

SYSTEM 1[®]
Sterile Processing System:
Liquid Chemical
Sterilization Anthology

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STERIS Corporation engaged Dr. Alfa to prepare this study and compensated her for her work. However, the statements, facts, views, and opinions expressed herein are solely those of Dr. Alfa, and STERIS Corporation makes no representation or warranty with respect to the contents of this paper.

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Definitions

Channel:

Element of a medical device that has hollow cylindrical tubing as part of the apparatus. The channel is open at both ends and is accessible to allow fluid to be flushed through the channel. For example, flexible endoscopes have biopsy channels that consist of lengths of Teflon® tubing that run from the biopsy port to the distal end of the flexible endoscope. The biopsy forceps are passed down this channel. The term channel is used in this document.

NOTE:

In the published literature, the terms channel and lumen are often used interchangeably. Teflon is a registered trademark of Dupont.

Abbreviations

1. **AER:** automated endoscope reprocessor is any machine that automates the disinfection and/or sterilization of flexible and/or rigid endoscopes (e.g., SYSTEM 1, Medivator, etc.)
2. **AAMI:** Association for the Advancement of Medical Instrumentation
3. **ANSI:** American National Standards Institute
4. **APIC:** Association for Professionals in Infection Control and Epidemiology
5. **BAL:** Bronchoalveolar lavage
6. **BI:** biological indicator
7. **CDC:** Centers for Disease Control
8. **CI:** chemical indicator
9. **D value:** time taken to kill 1 Log₁₀ of a specific organism
10. **ETO:** ethylene oxide
11. **FDA:** Food and Drug Administration
12. **HCFC:** hydro-chloro-fluorocarbon
13. **HFC:** hydro-fluorocarbon
14. **HLD:** high level disinfection
15. **H₂O₂:** hydrogen peroxide
16. **JIT:** just-in-time
17. **LCS:** liquid chemical sterilant
18. **MEC:** minimum effective concentration
19. **OPA:** ortho-phthaldehyde
20. **OSHA:** Occupational Safety and Health Administration
21. **PA:** peracetic acid
22. **QA:** quality assurance
23. **SGNA:** The Society of Gastroenterology Nurses and Associates
24. **TWA:** Time Weighted Average

Section 1

1.1 Overview of Device Reprocessing Flow

Overview of Disinfection/Sterilization Practices in Current use by Healthcare Facilities for Reprocessing Medical Devices (FDA cleared for US)

Reprocessing of reusable medical devices is a multi-step process that includes: cleaning, rinsing, wrapping (if storage is part of process), followed by disinfection or sterilization (depending on the intended use of the medical device). Currently, most North American countries follow the Spaulding classification that considers medical devices as “critical” if they enter sterile body sites or are in contact with blood; as “semi-critical” if the device contacts intact mucosal surfaces; and as “non-critical” if the device only contacts intact skin. Critical devices require sterilization after cleaning and prior to the next patient use because they pose the greatest risk of infection transmission. Semi-critical devices require, as a minimum, high level disinfection (HLD), and non-critical devices usually require cleaning and/or disinfection. The Spaulding classification and how it is utilized in the reprocessing of medical devices is clearly outlined in the Association for Professionals in Infection Control and Epidemiology (APIC) guidelines for clinical services (APIC 2000). If there were no device limitations, the ideal method of ensuring all devices are safe for reuse would be to steam sterilize devices after cleaning. Steam sterilization has been generally accepted to be the most robust method for sterilization, as it has the widest margin of safety. However, there are more and more medical devices that are temperature and/or moisture sensitive. Such devices currently require low temperature sterilization/disinfection methods. None of the low temperature methods has, to date, been demonstrated to be as robust as steam sterilization.

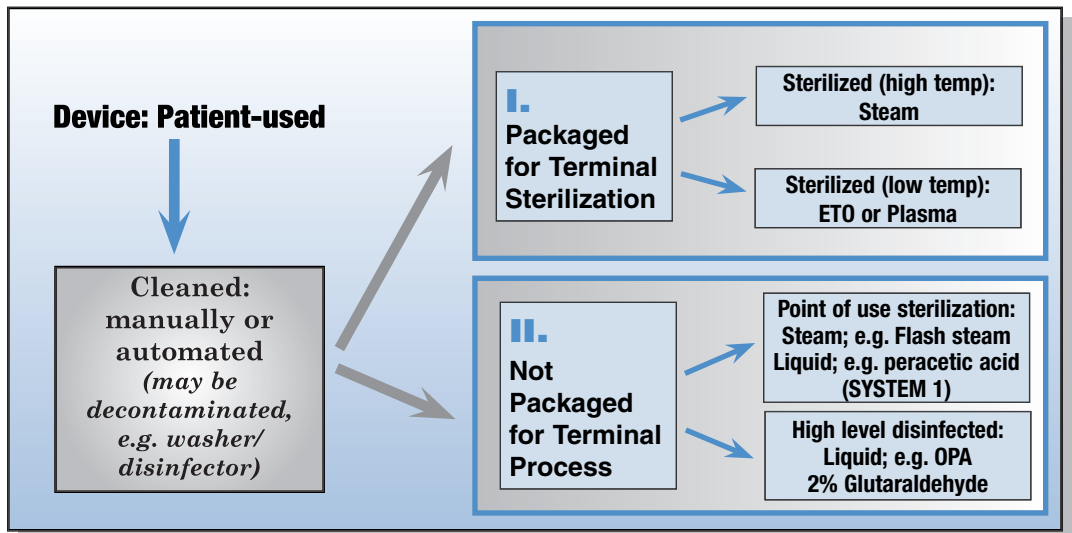
The historic approach has been to package/wrap medical devices used in surgical procedures in a manner that allows for sterile processing and presentation into the surgical field. The current approaches include synthetic or muslin wraps used in a double-wrap technique that allows sterile presentation. An outer wrap protects the package during storage; once the outer wrap is removed the inner wrap provides a sterile wrapping for the medical device. Alternatively, containerized systems have been developed that provide the same ability to keep the medical device(s) sterile during storage and facilitate sterile presentation of the instruments to the surgical field.

Figure 1 outlines the three broad approaches that are currently used for reprocessing critical and semi-critical medical devices. The most robust method is steam sterilization; however, for those medical devices that are temperature and/or moisture sensitive, alternatives for device sterilization must be used. The currently available FDA-cleared low temperature methods include: ethylene oxide (ETO), plasma, and liquid chemical sterilant (LCS). For semi-critical devices, the minimum requirement is HLD. As noted in Figure 1, steam, ETO, and plasma all use packaging and therefore achieve sterile storage, whereas for HLD and “point of use” sterilization (e.g. flash steam or SYSTEM 1[®]) there is no packaging that allows for long term sterile storage.

Some argue that an item cannot be considered sterile unless there is packaging to ensure sterile storage (Daschner 1999). One reason for this logic is that you need to provide adequate confidence that the item has been truly sterilized -- and to do that requires that the quality indicators demonstrate that the load is safe to release for use. While awaiting the results of the quality indicators, the medical devices must be packaged in a way to ensure sterility while in storage. The quality indicators usually are a chemical indicator (CI) as well as a biological indicator (BI). The BI contains spores (usually 10⁶ spores) that have been shown to be the most resistant microbial form to the sterilization process. The

same organism is not necessarily appropriate for all types of sterilization processes. For example, the BI for steam contains *Geobacillus stearothermophilus* spores whereas the BI for ETO contains *Geobacillus subtilis*. For adequate monitoring of the efficacy of a sterilization cycle, it is necessary to have a BI to verify that the complete sterilization cycle parameters were met. In principle, the BI results should be known before the load of medical instruments is released for patient use. Traditional BIs may take up to seven days of incubation before they can confidently be called negative. A negative BI indicates the contents of the sterilizer load can be released, as the quality indicator (the BI) has confirmed that the cycle conditions were adequate to kill the most resistant microbial form to a level that indicates there is less than a 1:1,000,000 chance of a surviving organism. In most hospitals using steam, ETO, and plasma sterilization, the load of medical instruments is often released prior to receiving BI results. Furthermore, many loads are run without a BI in the cycle (BIs are recommended in every load that contains implantables; otherwise they are recommended once per day the sterilizer is in use or at least once per week the sterilizer is in use). The inability to wait until the BI results are known is related to lack of sufficient inventory. Recent introduction of rapid readout BIs has greatly contributed to improving the turn-around time for BI results (hours instead of days).

FIGURE 1
Device
Reprocessing



As can be seen from the overview in Figure 1, medical devices that receive HLD or “just-in-time” (JIT) sterilization are not packaged for prolonged sterile storage. The device is used immediately after the sterilization process (usually with some means of containment to allow for aseptic transfer from the sterilizer to the patient). As such, if BIs were used in a liquid process or flash steam sterilization the results of the BI would not be known until after the device has been used. The lack of sterile storage to ensure reprocessed devices are not released until the results of the BI are known is often part of the reason some experts indicate that LCS cannot be a “sterilization” process (Bond 1993, Daschner 1999).

In light of this traditional reliance on BIs as quality indicators for adequacy of sterilization, it is interesting to note that the recent trend is toward “parametric release” of steam sterilization loads. This concept involves using stringent mechanical process indicators (e.g., steam quality, temperature, pressure) for the specific sterilization method rather than reliance on indirect quality indicators

1.2
Sterilization practices and current standards of practice

Steam autoclave

such as BIs. Utilization of parametric release dictates that the sterilizer load must also be stringently controlled for consistency in contents of packaging size, density, and arrangement to guarantee reproducible sterilization. Of note, the process trays for the SYSTEM 1 are designed to ensure consistency in placement of instruments within the tray and the daily QC cycle ensures stringent assessment of all mechanical processes. The single-use chemistry also ensures consistent microbial killing. Indeed an argument could be made that if process controls are tightly controlled for JIT sterilization (flash steam cycles and SYSTEM 1), the JIT methods are essentially compatible with parametric release conditions. This argument only applies if steam quality can be stringently monitored for flash sterilizers and the water filters stringently maintained for adequate filtration capacity for SYSTEM 1. The only parameter that is not tightly controlled is the manual pre-cleaning of instruments/devices. However, this part of medical device reprocessing is not well controlled for any delicate or heat sensitive device as most cannot withstand the currently available mechanical cleaning processes and require manual cleaning. Manual cleaning has been shown to be the most variable part of medical device reprocessing. This limitation is a factor for any of the currently used low temperature sterilization or HLD processes.

