Biofilm is a collection of microorganisms surrounded by the slime they secrete, attached to either an inert or a living surface. A simple illustration might be gelatin fruit salad with the individual pieces of fruit suspended in gelatin, which is allowed to dry and harden. Some familiar examples of biofilm include the plaque on teeth, the slippery slime on river stones and the gel-like film on the inside of a vase which held flowers for a week. Biofilm is the cosmopolite of the bacterial world, comfortable in any setting, existing wherever surfaces contact water.

More than 99 percent of all bacteria live in biofilm communities. Some are beneficial: the organisms lining a healthy intestine prevent damage from pathogenic toxins; the organisms of the female genito-urinary tract create an acidic environment which is noxious to pathogens. Other types of biofilm are harmful, harboring microorganisms which may cause chronic infection or perhaps lead to rejection of medical implants.

In industry, sewage treatment plants rely on biofilm to remove contaminants from water; but biofilm can also cause problems by corroding pipes and clogging water filters.

Pop Quiz:
What percent of bacteria live in biofilm?
99%
Give one example of a beneficial biofilm.
The organisms lining a healthy intestine; the organisms of a female genito-urinary tract
Where does biofilm exist?
Biofilm exists wherever a surface contacts water.
Biofilm Formation

Sidebar
One study detected biofilm on contact lenses removed from patients with microbial keratitis whose lens storage cases were treated with disinfectants such as hydrogen peroxide and chlorine release systems according to the manufacturer's instructions.

A biofilm is a microbially derived sessile community characterized by cells that are irreversibly attached to a substratum or interface or to each other. They are embedded in a matrix of extracellular polymeric substances which they have produced. Finally, they exhibit an altered phenotype with respect to growth rate and gene transcription.

Biofilm has been described in many systems since Van Leeuwenhoek examined the plaque on his own teeth in the seventeenth century and found “animalcules”. Leeuwenhoek's skill at grinding lenses, together with his naturally acute eyesight and great care in adjusting the lighting where he worked, enabled him to build microscopes that magnified objects over 200 times, with clearer and brighter images than any of his colleagues could achieve. Looking at the samples from his mouth with his microscope, Leeuwenhoek reported: "I then most always saw, with great wonder, that in the said matter there were many very little living animalcules, very prettily a-moving". In 1683, his were among the first observations on living bacteria ever recorded.

For many years, microbiologists studied microbial cells only in their planktonic state. These observations were usually made on agar plates, where colonies of bacteria were grown and tested for antibiotic sensitivity. Aggregations of these microbes were observed long before there was a method to study them. In the late 1980’s, the confocal scanning laser microscope allowed these aggregations, known as biofilm, to be evaluated in a natural hydrated three dimensional state.

Direct microscopic observations demonstrate unequivocally that more than 99.9% of bacteria grow as aggregated sessile communities (biofilm) attached to surfaces, rather than as free floating cells in liquid. Biofilm bacteria living in highly protected and cooperative communities are genetically different and profoundly resistant to therapeutic doses of antibiotics. Bacteria form biofilm preferentially in very high shear environments where fluid moves rapidly over a surface. Planktonic bacteria can adhere to surfaces and initiate biofilm formation in the presence of shear forces of nature that dwarfs those of heart valves.

Once a biofilm has formed and the exopolysaccharide matrix has been secreted by the sessile cells, the resultant structure is highly viscoelastic and behaves in a rubbery manner. When biofilm is formed in high shear environments it is
remarkably strong and resistant to mechanical breakage. When biofilm is formed in low-shear environments, such as an endoscope, it has a lower tensile strength and breaks off easily.

The environments suitable for microorganisms to colonize and establish biofilm are practically limitless. The nature of biofilm structure and the physiological attributes of biofilm organisms confer an inherent resistance to antimicrobial agents, whether these antimicrobial agents are antibiotics, disinfectants or germicides. Microbes within biofilm can be resistant to disinfectants by multiple mechanisms, including physical characteristics of older biofilm, genotypic variation of the bacteria, microbial production of neutralizing enzymes and physiologic gradients within the biofilm (e.g. pH). Bacteria within biofilm are up to 1,000 times more resistant to antimicrobials than are the same bacteria in suspension.

