site Field Study Evaluating the Effectiveness of Manual Cleaning of Flexible Endoscopes using an ATP Detection System. *American Journal of Infection Control* 41(6) p. S24.
21. Alfa, M.J., N.Olson and P. DeGagne. 2006. Automated washing with the Reliance Endoscope Processing System and its equivalence to optimal manual cleaning. *American Journal of Infection Control*, 34(9), 561–570.
22. Infection Control during GI Endoscopy. ASGE Standard of Practice Committee. *Gastrointestinal Endoscopy*. 2008. Vol. 67. No. 6 pp.781–790
23. Visrodia, K., C. Ofstead, H. Yellin, H. Wetzler, P. Tosh and T. Barron. 2014. The Use of Rapid Indicators for the Detection of Organic Residues on Clinically Used Gastrointestinal Endoscopes with and without Visually Apparent Debris. *Infection Control and Hospital Epidemiology* Vol. 35, No. 8. pp. 987–994.

24. Sciortino CV Jr, Xia EL, Mozee A. 2004. Assessment of a novel approach to evaluate the outcome of endoscope reprocessing. *Infect Control Hosp Epidemiol.* 25:284–90.
25. Obee PC, Griffith CJ, Cooper RA, Cooke RP, Bennion NE, Lewis M. 2005. Real-time monitoring in managing the decontamination of flexible gastrointestinal endoscopes. *Am J Infect Control.* 33:202–6.
26. Fushimi R, Takashina M, Yoshikawa H, Kobayashi H, Okubo T, Nakata S, *et al.* 2013. Comparison of adenosine triphosphate, microbiological load, and residual protein as indicators for assessing the cleanliness of flexible gastrointestinal endoscopes. *Am J Infect Control.* 41:161–4.
27. Alfa MJ, Fatima I, Olson N. 2013. Validation of adenosine triphosphate to audit manual cleaning of flexible endoscope channels. *Am J Infect Control.* 41: 245–8.
28. Alfa MJ, Fatima I, Olson N. 2013. The adenosine triphosphate test is a rapid and reliable audit tool to assess manual cleaning adequacy of flexible endoscope channels. *Am J Infect Control.* 41:249–53.
29. Priority Issues from the AAMI/FDA Medical Device Reprocessing Summit. 2011. <http://www.aami.org/events/eventdetail.aspx?ItemNumber=1284&navItemNumber=634>
30. *Chemical sterilization and high-level disinfection in health care facilities.* ANSI/AAMI ST58; 2013.
31. *Content and Format of Premarket Notification [501(k)] Submissions for Liquid Chemical Sterilants/High Level Disinfectants.* U.S Department of Health and Human Services; Food and Drug Administration. January 3, 2000.
32. *Sterilization of health care products — Vocabulary.* ISO/TS 11139:2006.
33. *The Effects of Sterilization Methods on Plastics and Elastomers, 2nd Edition.* Liesel K. Massey, 2005. William Andrew Publishing. ISBN: 0-8155-1505-7.
34. *CDC Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008* William A. Rutala, Ph.D., M.P.H.1,2, David J. Weber, M.D., M.P.H.1,2, and the Healthcare Infection Control Practices Advisory Committee (HICPAC).
35. *Ethylene Oxide Use in Hospitals A Manual for Health Care Personnel.* Danielson Neal E. Third Edition, American Society of Healthcare Central Service Professionals of the American Hospital Association Chicago IL, 1998
36. *Ethylene oxide sterilization in health care facilities: Safety and effectiveness.* ANSI/AAMI ST41:2008(R) 2012, Arlington, VA.
37. “Automatic, general-purpose ethylene oxide sterilizers and ethylene oxide sterilant sources intended for use in health care facilities”. ANSI/AAMI ST24:1999/(R)2013.
38. Foliente, R.L. *et al.* “Efficacy of high-level disinfectants for reprocessing GI endoscopes in simulated-use testing”. *Gastrointestinal Endoscopy, Volume 53, Number 4, 2001.*
39. USP, “<1227> Validation of Microbial Recovery from Pharmacopeial Articles, • *USP 34*, United States Pharmacopeia, pp. 783–786, 2011.
40. FDA, Maturin, LJ and JT Peeler, “Chapter 3: Aerobic Plate Count, • *Bacteriological Analysis Manual*, <http://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm063346.htm>
41. Mary A. Williams and L. Michael Snyder. 2015. *Wallachs Interpretation of Diagnostic Tests: Pathways to Arriving at a Clinical Diagnosis.* Edition 10. Wolters Kluwer Health. Philadelphia, PA. USA. Print.
42. Standard Methods Development for Surface Disinfectants http://www.biofilm.montana.edu/resources/knowledge_sharing_articles
43. Oliver JD. 2010. Recent findings on the viable but nonculturable state in pathogenic bacteria. *FEMS Microbiol Rev* 34:415.