Currently for its 510K approval process, the U.S. Food and Drug Administration (FDA) requires that any new sterilization method be shown to have equivalency to existing sterilization methods. However, the sterilization methods used as “benchmarks” for comparative purposes include only steam under pressure and ethylene oxide. As such, there are currently no benchmarks for LCS or plasma sterilization processes.

Steam under pressure has been used for many years as a method of sterilization (Block 1991). Over time, sterilizer autoclave jacketing and chamber characteristics have improved. Recent advances have demonstrated that pre-vacuum steam autoclaves and steam-flush pressure pulse autoclaves are far more efficient at rapid microbial killing than gravity displacement autoclaves. This is readily apparent in the D values for *G. stearothermophilus* using the two different methods (D value of 2.1 minutes in 121°C gravity displacement versus 0.05 to 0.07 minutes in 132°C pre-vacuum cycles). Currently hospitals will preferentially use pre-vacuum autoclaves for medical device reprocessing and limit gravity displacement to items such as respiratory tubing that cannot withstand the higher temperatures used in pre-vacuum cycles and to liquids that cannot be processed through pre-vacuum cycles.

Steam sterilization has the longest history and is known to be the most robust method (Block 1991). There are a number of guidance documents that provide users and manufacturers with guidance on the proper utilization of steam sterilization in the healthcare setting (e.g., Association for the Advancement of Medical Instrumentation {AAMI} guidance documents). It is recognized that adequate training of staff is required so that the appropriate process is strictly followed and to ensure the adequacy of interpretation of process indicators (e.g., appropriate utilization, interpretation of sterilizer printouts, BI indicator results, etc.). There are a number of steam cycles utilized in healthcare settings including:

- Pre-vac:** 132°C to 135°C for 3–4 minutes followed by up to 20 minutes dry time
- Gravity:** 121°C to 123°C for 30 minutes; followed by up to 30 minutes dry time
132°C to 135°C for 10–25 minutes followed by up to 30 minutes dry time

**Steam-flush/
pressure-pulse:** 132°C for 4 minutes, followed by up to 20 minutes dry time

Steam Sterilization cycles

The current guidelines recommend that appropriate BI and CI monitoring be performed on a regular basis as part of the quality assurance process for all of the above steam sterilization cycles.

One steam sterilization process that is controversial is “flash” steam sterilization. This refers to steam sterilization of unwrapped items (e.g., a crucial item in surgical procedure is dropped on the floor and is needed immediately to complete the surgery with no alternative available). Many guidelines (e.g., AAMI, APIC) indicate that this process should only be used in emergency situations and should not be used in place of standard steam sterilization cycles. Despite these recommendations, there has been development of containers to facilitate sterile transport and BIs for monitoring such cycles. An argument could be made that if adequate protective containers are developed, and appropriate precautions are taken during sterile transport to the patient, this JIT approach could be adequately validated to facilitate routine use in the hospital environment. Indeed, Barrett (2001) suggests that flash steam sterilization presents the same “risk” as conventional steam sterilization and that not to use flash steam sterilization may waste healthcare resources.

Ethylene Oxide (ETO)

The use of ETO has changed dramatically in the past ten years. Although ethylene oxide has a proven track record in low temperature sterilization of medical devices, recent environmental concerns about the toxic nature of this compound and its carrier gas have led to the likelihood that this method of sterilization will eventually not be used within healthcare facilities. The most common carrier gas used originally in the 12/88 formulations was Freon. With concerns about the effects of hydro-fluorocarbons on the ozone layer, the production of Freon (which is an HFC) has been banned. This has led to alternatives such as 100% ETO formulations and alternative carrier gases such as CO₂ or HCFC. Evaluation of alternate formulations for ETO has been shown to be effective (Alfa 1998). Despite these changes that facilitate ETO use without the use of HCF carrier, it appears that ETO itself may eventually be phased out of healthcare environments due to environmental concerns, safety issues in the healthcare setting, and the expensive monitoring required for this process.

Currently there are national guidance documents that provide users and manufacturers with extensive information on the appropriate use, monitoring, and efficacy testing for ETO sterilization. It should be noted that although there is a wide range of materials that can be adequately sterilized using ETO, there is variability in off-gassing requirements due to variations in ETO retention properties of various polymers/materials. The use of air abaters facilitates the rapid removal of residual fumes, but the lengthy turn-around time for ETO sterilization is a drawback. Despite this limitation, ETO is an effective low temperature process for medical devices where electronic wiring is a concern. Although gas plasma sterilization is an alternative, the plasma sterilizers do not provide the same degree of penetration as ETO.

Low Temperature Gas Plasma

In 1993, plasma sterilization was introduced. This approach does not have ETO’s long track record and, furthermore, it has device dimension constraints that limit what type of medical devices can be reprocessed. Medical devices with channels having dimensions of < 3.2 mm diameter and/or > 40 cm long have not been given FDA clearance for plasma sterilization in the USA. However, in other countries “adapters” are used to facilitate penetration of active ingredient into channels. The adapters fit onto the end of the channel and an ampule located inside the adapter is crushed to release hydrogen peroxide into the channel.

**Peracetic acid;
Just-in-time
sterilization**

There are no current national guidance documents (e.g., no American National Standard Institute {ANSI} or AAMI guidance documents) that specifically address use of plasma sterilization. However this method of sterilization is listed in standard of practice documents that review available sterilization methods (e.g., SGNA, APIC).

Although PA is available in other liquid formulations, the primary formulation used for processing reusable medical devices is STERIS 20 Sterilant in conjunction with SYSTEM 1. Peracetic acid is an oxidizing agent that has a sterilization claim of 12 minutes at 50°C but does not have an indication for HLD contact conditions (FDA website). The product is not reused and therefore does not require continued MEC testing. Instead, SYSTEM 1 utilizes CIs to demonstrate that appropriate exposure to the active ingredient has occurred in its chamber. There is no possibility of dilution or inactivation due to repeated use of PA in the SYSTEM 1 process because it is a single-use product. STERIS 20 Sterilant is only used in the SYSTEM 1 and is not used manually. Indeed the FDA clearance states that it is the combination of STERIS 20 Sterilant with the SYSTEM 1 processor that has been cleared for sterilization of reusable medical and dental devices.

There are no U.S. Occupational Safety and Health Administration (OSHA) exposure limits, but PA in concentrated form can cause eye and skin damage. However, the SYSTEM 1 processor is self-contained and the sterilant packaging is relatively tamper-proof so accidental exposure to the concentrate is uncommon.

The SYSTEM 1 process for sterilization is unlike HLD and other conventional sterilization practices. As a just-in-time sterilization method, it is most comparable to flash steam sterilization. Conversely, flash steam sterilization is used for moisture-resistant, temperature-resistant devices and SYSTEM 1 accommodates immersible, temperature-sensitive devices. SYSTEM 1 has an excellent fit as a sterilization process that can be used with flexible and rigid endoscopes that have channels. The fluid process and tightly controlled, reproducible cycle ensure consistent results (providing the user maintenance for filters is adequate and that the correct connectors have been used).

The current acceptance of SYSTEM 1 in the healthcare environment and its long successful track record indicate that this process is a widely used, reliable sterilization process that is recognized as the “benchmark” for LCS.

**1.3
High level
disinfection and
current standards
of practice**

High level disinfection is the current standard of practice as the minimal acceptable process for reprocessing semi-critical medical devices. The only difference between the microbial killing required for this process and sterilization is that HLD is not sporocidal whereas sterilization is. The predominant healthcare area for HLD is the reprocessing of flexible endoscopes. Over the years the importance of using an appropriate HLD has been well documented and currently the FDA regulates the clearance process for any new HLDs. A listing of FDA cleared disinfectants is available on the agency’s website (www.fda.gov/cdrh/ode/germlab.html).

Glutaraldehyde

This HLD has the longest history of usage and is the least expensive method currently available. As such, it is still the most wide-spread method used in healthcare facilities for semi-critical medical device reprocessing (Alfa 2002). The microbial killing efficacy of aldehydes has been shown to be effective providing adequate exposure time and temperature are used. Although most healthcare facilities utilize exposure for 20 minutes at room temperature (Rutala 1999), the FDA requires the label claims to state

usage conditions of 45 minutes exposure at 23°C to ensure that residual soil will not adversely affect microbial killing ability. This HLD can be used manually or in AERs. It has a reuse claim of 14-30 days providing the MEC is monitored to ensure the active ingredient is > 1.5%.

There are national guidelines on the appropriate use and environmental monitoring required for use of glutaraldehyde in healthcare facilities. The OSHA exposure limit is 0.05 ppm ceiling.

OPA

This HLD was introduced after FDA clearance in 1999. Although it is an aldehyde, it does not have the toxic vapors associated with glutaraldehyde. OPA is included in the listings of HLDs in various guidance documents but there have been relatively few peer-reviewed publications showing in-use efficacy compared to other HLD methods. It can be used manually or as a substitute for 2% glutaraldehyde in many of the commercially available AERs. Rutala (1999) indicates that OPA has a sterilization claim of ten hours at 25°C, but the November 2003 FDA-Cleared Sterilants and High Level Disinfectants with General Claims for Processing Reusable Medical and Dental Devices information indicated that for OPA: “No indication for device sterilization. Passes the AOAC Sporocidal Activity Test in 32 hours at 20°C and 25°C.” OPA has a reuse claim of 14 days providing the MEC test indicated that the active ingredient is > 0.3%.

There are no OSHA exposure limit guidelines.

Hydrogen peroxide

Although hydrogen peroxide has a history of excellent microbial killing ability (Block 1991, Rutala 1999), it has not been used widely as a HLD in medical device reprocessing. Hydrogen peroxide is an oxidizing agent that can cause serious eye damage in its concentrated form. Currently the FDA cleared formulation is a 7.5% hydrogen peroxide/0.85% phosphoric acid solution. It does not require activation and has a reuse claim of 21 days (providing MEC testing is done to ensure the active ingredient is \geq 6%). Formulations used in medical device reprocessing usually have additives to stabilize the pH and to reduce corrosive action. In most situations, it is used manually and, although it can be used in automated AERs, there are no published reports of this HLD being used in an AER.

The OSHA exposure limit is 1 ppm TWA.

Section 2

2.1

Functionality Overall Design Aspects

Characteristics of the SYSTEM 1[®] Sterile Processing System

The SYSTEM 1 is a compact sterilizer unit (38 inches wide, 24 inches deep, and 32 inches high) that utilizes liquid chemical sterilant (peracetic acid at 0.2% use-dilution) for the reprocessing of temperature sensitive medical devices. The SYSTEM 1 is designed as an immersion system that bathes all surfaces of the device (both external and internal) in liquid chemical sterilant (LCS). To achieve this there are different tray formats that are used dependent upon the type of medical device to be sterilized.