*Pseudomonas aeruginosa*, a bacterium frequently implicated in health-care acquired infections, is a common ‘pioneer’ bacterium and is used in a lot of biofilm research. In one experiment, researchers found that *Pseudomonas* cells adhere to stainless steel, even to electropolished surfaces, within 30 seconds of exposure. The instant the bacteria attach to a surface, they switch on certain genes involved in the synthesis of *alginate* (an unusually sticky form of slime), and switching them off again once the bacteria are engulfed in alginate.

**Pop Quiz**

**How is most bacteria studied?**
Most bacteria are studied in the planktonic state on agar plates.

**How are Biofilm resistant to disinfectants?**
Biofilm are resistant to disinfectants by multiple mechanisms including physical characteristics, genotype variations, neutralizing enzymes or gradients within the biofilm such as pH.
Biofilm in the Human Body

Sidebar

Legionnaire’s disease got its name because of a pneumonia infection that was contracted by large numbers of people attending an American Legion convention in 1976. The type of bacteria was called Legionella. It is now known that the infections were caused by biofilm in the water of the Convention Center’s air conditioning system.

The National Institutes of Health estimates that more than 80% of microbial infections in the human body are caused by biofilm, many of them creating chronic and reoccurring problems. Infections from biofilm are extremely difficult to treat. An important attribute of a biofilm is its ability to harbor and protect the organisms within it making them resistant to most antibiotics. The following illustration demonstrates just a few of the many ways biofilm may have an effect on our bodies.

© 2003, Center for Biofilm Engineering, Montana State University, P. Dirckx

Photo from Center for Biofilm Engineering, Montana State University, P. Dirckx. Used with permission.
Dental plaque may lead to mouth infections, periodontal disease, gingivitis and dental decay. Oral bacteria which enter the bloodstream can affect the heart, attaching to fatty plaques in the coronary arteries. The inflammation caused by periodontal disease increases plaque buildup, which may contribute to swelling of the arteries. Researchers have found that people with periodontal disease are almost twice as likely to suffer from coronary artery disease as those without periodontal disease.

Primary infections may also occur in the presence of intravenous catheters, urinary catheters and implantable devices. Secondary infections from a biofilm source may affect the brain, kidneys, joints and intervertebral spaces.

In cystic fibrosis, excess mucus production in the airways hosts bacteria such as Pseudomonas aeruginosa, which mop up dead white blood cells from the immune system, enabling them to construct their protective biofilm coat.

Biofilm is involved in the heart condition, endocarditis, a rare but serious disease in which one of the four heart valves, the heart lining, or heart muscle are infected by bacteria, usually comprising streptococci, and become inflamed. The formation of the endocarditic plaque is unique, involving bacteria, platelets, coagulation factors and leucocytes, and is considered a rather special kind of biofilm. Since the biofilm is resistant to antibiotics and the immune system’s white blood cells, often the only option is surgery to replace a damaged valve. Greater knowledge may allow new drugs to be developed that break up the biofilm.

Chronic ear infections and tonsillitis in children have been linked to biofilm formation as the causative agent. Other chronic biofilm infections include prostatitis, Legionnaire’s disease and peritonitis.

**Pop Quiz**

**What problems can develop from dental plaque?**
Mouth infections, such as gingivitis and dental decay may lead to cardiac disease and vascular inflammation.

**What lung disease is complicated by a biofilm in the trachea?**
Cystic Fibrosis
Biofilm in Flexible Endoscopes

Sidebar
There has not been a comprehensive study of patient to patient infections since 1992. The incidence of infection at that time was 1 in 1.8 million procedures. As we are currently doing more than 20 million procedures annually, it is difficult to calculate the actual risk but it is assumed to be quite low.

A new endoscope does not contain biofilm but shortly after the first use, a conditioning film is created on the biomaterials of the endoscope. The film is composed of the bodily fluids proteins, polysaccharides and other components. This alteration of the surface characteristic allows bacteria to commence growth and colonization.

Using proper procedures, this initial biofilm should be removed with manual pre-cleaning, brushing accessible channels, followed by high level disinfection and thorough drying. The drying step must take place between cases as well as at the end of the day. If the biofilm is not completely removed, it will continue to grow and develop through repeated cycles of use and cleaning. Research has shown that under minimal growth conditions, 67% of adherent Pseudomonas aeruginosa strains remain metabolically active.

Natural biofilm forms on a surface continually bathed in fluid and exposed to microorganisms. The development of biofilm in endoscopes is thought to be associated with residual moisture left in channels that provide a medium for opportunistic pathogens originating from water sources. The gradual build up of material over repeated uses in reprocessed endoscopes forms with cyclical exposure to high level of microbes. Each procedure-reprocessing cycle involves scope exposure to hydrated phases as well as drying phases. These repeated cycles over time may facilitate biofilm formation consisting of layers of dried organic material with embedded microorganisms.

It is important to recognize and appreciate that flexible endoscopes are reportedly associated with more documented cases of healthcare-acquired infections than any other type of reusable medical device (Muscarella, 2006). Despite these findings, there have been no subsequent published reports directly linking an endoscope which has been reprocessed appropriately according to the current guidelines and not defective in design, to transmission of an infectious agent. Most published studies and reports relate to outbreaks, defective instruments or observed breaches in the reprocessing procedure. This fact alone should make us acutely aware that reprocessing an endoscope requires meticulous compliance with the standards of infection control as well as the specific reprocessing steps for each endoscope. It is essential to understand the
capability of each automated reprocessor as it relates to the scopes and accessories that it will reprocess.

**Pop Quiz**

**What important step in reprocessing will help to prevent biofilm formation?**

Drying each scope after each procedure will help to prevent biofilm formation.

**What reusable medical device is associated with the most healthcare acquired infections?**

Flexible endoscopes.
Bronchoscopes and Duodenoscopes

**Side Bar**
A pseudo-infection occurs when a medical device is contaminated and specimens obtained using that device culture out a microorganism that is then attributed to the patient, even though the patient is not colonized or infected with the organism.

Bronchoscopes and duodenoscopes account for the highest number of reported endoscopic infections. Bronchoscopy is currently the most commonly employed invasive procedure in the practice of pulmonary medicine and accounts for most reported infections overall. Because they have long narrow lumens, cross connections, springs, valves, occluded dead ends and may have rough or pitted surfaces, bronchoscopes present a challenge for low-temperature sterilization or high level disinfection. Failure to follow disinfection recommendations have led to multiple outbreaks. The pathogen frequently associated with these outbreaks is Mycobacterium tuberculosis. Pseudo-outbreaks involving bronchoscopes most commonly involve water-derived environmental microbes such as Legionella and Pseudomonas aeruginosa.

In gastrointestinal endoscopy, ERCP (endoscopic retrograde cholangiopancreatography) is reportedly associated with the highest risk of infectious complications. During ERCP, the patient is at greater risk of infection because of manipulation of the bile and pancreatic ducts during diagnostic and therapeutic procedures.

A recent journal article (Aumeran 2010) reported a multi-drug resistant Klebsiella pneumoniae outbreak after ERCP in Germany. Sixteen patients were identified over a nine-month period. The microorganism was isolated only from patients who had undergone ERCP. Environmental investigations to determine the cause found no contamination of the washer disinfectors or the endoscopy rooms. Routine surveillance cultures of the endoscopes were repeatedly negative during the outbreak, but the epidemic strain was finally isolated from one duodenoscope after *brushing* the channels to find the offending organism. Practice audits in that facility revealed that manual cleaning and drying processes were not in compliance with the existing policies. Staff education and strict adherence to existing reprocessing guidelines ended the outbreak. The article suggests that regular audits to ensure rigorous application of cleaning, high-level disinfection and drying steps are crucial to avoid this type of contamination.