- i) There are closed trays for flexible and semi-rigid/rigid scopes and accessory devices, ensuring proper positioning of the device and appropriate containment for transport to the procedure site (Appollo 1997). There are currently two different types of closed trays for use with specific Quick Connects designed and tested for specific manufacturers and specific models of instruments.

- ii) There is an open tray for flexible endoscopes that do not require containment prior to reuse, ensuring appropriate placement of flexible scopes to prevent damage during the sterilization process. There is currently one open tray model for use with specific Quick Connects designed and tested for specific manufacturers and specific models of instruments.

Details regarding appropriate Quick Connects for specific instruments and the appropriate tray type can be obtained by contacting STERIS Corporation.

Before any medical instrument is reprocessed in the SYSTEM 1, it is critical to ensure that the manufacturer of that device has given approval for its reprocessing using peracetic acid. To achieve adequate perfusion of channels, a series of specific connectors is available to ensure appropriate fluid flow for the type of device being reprocessed. Many devices that have a channel require a connection to the SYSTEM 1 to ensure there is fluid flow through the channel. If fluid flow is not achieved in the channel of a device processed in the SYSTEM 1, sterilization will not be achieved (Rutala 1998, Sorin 2001, Alfa 1998). These studies emphasize how critical it is that if the device contains a channel that requires flow, the appropriate specific Quick Connect be used to connect it to the SYSTEM 1. If a medical instrument has no channel (e.g. rigid endoscopes that have no channels), then a Quick Connect is not needed when this type of instrument is processed in the SYSTEM 1.

Despite the simplicity of use (operator presses one button to start) the SYSTEM 1 has built in system checks (proper electro/mechanical functions, correct water temperature, fill-time parameters to ensure filters are not blocked, presence of PA) that ensure proper functioning and provide cycle parameter printouts to facilitate QA record keeping needs. The diagnostic cycle should be run once every 24 hours. The microprocessor controlled function of the SYSTEM 1 ensures reproducibility of the process.

Sterilization Cycle Parameters

The peracetic acid single-use STERIS 20 Sterilant in the SYSTEM 1 processor is delivered in tamper-proof cups that are placed in the machine. The SYSTEM 1 is designed to puncture the cup and mix the contents (35% PA and proprietary builders/buffers) with filtered water to produce the 0.2% use-dilution of PA that has a neutral pH of about 6.4 (Crow 1992). The SYSTEM 1 is computer controlled and the user needs only to properly place the instrument in the chamber (using proper channel connectors, if applicable), close the unit, and press the start button. Table 1 summarizes SYSTEM 1's overall cycle. It is apparent from this table that the devices are exposed to a total fluid volume of 50L during a complete cycle. This consists of 10L during the sterilization process followed by a total of 40L (four cycles of 10L each) in the sterile rinsing phase. All the water used in the process is filtered through a series of filters with the final filtration using 0.2µm membrane. This is an accepted method of sterilizing fluids for human injection. Studies have shown that as long as the 0.2 µm filter membrane is intact, the microbial retention capacity is extremely efficient and sterilization of fluids can be achieved (Block 1991).

During the sterilization cycle, the PA is heated to 50-56°C and constantly circulated through/over any instruments and their channels. This provides a number of very important benefits including:

- 1) A thorough perfusion of channels and instrument surface which reduces the likelihood that air bubbles will remain in channels and prevent fluid from contacting instrument surfaces.
- 2) The warm 50°C temperature ensures optimal chemical activity and facilitates

permeation of liquid into any residual soil/bioburden that may remain on the device.

- 3) The fluid flow may physically flush off material from the medical instruments which ensures adequate exposure to the PA and improves efficacy of killing (i.e. suspension kinetics for penetration versus penetration kinetics of soil/bioburden on a solid surface).

TABLE 1 SYSTEM 1 Sterile Processing System Cycle Parameters

Stage	Fluid	Exposure time	Temperature	Total fluid volume
Fill	Intake water; 0.2 µm filtered	~ 3 – 6 minutes	43-46 ⁰ C	10L
Sterilization	0.2% peracetic acid in proprietary builders/buffers diluted using 0.2 µm filtered intake water	12 minutes	50-56 ⁰ C	The 0.2 m filtered fill water (described above) dilutes the PA to the appropriate use-dilution, heats it to the correct temperature and then sterilization timing is started
Rinse 1	Intake water; 0.2 µm filtered	~ 2-3 minutes	43-46 ⁰ C	10L
Rinse 2	Intake water; 0.2 µm filtered	~ 2-3 minutes	43-46 ⁰ C	10L
Rinse 3	Intake water; 0.2 µm filtered	~ 2-3 minutes	43-46 ⁰ C	10L
Rinse 4	Intake water; 0.2 µm filtered	~ 2-3 minutes	43-46 ⁰ C	10L

Intake water may be potable tap water or reverse osmosis (RO) water.
Temperature of intake water must be 43-46°C.

Process

The SYSTEM 1 process is designed as a “point-of-use” sterilizer. Because of this “just-in-time” approach, packaging for storage is not utilized. Medical instruments are either sterilized in the SYSTEM 1 just prior to use (e.g., rigid laparoscopes and accessories) and transported in the appropriate SYSTEM 1 closed tray system to the site of use, or they are sterilized, dried, and then stored under non-sterile conditions (e.g., flexible endoscopes). If stored under non-sterile conditions, STERIS recommends that devices such as flexible endoscopes be reprocessed through the SYSTEM 1 before use. The SGNA and APIC guidelines (2000, Alvarado et al, 2000 SGNA Guideline) do not require reprocessing prior to use after overnight storage, but they do recommend that prior to storage the cleaned/disinfected flexible endoscope be rinsed with 70% alcohol and dried using forced air thereby ensuring the endoscope channels do not contain moisture during storage Although there are other liquid chemical products that have sterilant claims (e.g., 2% glutaraldehyde after 10 hours at 20°C) SYSTEM 1 is the only system using LCS that can efficiently sterilize within a realistic time-frame (Table 2) and is based on an integrated process that ensures reproducibility (because of the computer controlled instrumentation process) and sterilization (because of the efficacy of the PA chemistry).

A novel aspect of this method of sterilization is that, unlike steam, ethylene oxide, or plasma sterilization, the liquid sterilization process of SYSTEM 1 actually facilitates penetration and, to some extent, removal of soil (organic, inorganic, and bioburden) during the process. The transfer of heat and penetration of chemicals into an organism are better facilitated in a warm liquid environment than in a gaseous one. Indeed this is why both autoclaves and ethylene oxide sterilizers need to have a certain minimum humidity (moisture content) in order to function properly (if the moisture content is inadequate, sterilization may be

2.2
FDA cleared label claims

compromised). The oxidizing nature of PA helps break up proteins and the fluid flow facilitates flushing any dislodged material off the device.

The SYSTEM 1 is NOT a washer and manual pre-cleaning is critical prior to placing instruments in the SYSTEM 1 processor, but because of the fluid flow and the mode of action of the peracetic acid there is a degree of soil removal inherent in the SYSTEM 1 process. This actually provides for a process that reduces the likelihood of buildup over time (unlike the other sterilization or HLD that will essentially fix any residual soil onto the device during the process). As discussed by Lewis (1999) it is better to use a chemistry that facilitates the process rather than one that frustrates it.

In 1988 the U.S. Food and Drug Administration cleared the 510K application for the SYSTEM 1 Sterile Processing System and STERIS 20 Sterilant. The current (November 2003) FDA-Cleared Sterilants and High Level Disinfectants with General Claims for Processing Reusable Medical and Dental Devices information is given in Table 2. Of the 20 liquid chemical formulations listed, 18 have been cleared for use in device sterilization. Of these 18 liquid chemical sterilant formulations, only STERIS 20 Sterilant used in the SYSTEM 1 Processor has been cleared for a contact time frame that is realistic for use in sterilization where device turn-around time is critical (12 minutes at 50-56°C versus 3 – 10 hours at temperatures ranging from 20-35°C for the other formulations). The same problem of prolonged turn-around time exists for ethylene oxide sterilization where aeration times of >20 hours are often required. Although plasma sterilization (e.g., STERRAD) has turn-around times of ~ 45-73 minutes that are closer to that of the SYSTEM 1 (~ 30 minutes) there are channel dimension restrictions for the plasma process that preclude use with some medical devices. Plasma sterilization is not FDA cleared for channels > 40 cm long or < 3.2 mm internal diameter and as such, most flexible endoscopes cannot be processed by this method.

The FDA has cleared the use of STERIS 20 Sterilant in SYSTEM 1 for terminal point-of-use sterilization of both medical and dental instruments. The actual devices that can be processed in SYSTEM 1 are approved by STERIS Corporation and/or the device manufacturers after validation testing has been done. The STERIS Device Testing Program includes materials compatibility, functionality, and sterilization efficacy testing. There is no complete list of medical devices that can be appropriately reprocessed in the SYSTEM 1. This is the same situation that exists for all other sterilization methods including steam sterilization, ethylene oxide, and plasma sterilization.