In an article related to the study, the author (Muscarella 2010) acknowledges that these infections are most often associated with Gram-negative bacilli, particularly Klebsiella pneumoniae, Salmonella and Pseudomonas aeruginosa. All these are opportunistic non-spore forming bacteria that may be enteric or
environmental. The study also demonstrates the significant limitations of microbiological culturing or surveillance sampling of an endoscope to monitor reprocessing effectiveness. False negative results are not an assurance of a “sterile” scope. Their study underscores the importance of drying the duodenoscope, including the exposed elevator wire channel, after each and every use and before storage.

Pop Quiz:

**What makes endoscopes a receptive environment for biofilm?**
Any retained moisture in the endoscope will facilitate biofilm formation.

**What type of endoscope accounts for most of the health care acquired infections?**
Bronchoscope
Eliminating Biofilm

Sidebar
Research in water systems has demonstrated that biofilm associated bacteria may be 150-3000 times more resistant to free chlorine and 2-100 times more resistant to monochloramine than free-floating bacteria. Removal of biofilm from industrial surfaces has long been known as a difficult task requiring the use of heavy chemical detergents in conjunction with mechanical devices.

In order to destroy the cells responsible for forming the biofilm, the chemical or disinfectant must first react with the surrounding polysaccharide network. The cells themselves are not actually more resistant; rather they have surrounded themselves with a protective shield making it more difficult for the disinfectant to reach the bacteria cells in a biofilm compared to free-floating organisms. Incomplete removal of the biofilm will allow it to quickly return to its equilibrium state, causing a rebound in biofilm growth following disinfection. As previously mentioned, endoscopes represent the medical device most often linked to outbreaks and pseudo-outbreaks. Inadequate decontamination practices are the leading cause of this scope contamination, but defective scopes and automated reprocessor malfunction have also been implicated in outbreaks.

Current guidelines for endoscope disinfection, based on general infection control principles, have been developed, promulgated and published by many organizations. However there is currently no method to determine the efficacy of these regimes on a routine basis. Failure to completely clean and dry an endoscope using the current guidelines may lead to biofilm formation and is an important factor in the pathogenesis of endoscopy-related infections. It is acknowledged that the existing reprocessing methods, properly and carefully conducted, can and do produce acceptable quality instruments, but the processes are significantly dependent upon the training and diligence of the person performing the task. Studies suggest that human error is a major issue. Rapid turnover of equipment, inadequate training, failure to completely dry the instrument and lack of quality control may contribute to failure of the process (Muscarella 2006).

Biofilm formation within endoscope channels can result in failure of disinfection procedures and can create a vicious cycle of growth, disinfection, partial killing or inhibition and regrowth. Patients who undergo endoscopy with a biofilm-containing endoscope are at risk for an endoscopy related infection. Removal of biofilm from the internal surfaces of small diameter tubing within endoscopes presents a far more difficult challenge, due to poor access as well as the
chemical sensitivity of the many surfaces within these complex instruments. Research has shown that biofilm can retain pathogens in a vegetative state after being cleaned and disinfected by present methods.

**Pop Quiz**

What is the leading cause of scope contamination? 
Inadequate scope reprocessing is the leading cause of scope contamination.

What issues may interfere with proper scope reprocessing? 
Inadequate training, pressure for rapid turnover of equipment and failure to dry the scope may contribute to inadequate scope reprocessing.
Effective Disinfectant Agents

Many factors influence the choice of disinfectant: cost, environmental concerns and user hazards. Multiple use disinfectants require assessment for minimal effective concentration with test strips before each use. The end user should consider elimination of biofilm in the purchase decision; oxidizing products seem to perform better in the presence of biofilm. There are many high level disinfectants approved by the FDA; a current list can be found at www.fda.gov. The actions of two of the most commonly-used high level disinfectants are described in the following sections.

Glutaraldehyde

Glutaraldehyde, a saturated dialdehyde, has historically been the most widely used chemical for the high level disinfection of endoscopes. Most aqueous solutions of glutaraldehyde are acidic and must be activated (made alkaline to pH 7.5-8.5) in order to become sporicidal. The biocidal activity of glutaraldehyde is a consequence of its alkylation of sulfydryl, hydroxyl, carboxyl and amino groups, which alters RNA, DNA and protein synthesis within microorganisms. Glutaraldehyde has excellent biocidal activity, is active in the presence of organic matter and is non-corrosive to metals, rubbers and plastics (Rutala 1996). Glutaraldehyde may be used in manual or automated reprocessing protocols. Olympus, Pentax and Fujinon list glutaraldehyde as compatible with their endoscopes. Glutaraldehyde is compatible with most automated reprocessors. Glutaraldehyde can be reused for up to 14 days but must be checked frequently to maintain minimum effective concentration. Glutaraldehyde acts as a fixative and because of that, it may promote biofilm formation.

Glutaraldehyde is harmful if inhaled or swallowed and irritating to eyes and respiratory tract. It can also cause severe damage to the skin and eyes.

Peracetic Acid

Peracetic acid (PAA) is considered to be an effective oxidizing agent for the disinfection of flexible endoscopes. Peracetic acid is a highly biocidal oxidizer that maintains its efficacy in the presence of organic soil. Peracetic acid removes surface contaminants (primarily protein) on endoscopic tubing. Peracetic acid denatures proteins, disrupts cell wall permeability and oxidizes sulfhydryl and sulfur bonds in proteins, enzymes and other metabolites.

Although the biocidal effect of peracetic acid on sessile micro-organisms is well known, the effect of this disinfecting agent on microbial biofilm is not completely understood. According to the literature, Peracetic acid has the ability to fix a
biofilm and blood on artificial materials and had a limited efficacy in biofilm removal from silicone tubing in hemodialysis systems (Kovaleva 2010). One percent PAA-based disinfectant, recommended for disinfection of flexible endoscopes by the manufacturer, was effective against bacteria and yeasts in the planktonic and biofilm state immediately after treatment, but allowed regrowth of all biofilm if the drying procedure was skipped. The potential for microbial growth inside endoscope channels after disinfection mainly depends on the conditions within the endoscope channels during drying and storage.

Peracetic acid is very hazardous in case of skin or eye contact. It is slightly hazardous in case of inhalation (lung sensitizer). Inflammation of the eye is characterized by redness, watering, and itching. Skin inflammation is characterized by itching, scaling, reddening, or, occasionally, blistering.

Traditional disinfectant testing for these products has been done with single species free-floating laboratory cultures. In this process, the CT constant for a disinfectant is the product of (concentration) x (time) required to kill a particular bacteria. Test results show that the efficacy of a disinfectant must be measured by using a laboratory method where biofilm is grown under fluid flow conditions similar to the environment where the disinfectant will be applied (Buckingham-Meyer 2007). Since biocidal test data currently do not evaluate biocidal performance when pathogenic organisms are located in sessile state within a biofilm, current CT values should not be extrapolated to bacteria in biofilm.

**Pop Quiz**

**What is the best way to be certain the endoscopes are reprocessed correctly?**
Regular audits are the best way to ensure rigorous application of cleaning, high-level disinfection, and drying steps.

**What is the concentration/time for a disinfectant?**
The C/T (constant X time) represents the time required to kill bacteria and should not be extrapolated to bacteria in biofilm.
Studies and Literature Findings

Sidebar
There are no published clinical reports that directly link increased risk of infection transmission for flexible endoscopes that are reprocessed with glutaraldehyde. (Alfa and Howie 2010)

A review of the literature reveals the growing concern over biofilm. These studies illustrate a new concept on biofilm formation in endoscopes and also the apparent realization of the existence of biofilm in used scope channels.