TABLE 2

FDA-cleared Liquid Chemical Sterilants and high level disinfectants cleared for reusable medical and dental devices*

Agent	Active ingredient conditions	Sterilant contact conditions	High level disinfectant
Banicide® Advanced	3.5% glutaraldehyde	10 hours at 25°C 30 days max reuse	45 mins at 25°C
Cidex OPA® Solution (Advanced Sterilization Products)	0.55% ortho-phthaldehyde	No indication for device sterilization	Manual Processing: 12 min at 20°C, 14 day max reuse AER: 5 min at 25°C 14 days max reuse
Sterilox Liquid High Level Disinfectant System (Sterilox Technologies Inc.)	Hypochlorite 650-675 ppm active free chlorine	No indication for device sterilization	10 min at 25°C Single-use

Agent	Active ingredient conditions	Sterilant contact conditions	High level disinfectant
Sporicidin Sterilizing and Disinfecting Solution (Sporicidin International)	1.12% glutaraldehyde, 1.93% phenol/phenate	12 hours at 25 ⁰ C 14 days max reuse	20 min at 25 ⁰ C 14 days max reuse
Rapicide High Level Disinfectant and Sterilant (MediVators Inc.)	2.5% glutaraldehyde	7 hours 40 min at 35 ⁰ C 28 days max reuse	5.0 min at 35 ⁰ C 28 days max reuse
Cidex OPA Solution High Level Disinfectant (Advanced Sterilization Products.)	0.55% ortho-phthaldehyde	No indication for device sterilization	12 min at 20 ⁰ C 14 days max reuse
Cetylcide-G Concentrate and Diluent Concentrate	3.2% glutaraldehyde	10 hours at 20 ⁰ C 28 days max reuse	40 min at 20 ⁰ C 28 days max reuse
MedSci 3% Glutaraldehyde (MedSci, Inc.)	3% glutaraldehyde	10 hours at 25 ⁰ C 28 days max reuse	25 min at 25 ⁰ C 28 days max reuse
EndoSpore Plus Sterilizing and Disinfecting Solution	7.35% hydrogen peroxide, 0.23% peracetic acid	3 hours at 20 ⁰ C 14 days max reuse	15 min at 20 ⁰ C 14 days max reuse
Sporox Sterilizing & Disinfection Solution (Reckitt & Colman Inc.)	7.5% hydrogen peroxide	6 hours at 20 ⁰ C 21 days max reuse	30 min at 20 ⁰ C 21 days max reuse
Peract 20 Liquid Sterilant/Disinfectant (Minnotech Corp)	1.0% hydrogen peroxide, 0.08% peracetic acid	8 hours at 20 ⁰ C 14 days max reuse	25 min at 20 ⁰ C 14 days max reuse
Procide 14 N.S. (Cottrell Limited)	2.4% glutaraldehyde	10 hours at 20 ⁰ C 14 days max reuse	45 min at 20 ⁰ C 14 days max reuse
Omnicide Long Life Activated Dialdehyde Solution (Cottrell Limited)	2.4% glutaraldehyde	10 hours at 20 ⁰ C 28 days max reuse	45 min at 20 ⁰ C 28 days max reuse
Omnicide Plus (Cottrell Limited)	3.4% glutaraldehyde	10 hours at 20 ⁰ C 28 days max reuse	45 min at 20 ⁰ C 28 days max reuse
Metricide Plus 30 Long-Life Activated Dialdehyde Solution (Metrex Research Inc)	3.4% glutaraldehyde	10 hours at 25 ⁰ C 28 days max reuse	90 min at 25 ⁰ C 28 days max reuse
Metricide 28 Long-Life Activated Dialdehyde Solution (Metrex Research Inc)	2.5% glutaraldehyde	10 hours at 25 ⁰ C 28 days max reuse	90 min at 25 ⁰ C 28 days max reuse
Metricide Activated Dialdehyde Solution (Metrex Research Inc.)	2.6% glutaraldehyde	10 hours at 25 ⁰ C 14 days max reuse	45 min at 25 ⁰ C 14 days max reuse
Cidex Activated Dialdehyde Solution (Johnson & Johnson Medical Products)	2.4% glutaraldehyde 14 days max reuse	10 hours at 25 ⁰ C 14 days max reuse	45 min at 25 ⁰ C
Cidex Formula 7 Long-Life Activated Dialdehyde Solution (Johnson & Johnson Medical Products)	2.5% glutaraldehyde	10 hours at 20-25 ⁰ C 28 days max reuse	90 min at 25 ⁰ C 28 days max reuse
Cidex Plus 28 Day Solution (Johnson & Johnson Medical Products)	3.4% glutaraldehyde 28 days max reuse	10 hours at 20-25 ⁰ C 28 days max reuse	20 min at 25 ⁰ C
Wavicide -01 (Wave Energy Systems)	2.5% glutaraldehyde	10 hours at 22 ⁰ C 30 days max reuse	45 min at 22 ⁰ C 30 days max reuse
STERIS 20 Sterilant (STERIS Corporation)	0.2% peracetic acid	12 min at 50-56 ⁰ C Single-use only	No indication for high level disinfection

*Table extracted from device evaluation information on the FDA website (dated November 2003). www.fda.gov/cdrh/ode/germlab.html

It is up to the device manufacturers to validate the sterilization processes compatible with their particular device. It is pivotal that users only sterilize medical devices using a process that has been validated for that particular device. In 1997, 1200 devices from over 50 manufacturers had been tested for SYSTEM 1; the list continues to grow with additional ongoing testing. The types of non channel-containing devices that have been manufacturer-validated for reprocessing in the SYSTEM 1 (Malchesky 1997) include but are not limited to: camera heads and couplers, cannulae, dental handpieces, electrodes, rigid endoscopes, graspers and forceps, laryngoscopes, microsurgical instruments, ophthalmic instruments and accessories, respiratory therapy equipment, speculums, telescopes, tracheal introducers, ultrasound probes, light cables, and guides.

2.3 History of usage

Although there is no comprehensive listing of the medical instruments that can be processed in SYSTEM 1, a listing of Quick Connects is available from STERIS Corporation. All devices requiring Quick Connects must be connected to the SYSTEM 1 using their validated Quick Connect. This list is continually changing as new Quick Connect kits are developed and validated. The extent of this list indicates that there is a wide range of device types/models that can be sterilized using the SYSTEM 1 process.

The first peer-reviewed report describing in-hospital use of the SYSTEM 1 sterilization process was published in 1995 by Wallace et al. The article describes problems encountered in 1988 with the glutaraldehyde high level disinfection process in a community hospital in the USA. Despite adherence to CDC guidelines for high level disinfection, this hospital experienced a series of pseudo-outbreaks involving *Mycobacterium chelonae*. They switched their flexible endoscope terminal decontamination protocol from glutaraldehyde to the SYSTEM 1 process in 1988. Subsequent concurrent culture tests of the endoscope suction channels (twice per month for a year) and prospective evaluation of 220 patients undergoing endoscopy demonstrated that there were no further problems with mycobacteria in their flexible endoscopes (bronchoscopes, colonoscopes, and gastroscopes) after switching to the SYSTEM 1 process.

Subsequent to FDA clearance in 1988 and in-hospital utilization of the SYSTEM 1 from 1988 onwards, this process has a history of successful use for over 15 years. There has been wide acceptance in the medical community as reflected by the large number of sites world-wide that are using the SYSTEM 1. The Wirthlin study (a survey commissioned by STERIS in May 2003) surveyed 360 American hospitals and found that the SYSTEM 1 process was used by 69% of the operating rooms in the hospitals contacted. Furthermore, SYSTEM 1 is a sterilization method recommended in a wide range of guidance documents including: ANSI 1995, APIC 2000, SGNA 2000, Minimal Access Therapy Decontamination Working Group 2000. There has also been thorough research that critiques various aspects of the SYSTEM 1 sterilization process.

Although SYSTEM 1 is currently the most extensively used PA sterilant, this chemistry has been known to have efficient microbial killing properties since the early 1900s (Block 1991) and there have been multiple other applications of PA as a disinfectant/sterilant. There are PA formulations that have been utilized in food industry clean-in-place equipment (Malchesky 1992), for sterilizing external surfaces of materials used in the preparation of parenteral infusion bags (Escalup et al 2001), as well as for dialyzers. For example, Renalin (Minntech Corp) is a PA formulation that has been successfully used in the reprocessing of dialyzers using a 12 hour exposure time (same patient reuse). NuCidex (Johnson & Johnson Medical) has been used for medical device sterilization at a 10 minute exposure time. Peract20 (Minntech Corp) has been used outside the USA for sterilization of flexible endoscopes using a 10 hour exposure time (Malchesky 1997).

A 1995 survey of one thousand readers (24% response rate) indicated that SYSTEM 1 was a popular choice for reprocessing both flexible endoscopes (45% used this method) and rigid scopes (26%). A 1998 trans-Canada survey on reprocessing of flexible endoscopes performed reported that 24% of the 37 hospitals surveyed were using SYSTEM 1. These surveys support the wide-spread acceptance of sterilization of reusable medical devices using SYSTEM 1 in the medical community.

2.4 Just-in-Time Approach

The devices processed in SYSTEM 1 are not intended for sterile storage, rather they are intended for use immediately after the process, similar to flash steam sterilization. The SYSTEM 1 process based on the just-in-time approach is unique compared to routine sterilization using steam, ETO, and plasma sterilization where the devices undergoing terminal sterilization are packaged to allow sterile storage. The SYSTEM 1 has closed trays specifically designed for flexible and semi-rigid/rigid scopes and accessory devices. These processing trays ensure proper positioning of the device and appropriate containment for transport to the procedure site (Appollo 1997). There are currently two different types of closed trays for use with specific Quick Connects designed and tested for specific manufacturers and specific models of instruments.

There is a sense that a liquid chemical cannot truly be used for sterilization of medical devices because there is no way to store the sterilized item as packaging is not used for LCS treatment. SYSTEM 1 is truly the “flagship” of liquid chemical sterilization because it has realistic turn-around times, is environmentally safe, has excellent efficacy, and a proven track record. Because SYSTEM 1 has FDA clearance as a sterilant there has been much attention to both flexible and rigid endoscope/accessory reprocessing in the SYSTEM 1 system. The ability to truly sterilize a complex device such as a flexible endoscope is a valid concern because of the complicated inner design of channels, etc. However, that caveat applies to ALL HLD and sterilization methods.

This sterile storage issue is frequently controversial. However, flash steam sterilization has the same limitation of being a JIT process that has no packaging for sterile storage yet is accepted within the healthcare profession. National guidelines specify that flash sterilization should only be used in emergency situations and not as a “convenience.” Despite these limitations there has been a proliferation in the development of BIs and containment “trays” or other protective wrappers for use with “flash” cycles. The robustness of the steam sterilization process and the protective packaging makes the JIT flash cycles attractive for the busy hospital setting. There is no doubt that the SYSTEM 1 process is not as robust as steam sterilization (none of the low temperature HLD or sterilization methods is as robust as steam) however, for the manufacturer approved devices that can be processed in this system, the data indicates that these devices are sterile at the completion of the process, providing the appropriate maintenance and QA for the machine and filters has been performed. Similar to “flash” steam sterilization cycles, there are containment trays that allow transport of the instruments removed from the SYSTEM 1 to the site of use.

The JIT approach is an excellent fit for processing of flexible GI endoscopes as the issues of sterile storage are not as critical. It would seem optimal to use the best killing method available that is still compatible with the heat limitations of this device. To argue over whether flexible endoscopes can ever be sterilized is a different issue that is related to the design considerations of this device and is separate from whether the sterilization process works or not. There is no doubt that endoscope design is a problem for any of the low temperature HLD or sterilization methods. However, in light of this constraint it seems prudent to utilize the most efficient method that will give reasonable turn-around times and give optimal microbial kill.