A study by Alfa and Howie (2010) found that little is known regarding the progressive buildup of residual patient material and organisms within the channels of reprocessed flexible endoscopes throughout the life of the device. The gradual build up of material over repeated use in reprocessed flexible endoscopes forms by a very different kinetic background than other types of biofilm. The initial stages of formation, surface conditioning from patient secretions, microbial attachment, growth and colonization, are similar to natural biofilm buildup. However, medical devices such as gastrointestinal endoscopes are used repeatedly during a day, with cyclic exposure to high levels of microbes, due to contact with the mucosal surface of the gut. In addition, each procedure-reprocessing cycle involves scope exposure to hydrated phases, post patient cleaning and disinfection, as well as drying phases between procedures and during storage.

The data in the study showed that the combination of an organic matrix and aldehyde (fixative) disinfection quickly produced a protective buildup biofilm that facilitated high levels of organism survival. A key finding was that once established, the microbial load of buildup biofilm formed by glutaraldehyde exposure had a faster rate of accumulation than in natural biofilm formation. However, if an oxidizing agent such as peracetic acid or AHP (accelerated hydrogen peroxide: similar to peracetic acid) was used for disinfection and if organic levels were kept low, organism survival did not occur.

If initial biofilm is not removed, repeated instrument use can facilitate a buildup biofilm formation over time, consisting of layers of dried organic material with embedded microorganisms. Data suggests that deep within the biofilm structure, organisms are protected from the disinfectant challenge, particularly from glutaraldehyde. This supports current concerns regarding the exposure of low concentrations or activities of biocides to organisms embedded within biofilm and the selection of tolerant bacteria.

The results of the buildup biofilm models in this study indicate that high level disinfection is effective at killing bioburden within young biofilm but not within a
mature biofilm. It also highlights the value of studying biofilm formation in reprocessed scopes over extended periods of time. The buildup biofilm model demonstrated for the first time that although a longer time was needed for organisms to be detected within the buildup biofilm, outgrowth of surviving bioburden in buildup biofilm was faster and the ultimate level achieved was greater. These data provide a possible explanation for published reports describing the persistence of residual levels of organisms in scope channels even when proper reprocessing is followed.

These experimental results revealed that buildup biofilm formation reduced the efficacy of microbial killing by the high level disinfectants in the study, glutaraldehyde and accelerated hydrogen peroxide (AHP), although AHP had a superior ability to reduce bacterial loads. The findings suggest that biofilm is difficult to eliminate during endoscopic reprocessing. They also stress the importance of reducing bioburden during pre-cleaning and the imperative to maintain a contaminant-free, dry scope during storage.

In an Australian study (Pajkos 2004), the channels of thirteen endoscopes were examined endoscope. Biofilm was present on the suction/biopsy channels of five scopes. Biofilm was also present on the air/water channels of twelve scopes, with the level of contamination determined to be extensive on nine of those. Because the smaller endoscope channels (air/water) cannot be brushed but must rely on flushing with detergent and water to remove bioburden, it does not seem unreasonable that they would be more likely to have a biofilm. A better method to remove bioburden from these channels, either with more effective detergents or through changes in scope design and channel accessibility, would help to eliminate this risk factor.

Currently, there is no efficient method to determine whether an endoscope channel is free of soil prior to disinfection. Emergent approaches (e.g., detection of adenosine triphosphate [ATP]) to evaluate the effectiveness of endoscope cleaning or endoscope reprocessing have been evaluated, but no method has been established as a standard for assessing the outcome of endoscope reprocessing. A number of companies have produced testing strips, swabs and brushes that can detect residual bioburden (ATP) but these tests are expensive, time consuming and cannot check channels that cannot be brushed. Staff must rely on brushing some channels but only flushing others. Seeing clear rinse water after cleaning is the only indicator that a channel is clean. The presence of any bioburden will compromise the disinfection/sterilization process and may result in an inadequately decontaminated instrument that could pose a potential risk of health-care acquired infection.
At the present time, routine scope cultures are not recommended, according to the **Multi-Society Guidelines** (Society for Healthcare Epidemiology of America, 2003). Except in the case of an outbreak, the results of routine cultures have been inconsistent, with both false positive and false negative results. Ongoing research will continue to provide insights and concerns in our quest to provide the optimum process for scope care.

**Pop Quiz**

As suggested in the buildup biofilm model, what may be facilitated by reprocessing cycles?
- Biofilm formation.

What type of biofilm can be eliminated by high level disinfection?
- High level disinfection can eliminate a new or young biofilm.

What high level disinfectant tends to support biofilm formation?
- Glutaraldehyde

How can one determine that an endoscope channel is clean prior to high level disinfection?
- At the present time there is no absolute way to determine channel cleaning. Strict adherence to reprocessing guidelines will provide the best outcome.
Photographic Documentation of Endoscopic Biofilm

In an experiment to determine the effectiveness of scope cleaning procedures, Dr. David Lewis, Visiting Scientist, Department of Marine Sciences, University of Georgia, conducted an experiment in which he replicated the high pressure environment of a colon during a colonoscopy by placing the tip of an endoscope contaminated with a florescent biofilm into a balloon and inflating the balloon. He grew the biofilm from water in a brook and added florescence so that the biofilm would be more visible in photographs. The scope was then manually cleaned and disinfected with glutaraldehyde and peracetic acid. As a final step, the air water nozzle was removed to check the air water channel for any residual biofilm. The following photos clearly illustrate the challenge presented by biofilm.

Figure 1. This photo shows the distal tip of the colonoscope contaminated with the biofilm mixture. The fluorescence permits better visualization of the biofilm.
Figure 2. This photo shows the scope tip after manual cleaning. Note the remaining biofilm.

Figure 3. This photo is the distal tip of the colonoscope after 10 minutes in peracetic acid. Most biofilm has been eliminated from the tip.
**Figure 4.** This photo shows the distal tip of the colonoscope after Cidex and alcohol. Clearly, biofilm remains.

**Figure 5.** Brushing of the colonoscope air/water channel after removal of air water nozzle reveals biofilm debris remaining in the channel. The increased
pressure of the balloon shows how bioburden from the patient can backfill the channels. In the case of the air/water and auxiliary water channel, the inability to access the channel with a brush make mechanical cleaning impossible and removal of bioburden and biofilm more difficult.
Ensuring Patient Safety

Sidebar
Recognizing the importance of infection control in GI endoscopy, the Society of Gastroenterology Nurses and Associates has created a resource center at http://infectioncontrol.sgna.org/. The website provides a central location for SGNA infection control resources and information, in order to help GI units and facilities determine processes and answer questions.

The responsibility for effective endoscope care and reprocessing is universal, shared by physicians, nurses and assistive personnel. A unit which adheres to best practices of endoscope disinfection, including policies and procedures, training, resources and a quality improvement program will ensure that every scope is patient ready.

The Society of Gastrointestinal Nurses and Associates states that infection control education is a critical part of the orientation and continuing education for all personnel who work in the gastrointestinal endoscopy unit.

Orientation topics should include:
1. Standard precautions
2. Personal protective equipment
3. OSHA rules on occupational exposure to blood-borne pathogens
4. Reprocessing procedures for endoscopes and accessory equipment
5. Mechanisms of disease transmission
6. Maintenance of a safe work environment
7. Safe handling of high level disinfectants (HLD) and sterilants
8. Procedures for waste management

Initial orientation and ongoing competency training is mandatory for each staff member who handles scopes. A nurse or lead tech that is responsible for scope repairs and reprocessing will help to ensure compliance. Education resources are readily available: established guidelines and teaching aids for scope reprocessing can be obtained through professional organizations such as the Society of Gastrointestinal Nurses and Associates (SGNA) and the Association of peri-Operative Nurses (AORN); in-service training can be obtained from representatives of scope manufacturers.