Section 3

3.1 Efficacy of Chemistries

Comparison of the SYSTEM 1® Sterile Processing System to other Standards of Practice

Peracetic acid (0.2% when diluted) delivered using the SYSTEM 1 has been given FDA clearance for label claims for sterilization of medical and dental instruments. The peracetic acid reaction in water is given below:



Then:



The possible mechanisms of microbial killing include (Malchesky 2000, Rutala 1999):

- disruption of sulfhydryl (-SH) and sulfur bonds in proteins and enzymes
- dislocation of the chemiosmotic function of membrane transport impeding cellular activity
- oxidization of essential enzymes (e.g., inactivates catalase)
- protein denaturation

Peracetic acid by itself is corrosive when in contact with copper, brass, bronze, plain steel, and galvanized iron (Rutala 1999); however, additives and pH adjustments used in STERIS 20 Sterilant reduce these corrosive effects. SYSTEM 1 is one of the few sterilizing methods that are commonly used for both semi-critical (e.g., flexible endoscopes) and critical (e.g., rigid endoscopes) heat sensitive medical devices.

Peracetic acid, once mixed in water to a 0.2% use dilution, has been shown to be non-toxic and environmentally safe for disposal down the sewer (Rutala 1999, Malchesky 1993). Furthermore, after the 40 L of rinsing with 0.2 µm filtered water, testing has shown that there were no detectable residues and no evidence of cumulative increase due to repetitive exposure to SYSTEM 1 (Malchesky 1993). Alfa (1998) has also shown that using tissue culture testing of carriers exposed to PA there were no detectable residuals that damaged human cell lines.

The material testing program performed at STERIS is used to validate compatibility of device materials with the SYSTEM 1 process before manufacturer approval is given for the device to be processed by SYSTEM 1. Despite these material compatibility tests, instrument damage due to exposure to PA during hospital use has been described. Many sites report no serious functional damage to flexible endoscopes over repeated usage (Mannion 1995, Bradley 1995, Wallace 1995, Seballos 1995, Duc 2001) whereas others indicate that the cost of repairs is higher for sites that use SYSTEM 1 compared to glutaraldehyde (Debian 1999). Lewis has shown micrographs to demonstrate that glutaraldehyde encrusted material inside flexible endoscope channels is removed after 2-5 cycles in SYSTEM 1 (Lewis 1999). Tucker has supported this finding by surface chemistry analysis (1996). These data suggest that because STERIS 20 Sterilant is oxidative and breaks down protein encrustations, that switching from glutaraldehyde reprocessing of flexible endoscopes to PA may initially result in the exposure of small channel perforations that were previously encrusted. Thorough analysis of the corrosive nature of SYSTEM 1 process during hospital use is difficult to properly interpret as repair costs vary from hospital to hospital and are certainly dependent upon the handling and/or mishandling at different sites. However, regardless of this difficulty, these findings suggest that sites that have concern for repair costs due to SYSTEM 1

processing might find the implementation of a preventative maintenance program for flexible endoscopes useful. In this manner any potential corrosive problems can be dealt with before they are problematic and result in penetration of fluid into the fiberoptics resulting in expensive repairs. This approach would likely be valuable regardless of the type of chemistry used in reprocessing.

PA Compared to Glutaraldehyde

Glutaraldehyde is commonly used as a high level disinfectant for flexible endoscopes and other semi-critical medical devices. As shown in Table 2, there are a number of glutaraldehyde formulations that are commercially available and approved for high level disinfection of medical devices as either alkaline (needs activation) or acidic (no activation needed) formulations. The efficacy of glutaraldehyde compared to PA in SYSTEM 1 has been reported in a number of studies. Holton (1994) tested PA (STERIS 20 Sterilant used manually, a use not recommended by the manufacturer) and reported that PA was as effective as 2% alkaline glutaraldehyde at killing mycobacteria and cryptosporidium in the presence or absence of an organic soil load. However, PA provided a greater log₁₀ reduction in mycobacterial load compared to the glutaraldehyde treatment. Although this study indicated that STERIS 20 Sterilant (not used in SYSTEM 1) was as effective as glutaraldehyde, there was survival of cryptosporidium after exposure to both processes. A later study by Sell et al (2000) using STERIS 20 Sterilant in SYSTEM 1 demonstrated that both cryptosporidium oocysts and Giardia were effectively killed. Similarly Jackson (1996), Foliente (1999, 2001) and Cronmiller (1999) found SYSTEM 1 to be more effective at killing test organisms (including *Mycobacterium chelonae*) under simulated-use conditions compared to 2% glutaraldehyde. Cronmiller (1999b) tested glutaraldehyde at both 20 and 45 minutes exposure at room temperature and reported that alcohol rinsing was critical to ensure effective eradication of *Enterococcus faecalis* by glutaraldehyde. Deva (1998) also compared SYSTEM 1 to 2% glutaraldehyde but their data are hard to interpret as samples taken from gastroscopes were enriched in broth and organisms were detected by this broth enrichment method from all disinfection/sterilant methods tested. This seems unusual as there should have been no detectable organisms post-disinfection yet there were 8-48% of samples showing growth. This raises questions about the sampling technique used as even one organism introduced accidentally could result in broth enrichment.

From a clinical use perspective, a number of reports indicating that problems with bacterial contamination and pseudo-outbreaks associated with glutaraldehyde reprocessing of flexible endoscopes were solved by switching to the use of SYSTEM 1 (Wallace 1990, 1995, Cowan 1999). Indeed, Seballos (1995) switched from glutaraldehyde to SYSTEM 1 as they stated that they preferred sterilization of their flexible endoscopes over high level disinfection. Similarly Lewis (1999) recommends use of sterilization process for flexible endoscopes rather than HLD.

PA Compared to OPA

The other recently introduced HLD is OPA which was cleared by the FDA in 1999. OPA is a clear blue liquid that has a pH of 7.5. Although OPA is an aldehyde and in that respect is similar to glutaraldehyde, it is less efficient at protein cross-linking and its fumes are substantially less than those from glutaraldehyde. Various evaluations have shown that OPA is more efficient at microbial killing than glutaraldehyde but that there are skin staining problems associated with OPA. OPA must be very thoroughly rinsed off of medical devices after exposure to prevent permanent staining of a patient's skin.

Because of its relatively recent introduction to the healthcare market, there are no peer-reviewed publications (to the best of the author's knowledge) that provide experimental or clinical data that directly compare OPA to SYSTEM 1 for efficacy of medical device reprocessing. The published data on OPA are primarily directed at showing its efficacy and compatibility in the clinical setting (Rutala 1999). The exposure time for OPA varies in different countries (e.g. five minutes in Europe, Asia, and Latin America but 10 minutes in Canada and 12 minutes in the US). However, as indicated in Table 3, SYSTEM 1 has the shortest overall turn-around time when compared to other HLDs used in automated endoscope reprocessors or plasma and ETO gas sterilization.

PA Compared to ETO

Although ETO is an effective sterilant with a long track record, good material compatibility, and excellent microbial killing characteristics (Table 3), it is not commonly used for the reprocessing of GI flexible endoscopes (Alfa 1999) or minimally invasive surgery sets because of the long aeration times (~ 20 hours) required post-exposure. It is used for sterilization of bronchoscopes (often because of the need for sterile presentation in the operating room where bronchoscopies are often performed). Vesley has shown that the use of ETO does not guarantee sterility in narrow channels such as the elevator wire channel of flexible endoscopic retrograde cholangiopancreatography (ERCP) scopes (Vesley 1992). This has also been substantiated by simulated-use studies using channel carriers (Alfa 1998) where *E. faecalis* and *G. subtilis* could survive exposure to 100% ETO and HCFC ETO sterilization when in the presence of organic soil. This emphasizes that whatever residual soil or bioburden that remains after cleaning will still be present after the ETO process (indeed it will be essentially fixed onto the surface after the ETO process). As mentioned previously, the value-added aspect of fluid flow and the oxidative nature of PA during SYSTEM 1 processing contribute to breakdown and removal of any residual material during the sterilization cycle as shown by Lewis (1999) and Alfa (1998).

ETO is an accepted low temperature sterilant. Comparative evaluations of ETO and PA have demonstrated that SYSTEM 1 has equivalent microbial killing efficacy as ETO (Wallace 1995, Alfa 1998, Foliente 1999, 2001). For flexible and rigid endoscopes, SYSTEM 1 has been recommended by many (spanning a ten-year period of study) to be an excellent method for low temperature sterilization (Wallace 1990, 1995, Bradley 1995, Seballos 1995, Villate 1997, Alfa 1998, Cronmiller 1999a, Cowan 1999, Foliente 2001, Duc 2001). SYSTEM 1 provides a substantially shortened turn-around time compared to ETO sterilization (Table 3) and furthermore SYSTEM 1 has fewer biosafety and environmental drawbacks than ETO.

PA Compared to H₂O₂

There are many evaluations of the microbial killing ability of hydrogen peroxide (Bond 1991, Rutala 1999), but few clinical studies that compare the use of hydrogen peroxide to PA for use as an HLD for flexible endoscopes or other medical devices. The currently marketed hydrogen peroxide product cleared for HLD (contains 7.5% hydrogen peroxide and 0.85% phosphoric acid) has been shown to have good microbial killing properties (Rutala 1999) and has sterilization claims for six hour contact times (Table 2). The FDA cleared contact time for HLD is 30 minutes at room temperature. The use of H₂O₂ for HLD of medical devices is not widespread. Foliente did perform simulated-use testing that compared PA and H₂O₂ for GI endoscope reprocessing and reported that HLD was achieved with both PA and H₂O₂. Although H₂O₂ was stated to have achieved HLD in the report, there were residual organisms (up to 87 cfu) remaining after 30 minute exposure at room temperature to 9.4 x 10⁶ cfu of *Mycobacterium chelonae*. Under the same challenge conditions, PA was more effective compared to H₂O₂ because it showed no residual organisms (Foliente 2001).

PA Compared to Plasma (H₂O₂)

A problem that has yet to be completely addressed for H₂O₂ is the material compatibility concern with brass, zinc, copper, and nickel or silver plating (Rutala 1999). In addition, serious damage can result if there is contact with eyes. As such, PA is a more environmentally and user friendly formulation that has fewer materials compatibility concerns than H₂O₂.

Low temperature gas plasma sterilizers were introduced to the US market in 1993. The gas plasma used in the STERRAD system (Johnson & Johnson) is created when hydrogen peroxide is vaporized and an electrical field is created using radio frequency. Microbial killing is thought to be due to free radicals (e.g., hydroxyl and hydroperoxyl) that are generated when the plasma is formed. The most recent version of the sterilizer has two plasma stages per sterilization cycle. Penetration into long narrow channels is problematic and currently channels > 40 cm long or < 3.2 mm internal diameter have not been FDA cleared for use in the STERRAD system. The plasma rapidly deteriorates and is safe for the environment and healthcare workers. The unit is simple to install, operate, and monitor with a wide range of compatible device materials. However, cellulose (paper), linens, and liquids cannot be processed and packaging must be synthetic (e.g., polypropylene wraps, polyolefin pouches, or special trays).

The plasma process has been shown to have killing ability against a wide range of microorganisms provided there is no residual organic material (Alfa 1996, Rutala 1998). The one peer-reviewed publication (to the best of the author's knowledge) that compares SYSTEM 1 directly to Plasma sterilization is that of Rutala (1998). Unfortunately, the comparison used a channel carrier that was not connected to the SYSTEM 1 therefore it is not possible to assess killing efficacy as the SYSTEM 1 was not used according to the manufacturer's instructions as reviewed in Alfa's (1998) letter to the editor.

3.2 Efficacy of microbial killing to achieve sterilization for the SYSTEM 1 Sterile Processing System Microbial Killing Efficacy of PA

The D values (time taken to kill 1 Log₁₀ of a specific organism using a specified agent/method) for spore suspensions in the STERIS 20 Sterilant are 11.3 seconds for *Geobacillus stearothermophilus* and 2.9 seconds for *Geobacillus subtilis*. Table 4 summarizes D value data for a variety of sterilization methods. The low D values for STERIS 20 Sterilant attest to the efficient penetration of peracetic acid into a spore in the liquid sterilization process compared to heat penetration in steam sterilization or ethylene oxide penetration in a gas sterilization process. The D values for SYSTEM 1 are comparable to those obtained for steam at 132°C. For all terminal sterilization processes, the ability of the active ingredient/process to penetrate into microorganisms is a critical factor that will be reflected in the D values obtained. As shown in Table 4, as the steam temperatures increase the D values decrease. Likewise for ethylene oxide, when the temperature is increased the D values decrease. Although spores are used as the test organism because they are generally the most resistant forms to sterilization, it is still important to ensure that a representative range of microorganisms likely to be encountered in device reuse is also tested.

Many research studies have been performed and published in peer-reviewed journals that demonstrate the wide range of microorganisms that can be effectively killed by the SYSTEM 1 process including but not limited to:

- Viruses (e.g. HIV, Hepatitis B, Polio virus, etc.)
- Vegetative bacteria (e.g. *Staphylococcus species*, *Streptococcus species*, *Pseudomonas species*, *Enterobacteriaceae*, *Helicobacter species*)
- Mycobacteria (e.g. *M. tuberculosis*, *M. chelonae*, etc.)
- Spores (e.g. *Geobacillus stearothermophilus*, *Geobacillus subtilis*, etc.)
- Fungi (e.g. *Candida species*, *Aspergillus species*, *Trichophyton species*, etc.)
- Parasites (e.g. *cryptosporidium*, etc.)

(Wallace 1995, Malchesky 2000, Larson 1994, Holton 1994, Jackson 1996, Wallace 1995, Bradley 1995, Seballos 1995, Whitbourne 1995, Alfa 1998, Villate 1997, Cronmiller 1999, Foliente 2001, Duc 2001).

When analyzing the killing ability of the SYSTEM 1 process it is important to ensure that the evaluation employed the entire SYSTEM 1 process (i.e., STERIS 20 Sterilant used in the SYSTEM 1 processor). Some studies utilized PA outside of the SYSTEM 1 processor and concluded that SYSTEM 1 could not eradicate certain microorganisms (e.g., Holton tested 0.2% PA as a liquid at 25°C which is not the temperature that PA is used at in the SYSTEM 1 process). Critical assessment of the literature is necessary to ensure the readers are not left with incorrect conclusions about the efficacy of the SYSTEM 1 process.

Currently prions are the most problematic infectious entity in the sterilization of reusable medical devices. No current sterilization or HLD method has been shown to be totally effective in inactivating prions. Limited experimental data suggest that the amount of detectable prion protein on carriers is reduced when exposed repeatedly to the SYSTEM 1 process (Antloga 2000, Chen 1998). However, whether this is due to wash-off or inactivation of the prion protein has not yet been determined because infectivity studies are yet to be done. Current guidelines recommend extended steam sterilization cycles (e.g., pre-vac at 134°C for >18 minutes, or gravity 121°C to 132°C for >1 hour) as the most effective way to sterilize reusable medical devices that are exposed to prions and require reprocessing (Rutala 2001, Spencer, 2002). Indeed, current recommendations are to use disposable medical devices if high-risk procedures are performed on high-risk patients (Rutala 2001). For low-risk procedures and low-risk patients, existing reprocessing methods are recommended.

Impact of Soil on Sterilization Efficacy

Many studies have demonstrated that the microbial killing efficacy of many HLDs and sterilants is detrimentally affected if a soil challenge is present (Alfa 1998, APIC, Rutala 1999). Although all medical devices should be thoroughly cleaned prior to exposure to an HLD or sterilant, the manual cleaning stage is the process that is prone to the highest variability and is often linked to disinfection/sterilization failures that lead to infection transmission (FDA/CDC alert). Indeed this is the basis for the FDA requiring that disinfectant/sterilants have testing performed using “worst-case” conditions of an organic/inorganic challenge without washing. This allows assessment of the impact of organic material on the killing ability of the product and provides a measure of the margin of safety for the process. As indicated by Vesley (1992), residual soil buildup is known to occur in the channels of flexible endoscopes so an organic challenge is needed when studying killing efficacy in such a device. Rutala (1999) also provides information on the chemicals cleared by the FDA with respect to the impact of organic material. Although hydrogen peroxide, peracetic acid, glutaraldehyde, peracetic acid/hydrogen peroxide, and OPA are all listed as having organic material resistance (Rutala 1999), the aldehydes are known to cross-link and fix proteins onto surfaces, whereas oxidizing agents such as hydrogen peroxide and peracetic acid break down protein structure, and when

Reuse of Liquids versus Single-use

combined with fluid flow (as in the SYSTEM 1 processor) will facilitate the process by helping ensure the organic soil is removed from the device surface.

Table 2 indicates that there are currently 20 liquids cleared for use as either HLDs or sterilants for medical and dental device reprocessing. Of these 20 formulations, only two (Sterilox and SYSTEM 1) are single-use formulations and all the others have maximum reuse claims that range from 14 – 30 days. All of the reuse claims require that the minimum effective concentration (MEC) must be evaluated on a regular basis by test strips provided for this purpose. This is due to organic material (from reprocessed patient-use devices) that may inactivate the active ingredient or from the introduction of fluid from the manual wash that may dilute the active ingredient concentration. The issue of reuse for most users pivots around the increased cost associated with single-use formulations. If an HLD can be reused for several weeks it results in a lower per run operating cost. Cronmiller (1999) reported that the per run cost for glutaraldehyde (including manual precleaning) was \$13.30 (1999) and for SYSTEM 1 the per/cycle cost (including manual precleaning) was \$20.30. Rutala (1999) indicates the cost of SYSTEM 1 is \$6.11 vs. \$0.45 per cycle compared to HLDs. No cost figures are available for Sterilox compared to reused formulations. Despite the cost differential for SYSTEM 1 over glutaraldehyde, Cronmiller (1999) indicated that the additional cost was offset by the rapid turn-around time, effective sterilization, and minimization of hazardous chemical exposure to workers. The single-use products are also advantageous in that this approach virtually precludes failure due to exhausted chemistry and ensures a highly reproducible cycle with respect to microbial killing efficacy. If there were no cost differential logic would indicate that a single-use product would be preferred as it is more likely to ensure a reproducible cycle.

TABLE 3

Comparison of characteristics of various disinfectants/sterilants:

Disinfectant/ Sterilant	Exposure time Active ingredient	Total Cycle time	HCW biosafety issues	Environmental issues	Materials incompatibility
PA in SYSTEM 1 (0.2%)	12 minutes	~30 minutes ¹	Low	Low	Aluminum anodized coating (cosmetic) ²
Glutaraldehyde (2%)	20 – 45 minutes	~ 45 minutes ¹	High	High	None
OPA (0.55%)	12 minutes ³	~ 30 minutes ¹	Low	Mod	None
H ₂ O ₂ (7.5%)	20 minutes	~ 30 minutes ¹	N/A	Low	Brass, copper, zinc, nickel/ silver plating
ETO (100%, HCFC & CO ₂ formulations)	1-2 hours	~ 20 hours	High	High	None
Plasma (H ₂ O ₂ gas plasma)	~50 minutes	~52 minutes	Low	Low	Paper, linens and other adsorptive materials

1) The total turn-around time varies dependent on the AER used and whether a “cleaning” cycle is incorporated as part of the AER process. The times indicated assume the HLD is used in an AER.

- 2) There are proprietary builders and buffers used in SYSTEM 1 to reduce corrosive nature of PA for copper, brass, and zinc.
- 3) The OPA cleared exposure times range from 5-10 minutes in other countries.

TABLE 4

D-values for Various Sterilization Methods

Sterilization method	Organism	D-value (min)	Reference
STERIS 20 Sterilant	<i>G. stearothermophilus</i>	.19	Kralovic 1993
	<i>G. subtilis</i>	.05	Malchesky 2000
Steam: 121°C 132°C*	<i>G. stearothermophilus</i>	2.1	Kralovic 1993
		.05 -.07	Block 1991
Ethylene Oxide: (130°C, using paper carriers)	<i>G. stearothermophilus</i>	2.6	Block 1991
	<i>G. subtilis var. niger</i>	2.1 – 5.8	
Plasma			
(H₂O₂ gas plasma: (STERRAD)			
paper carriers	<i>G. stearothermophilus</i>	1.96-2.79	STERRAD manual
non paper carriers	<i>G. stearothermophilus</i>	1.0	STERRAD manual

* D values at higher steam sterilization temperature/pressure are known to be variable due to difficulties in accurately controlling such short exposure times and the effect of residual air on killing ability.