Each supervisor must remain current on infection control guidelines and manufacturer’s recommendations and be able to identify problems and lapses in technique. An observant manager can gain valuable insight by observing scope storage areas:
- Are the scopes hung vertically without obstruction?
- Is the cabinet bottom stained with fluids from an improperly processed scope or un-rinsed chemical?
- Is there a tell-tale odor?

Nurses and physicians should be trained to check each scope before use to be sure it is patient ready. This inspection should include making sure that air/water channels are clear and functioning. In addition, water should be suctioned through the biopsy channel, the angulations should be checked. Post procedure, immediate care of the scope is the best prevention of biofilm formation. After wiping the insertion tube to remove bioburden, the suction/biopsy channel should be immediately flushed with detergent and water; the air/water and auxiliary water (or ERCP elevator channel) should be flushed until clear. The scope should be promptly brought to reprocessing area for leak testing and reprocessing.

The original equipment manufacturer will provide the most accurate information for reprocessing the instrument. Each automated reprocessor must be validated to be able to reprocess and disinfect each scope and accessory in your inventory. As new scopes are added to inventory, training should be commensurate with their introduction to the unit. Automated reprocessors may be implicated in the transmission and creation of biofilm. They, too, can become contaminated with a biofilm and transmit organisms back to reprocessed instruments. Water filters can also become contaminated with biofilm.

Before purchasing a reprocessor, decision-makers should do their homework on available features. The Society of Gastrointestinal Nurses and Associates recommends that:

1. The machine should circulate fluids through all endoscope channels at an equal pressure without trapping air.
2. The reprocessor should be capable of disinfecting all channels of each scope, especially the small lumen of the ERCP elevator channel. Channel flow sensors provide an added measure of compliance.
3. Automated reprocessors must be validated to reprocess valves, tubings and accessories.
4. The detergent and disinfectant cycles should be followed by thorough rinse cycles and forced air to remove all used solutions.
5. The disinfectant should not be diluted with any fluids.
6. The machine should be self-disinfecting.
7. No residual water should remain in hoses and reservoirs.
8. Cycles for alcohol flushing and forced air drying are desirable.
9. The machine should feature a self-contained or external water filtration system.
10. A method to automatically store or print data verification of cycle completion is desirable.
Pop Quiz

**Whose responsibility is proper endoscope care?**
Everyone involved should take responsibility to take proper care of these valuable instruments. Observe, report, and correct any lapses in protocol.

**How often should training take place?**
There should be a thorough initial training followed by annual competency. There should be additional training each time a new instrument or piece of reprocessing equipment is brought into the unit.

**What are the steps in immediate post procedure scope care?**
Wipe the scope to remove bioburden from the insertion tube. Immediately flush the suction/biopsy channel with detergent and water and flush the air/water and auxiliary water (or ERCP elevator channel) till clear.
Conclusion

Every patient is entitled to a perfectly clean, pathogen free endoscope. Health care providers have the responsibility to ensure the best care and equipment possible for each and every patient. This can be done by using appropriate agents, following recommended disinfecting procedures and by ensuring thorough drying between procedures and before storage.

The emergence of biofilm as a factor in endoscope decontamination has altered policies and procedures for many practitioners. Researchers and health care providers are only beginning to recognize the importance of biofilm in the total picture of infection control and especially as it relates to health-care acquired infections from endoscopes. As more information about biofilm is revealed, it can be anticipated that manufacturers will reevaluate scope design in order to facilitate biofilm removal. It is also anticipated that reprocessing chemicals will be developed that will better attack and remove biofilm, thus ensuring the clean, pathogen free scope.