Spore test organism for LCS

Quality assurance for all sterilizers demands the demonstration of proper functioning by testing the process with the most resistant microbial form. This is traditionally achieved by processing a biological indicator (BI) through the sterilizer on a regular basis (each day the sterilizer is used or at least weekly). Currently SYSTEM 1 has a BI that consists of a filter paper strip impregnated with *G. stearothermophilus* spores. These spore strips are the same ones used for monitoring steam and ETO sterilization with the only difference being that in the LCS process they are not used as self-contained spore strips. The spore strip is placed in the SYSTEM 1 chamber using a specific clamp provided by the manufacturer. After processing, the spore strip is removed using the clamp and the strip is aseptically transferred into a tube of broth. The broth containing the processed spore strip is then incubated at the appropriate temperature (60°C for *G. stearothermophilus*) to determine if any viable organisms remain.

Kralovic (1993) evaluated both *G. subtilis* and *G. stearothermophilus* spore strips and demonstrated that although there was some spore wash-off (0.2 – 1.8%) that the commercial BIs evaluated were reproducible and acted as verifiable indicators of the LCS process in the SYSTEM 1 reprocessor. Evaluation of D values for a wide range of spores have confirmed that *G. stearothermophilus* has the highest D value (i.e., is the most resistant to the SYSTEM 1 process) and is the most appropriate spore to use for a BI in the SYSTEM 1 (Kralovic 1993, Malchesky 1994, Malchesky 1999). In-use testing of the SYSTEM 1 by Seballos (1995) did not identify any problems with the use of the *G. stearothermophilus* spore strips as the BI for the SYSTEM 1. However, there have been in-use problems identified that were related to using the incorrect clamp to hold the BI strip (Gurevich 1993). This study emphasizes that the manufacturer recommended clamp must be used otherwise spores may survive the SYSTEM 1 process because they are sequestered under the clamp.

3.3
Efficacy of the
mechanical
process of the
SYSTEM 1 Sterile
Processing System

Bond's editorial (1993) raised questions about the ability of BI spore strips sold for monitoring ETO and steam sterilization to adequately monitor a LCS process. Bond indicated concern regarding the wash-off of spores that Kralovic (1933) reported. Although the wash-off was low and would have minimal impact on the BI's ability to monitor whether adequate killing had occurred in the SYSTEM 1, Bond was more concerned about the spores that had washed off and whether they could potentially contaminate devices in the load. In addition he stated that "...disinfection procedures cannot be monitored biologically...." The concern about wash-off of spores is valid; however, other factors that need to be considered include:

- *G. stearothermophilus* can only grow at >50°C therefore could not cause human infections.
- Those spores that are washed off would be effectively killed by the PA.

Wash-off of spores does not occur in steam, gas, or plasma sterilization. Ideally BIs for liquid chemicals would be improved if a means to prevent the fluid removal from the test strip could be identified.

Since its introduction in 1988, both the basic reprocessing unit and the LCS used have remained unchanged (attesting to the validity of the original design concept), however, there have been a few important improvements in some of the unit's changeable components. These changes include: trays specifically designed to accommodate the new laparoscopic medical devices, and Quick Connect that are designed for use with specific types of channel containing instruments. It is apparent from the literature that one problem associated with errors in reprocessing channel containing devices in the SYSTEM 1 is related to improper connections made between the fluid flow of the SYSTEM 1 and channel-containing devices (FDA/CDC alert 1999, Sorin 1999, Sorin 2001). These errors include: not using a channel adaptor; using an incorrect channel adaptor that provides inadequate fluid flow; connecting the channel connector to the wrong site on the medical instrument; and modifying the manufacturer's channel adaptor.

The problem of inappropriate connection is not unique to the SYSTEM 1, it is also common to all washers and washer/disinfectors that are designed to provide fluid flow to channel-containing devices. To prevent this possible error, tethered Quick Connect kits have been designed that are unique in that they provide validated fluid flow connections for channel-containing devices utilizing connector fittings that are designed to only fit the appropriate connection site. This virtually eliminates any possibility of miss-connection by the user. Furthermore, the flow connections have been designed in a manner that ensures adequate perfusion of all connection sites. An important addition is the attachment of an inert label that provides a checklist of the instruments approved for use with the specific Quick Connect.

From a safety perspective, the mechanics of the SYSTEM 1 processor provide a closed, secure reprocessing system that cannot be accidentally opened until the cycle is completed or purposely stopped. There is complete containment of fumes and chemicals because the inner chamber is sealed once the lid is closed. As indicated by Wallace (1995), the lack of adverse effect to healthcare workers using SYSTEM 1 is a distinct advantage compared to glutaraldehyde

The SYSTEM 1 unit is designed to facilitate ease of installation. It uses regular electric current with no special wiring requirement and can be installed to accept mains hot and cold water. Drainage can go through a regular sink (although an independent drain can be plumbed in if desired). The footprint of the base unit is

Installation
considerations

small and can fit on existing cabinetry. Alternatively, a trolley for the unit can be purchased for ease of positioning.

Maintenance

As with all instrumentation there are maintenance requirements that are important for the SYSTEM 1. The SYSTEM 1 has a diagnostic cycle that should be performed each day of use to ensure that all mechanical components are functioning properly. However, in addition to this process, users should make sure that the tray is dried out at the end of the day to ensure there is no residual fluid that might facilitate microbial growth. In addition, the tray should be lifted up to make certain there is no residual water present in the area underneath. If water is present in this chamber, it should be removed as well. It is important that this check is done daily when the unit is in use, otherwise residual water may facilitate microbial growth that could then lead to biofilm formation. It is well known that any water left standing at room temperature can become contaminated with environmental organisms and these can grow readily in such fluid.

In addition to maintenance for the SYSTEM 1, there are some preventative maintenance steps that are needed for the devices processed in the SYSTEM 1, particularly flexible endoscopes. Some cosmetic damage to the finish on some flexible endoscopes has been attributed to the corrosive nature of PA despite the added builders/buffers and neutral pH of the STERIS 20 Sterilant. Since it is well known that the most effective sterilization methods are harsh (both to the microorganisms and the medical instruments) it seems prudent that preventative maintenance should be undertaken for those instruments that are delicate and expensive (e.g., flexible endoscopes). To minimize the inevitable material damage that occurs over usage for all methods, it might be valuable for sites to have a preventative maintenance program for flexible endoscopes with a six month required inspection even if no usage problems have been identified. This is already the norm for surgical instrumentation – as the functionality is checked each time the instrument is reprocessed and any sharpening, lubrication, etc. is performed. In addition, the instruments should be visually inspected with a magnifying glass in good lighting to ensure there is no corrosive damage. Flexible endoscopes are complex, so a preventative maintenance program with a thorough, regular visual inspection might be useful. In this way it would be possible for the repair service to ensure that any minor corrosive damage is corrected prior to it becoming problematic (e.g., re-epoxy areas that on inspection appear to have deteriorated). This approach would likely be valuable for flexible endoscopes regardless of which HLD or sterilant is used.

Fluid flow/water treatment

Some of the major strengths of the SYSTEM 1 process include:

- the fluid flow path (external surfaces and internal channels);
- the large volume of fluid that the reprocessed device is exposed to per cycle;
- sterile water rinse

SYSTEM 1 uses a series of filters with the final one being 0.2 μm to produce the sterile water used for all stages of the process. This type of filtration provides water of adequate quality for human injection (Malchesky 19993). It is critical that the filtration system is maintained for adequate filtration of water. It should be noted that viral particles that are smaller than the 0.2 μm cutoff will not be filtered out; however this should not be a problem since potable water should be virus-free. Furthermore, if the filters have even minute tears/breaks then adequate filtration will not be achieved. Alfa (1998) has demonstrated that samples (50 mls) of the use-dilution sterilant that

were aseptically withdrawn from the chamber water at ten minutes into the 12 minute sterilization stage of the SYSTEM 1 cycle (taken by aspiration from tubing within the SYSTEM 1 housing using a research model that allowed access to these hoses) did not have any detectable microorganisms. This demonstrated that any washed off organisms (devices had been soiled with 10⁶ cfu of various microorganisms) were adequately killed. Furthermore, if the tap water filtration had not been effective there would have been organisms other than the ones on the test devices detected.

The SYSTEM 1 has a series of mechanical checks that ensures accurate fill times or automatic cycle failure. This provides assurance that when the filters are clogging the unit identifies this as a potential problem so that the filters can be changed. This helps ensure that proper filtration will be achieved. Although tap water can be used as the source for water for the SYSTEM 1, an alternative is to use reverse osmosis water. This ensures a quality of water that will greatly extend the use life of the filters in the SYSTEM 1 processor.

The recent study by Duc (2001) provides an excellent summary that is reflective of the history of use over the past 15 years for the SYSTEM 1. Duc (2001) used GERMADE and ASTM validation protocols to evaluate the SYSTEM 1 for flexible endoscopes and concluded that the SYSTEM 1 was the most effective sterilization process they have tested.

Discussion of In-use Issues Reported in the Literature

As reported by Kirschke et al (2003) and Srinivasan et al (2003), two hospitals experienced large outbreaks of *Pseudomonas aeruginosa* infections (at one site *Serratia marcescens* was also detected) associated with bronchoscopy. The incident was traced to a design change (1997) of Olympus flexible bronchoscopes that involved replacing the biopsy port housing with a new housing featuring a threaded outer cap held in place by a bushing and adhesive. This housing was not supposed to be removable, but unexpectedly the outer cap would loosen during use to the point where it could be removed by simple hand twisting. The investigation reported that fluid and organisms became lodged under the cap within the threads. These organisms could then be carried down the biopsy channel to the distal end when fluid was injected into the biopsy port, or aspirated out into the sample when the suction valve was depressed.

In both sites, the bronchoscopes were reprocessed using OPA in AERs (Medivator and Olympus AER). Despite repeated rounds of cleaning and HLD, the organisms remained sequestered, resulting in multiple exposures in subsequent patient procedures. Even ETO sterilization did not eradicate the sequestered organisms. Once the problem was identified, Olympus initiated a recall on November 30, 2001 for all affected models.

In this instance there were no breaks in the reprocessing protocol for cleaning, HLD, or drying. The problem has been attributed to an endoscope design fault. The two reports (Kirschke 2003, Srinivasan 2003) focus attention on the need for active surveillance to determine when the rate of culture positivity for BAL samples exceeds baseline as well as the need for adequate endoscope traceability regarding which flexible endoscope was used for what procedure on a given patient.

Section 4

4.1 Olympus bronchoscope recall

These reports emphasize that, regardless of the low temperature method used (OPA or ETO), when organisms were sequestered (in the biopsy port housing) there was failure of the disinfection/sterilization phase of flexible endoscope reprocessing. These outbreak descriptions demonstrate how a large number of patients can be exposed in a relatively short period of time before a problem is noticed. For example, in Tennessee over a four month period, 66 procedures were performed on 60 patients and 47% were positive for *P. aeruginosa* (reported as much higher compared to previous rates). At Johns Hopkins there were 414 patients that underwent 665 bronchoscopies (over approximately an eight month period) and 97 had BALs that grew *P. aeruginosa* (31% culture positivity compared to 10% normal baseline rate).

This problem emphasizes the usefulness of a preventative maintenance program for flexible endoscopes. Service technicians should inspect all parts for corrosiveness, loose parts, liquid penetration, etc., and repair any defects before they become major problems. In addition, this approach would have likely reduced the risk to patients in the above two scenarios, as the loose biopsy-port cap should have been identified and corrected if the endoscopes had been inspected by service technicians. This is the first reported infection-transmission problem associated with a flexible endoscope design change. The compressed time period indicates how quickly flexible endoscopes can become “contaminated transmitters” of microorganisms, as Srinivasan (2003) reported that within one month of utilization of the bronchoscopes with the design flaw there was an increase in the percentage of BALs showing *P. aeruginosa* that was above the historical baseline. Similarly, Kirschke (2003) reported that within three procedures where the faulty scopes were used, *P. aeruginosa* in BAL samples were detected. These two reports indicate how quickly organisms can become sequestered, multiply, and lead to infection transmission problems.

4.2 Storage of flexible endoscopes (alcohol rinse and drying)

In 1992, Kaczmarek reported that in a survey of US hospitals, 23% of scopes tested showed large numbers of organisms ($> 10^5$ cfu/ml) growing in the internal channel samples. This finding combined with other studies showing the impact of flexible endoscopes stored with moisture in channels (Alfa 1991) support the recommendation that the channels for flexible endoscopes should be rinsed with alcohol and force-air dried prior to storage (APIC, SGNA). A subsequent survey in Canada has shown that the implementation of the alcohol flush and drying has become relatively widespread as it is used by 97% of hospitals surveyed. However, a study by Alfa (2002) indicated that microbial replication in the biopsy channel still occurred occasionally (7% of 119 samples from 37 different hospitals) and was associated with inadequate drying prior to storage.

It is important to ensure that whatever method is used for HLD/sterilization (i.e., manual or AERs) that scopes are properly dried prior to storage. Alfa (1991) showed that ten minutes of forced air was adequate (even without an alcohol rinse), but current guidelines recommend flushing channels with 70% alcohol followed by forced air drying (APIC 2000, SGNA 2000, Rutala 2000, Alvarado 2000). It should be noted that if flexible endoscopes are reprocessed in an AER using filtered water then alcohol/drying is not needed between each patient use; it is only needed at the end of the day when the scope will be put into storage. However, if the final rinse uses tap water, then alcohol rinsing/drying is needed between each patient use and prior to storage. This is because the alcohol has been shown to be valuable not only to ensure drying, but to facilitate killing of any residual tap water organisms that might remain after the final rinse if tap water is used. Indeed the well planned study by

Cronmiller (1999) reported that without alcohol rinsing *Helicobacter pylori* could not be adequately eradicated by exposure to 2% glutaraldehyde. Although the SYSTEM 1 is a sterilization method and Cronmiller (1999) showed that with or without the alcohol rinse the SYSTEM 1 effectively kills microorganisms, flexible scopes that are processed through the SYSTEM 1 should be alcohol rinsed and force-air dried prior to storage. STERIS recommends reprocessing of flexible endoscopes prior to patient use after storage under non-sterile conditions.

The need to store flexible endoscopes dry is critical in North America because flexible endoscopes are not re-disinfected prior to the next patient-use. Riley (2002) has shown that as long as flexible endoscopes are stored dry, they can be safely used up to one week of storage post-processing. After this they should be re-sterilized/HLD before patient-use.

Recently, there has been development of a novel storage cabinet for flexible endoscopes that ensures reproducible and thorough drying of scopes inside the cabinet (www.lancet.co.uk). In addition to the HEPA filtered air flowing through all channels for a one hour period whenever the scope is connected into the cabinet (timer controlled to automatically shut off), the cabinet is also equipped with UV lights that provide short (five minute) exposure immediately after the cabinet has been opened that is aimed at preventing external microbial contamination of the stored endoscopes. Although there are no published data showing the efficacy of this storage cabinet, the concept of incorporating the drying air into the storage cabinet seems extremely valuable. The impact of UV irradiation on endoscope sheath materials has yet to be reported.

4.3

FDA/CDC Alert

In September 1999, the FDA and CDC circulated a public advisory regarding infections and pseudo-infections that were linked to bronchoscopes and other flexible endoscopes that were inadequately reprocessed by AERs. The objective of this advisory was to inform healthcare facilities that provide flexible endoscopy procedures that patient-used flexible endoscopes must be reprocessed in a manner that ensures they are properly prepared for the next patient contact. The alert indicated that the major problems identified included:

- inconsistencies between the reprocessing instructions provided by the manufacturer of the bronchoscope and the manufacturer of the AER; or
- bronchoscopes were inadequately reprocessed when inappropriate channel connectors were used with the AER.

The main messages from the advisory were:

1. Staff should be properly trained and compliant with proper cleaning protocols for flexible endoscopes.
2. Ensure with both the endoscope manufacturer and the AER manufacturer that the specific flexible scopes used are compatible with the AER. In particular, issues related to manual reprocessing of the elevator wires of some scopes that cannot be properly reprocessed by the AER was emphasized.
3. Ensure there are no conflicts in the reprocessing instructions provided by the flexible endoscope manufacturer and the AER manufacturer.
4. If a particular model of endoscope has no instructions for reprocessing in an AER, it should be manually reprocessed following the chemical germicide manufacturer's instructions.

5. Reprocessed endoscopes should be stored in a manner that minimizes moisture and/or likelihood of contamination. There are studies that have demonstrated that a final drying step that includes flushing all channels with alcohol followed by purging the channels with air (to remove the alcohol) greatly reduces the possibility of recontamination of the endoscope by water-borne microorganisms.
6. Ensure staff compliance with the facilities reprocessing instructions.
7. Provide adequate training that includes documented ongoing competency of all endoscope models and AERs used in the facility.
8. Implement a comprehensive quality control program.

When reported problems with infection or pseudo-infection transmission by flexible endoscopes were investigated, it was often revealed that there were problems with staff compliance during the cleaning process or that there was inappropriate connection of the flexible endoscope to the AER thereby not allowing adequate channel perfusion. These have been ongoing problems for a number of years for almost all types of flexible endoscopes, AERs (e.g., SYSTEM 1, Medivator, and Olympus AERs), and LCS formulations (e.g., PA, glutaraldehyde and OPA).

As suggested by Cowen (1999), high level disinfection for flexible endoscopes has a narrow margin of safety and whenever there are slight transgressions (e.g., inadequate manual cleaning), this is sufficient to cause problems. This is unlike steam sterilization where there is a large margin of safety. Indeed when the history of infection transmission is reviewed, flexible endoscopes are the devices that have had the most problems reported in the peer-reviewed literature. Bronchoscopes are the most problematic flexible endoscopes in infection transmission. This is likely because of the body site (lungs) that the endoscope enters, and the fact that many bronchoscopic procedures are performed to help with diagnosis of potential infectious problems in the lungs. Also, sampling involves flushing fluid down the biopsy channel with a high degree of exposure to the entire length of the inner channel to patient secretions and organisms. In GI endoscopic procedures the samples are usually obtained by taking biopsies. A biopsy pulled through the biopsy channel would likely result in less “soiling” of the inner channel than a 50 ml fluid sample being instilled then aspirated up the suction channel of a bronchoscope.

The single most important take-home message from the CDC/FDA advisory is that significant infection transmission problems can occur in bronchoscopy procedures if staff are not competently trained or do not stringently comply with current guidelines on a continued basis.

Section 5

Summary

In this report, the SYSTEM 1 Sterile Processing System has been systematically compared to low temperature HLD, gas, and plasma methods currently used for reprocessing reusable medical devices. Steam and ETO are both considered benchmark sterilization methods that have been extensively studied. There is no single ideal sterilization method as each has strengths and weaknesses.

Kaczmarek showed that buildup is visibly detectable inside flexible endoscope channels that are cut open. Lewis (1999) showed that SYSTEM 1 could remove much of this buildup as demonstrated when the channels were cut open for visual inspection. The value of the oxidizing chemistry of the SYSTEM 1 process at removing

glutaraldehyde-fixed protein material from the inner surface of endoscope channels has been demonstrated by Tucker (1996) using surface chemistry analysis of patient-used flexible endoscopes. Furthermore, Alfa (2002) showed that buildup of soil was greater in scopes processed in centers using glutaraldehyde compared to SYSTEM 1.

The SYSTEM 1 process can be used for both rigid and flexible endoscopes and accessory devices. The data indicate that for flexible endoscopes (these are the most difficult to clean adequately) the SYSTEM 1 process is an optimal fit compared to other available low temperature methods (e.g. glutaraldehyde, OPA, plasma, and ETO). The chemistry facilitates rather than frustrates the process (Lewis 1999).

SYSTEM 1, using PA, has the longest record of current FDA-cleared LCS formulations and has been shown to be effective when used according to the manufacturer's recommendations. Indeed the recent study by Duc (2001) provides an excellent summary that is reflective of the history of use over the past 15 years for SYSTEM 1. Duc (2001) used GERMADE and ASTM validation protocols to evaluate SYSTEM 1 for flexible endoscopes and concluded it was the most effective they have tested.

All the data and reports reviewed over the past 15 years for the SYSTEM 1 process indicate that although some areas of controversy remain (e.g., lack of sterile storage, BIs, corrosiveness of PA) the overwhelming evidence indicates that SYSTEM 1 is a proven process that is widely accepted in both the healthcare community and by guidance setting groups (e.g., guidance documents). As indicted by Rutala (1996, 1999), there is no one ideal HLD/sterilant. However, of the LCS formulations used for sterilization of medical devices, the use of PA in SYSTEM 1 is certainly the most widely researched and has the most demonstrable record.

Appendix: Reference list

References using the SYSTEM 1 Process have been identified with shading in the “year” column. Non-shaded references show important related aspects although SYSTEM 1 was not included in the study.

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