Biofilm and instrument reprocessing

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✓ Endoscope related infections

✓ Fundamentals of biofilms
  - Biofilm basics
  - Biofilm and endoscopes

✓ Proper high-level disinfection of endoscopes
  - Cleaning is a prerequisite for effective high-level disinfection
  - High-level disinfection
Endoscopy Evolution

1805-1932  Rigid

1932       Semi-flexible

1952       Flexible

1983       Flexible fiberoptic (video)

2001       Capsule endoscopy

Light source
Lenses
Tube (rigid, flexible, capsule)
Complex design and multiple internal channels inside a flexible endoscope

Complex design and multiple internal channels inside a flexible endoscope
Variety of endoscopes and endoscope models

900 bed healthcare system: 159 endoscopes

- Bronchoscope
- Video bronchoscope
- Ultrasound fiberoptic bronchovideoscope
- Colonoscope
- Colonovideoscope
- Sigmoidoscope
- Cystofiberscope
- Cystoscope

- Rhinolaryngoscope
- Gastroscope
- Gastrovideoscope
- Duodenoscope
- Trachea intubation scope
- Video balloon enteroscope
- Duodenovideoscope
- Ureteroscope
- Choledochoscope
- Cysto-nephro fiberscope
Endoscopy-related infections can be divided into two types:

- **Internal**: Endogenous infections (resulting from the patient’s own microbial flora)
  
  Example: Pneumonia resulting from aspiration of oral secretions in a sedated patient during flexible bronchoscopy

- **External**: Exogenous infections (resulting from the transmission of pathogens by the endoscope)
  
  Most frequently reported:
  - Transmission of *P. aeruginosa* and *Salmonella spp.* during GI endoscopy
  - Transmission of *P. aeruginosa* and *Mycobacteria* during bronchoscopy
Endoscope related infections

- For surgical procedures, the skin is typically prepped by cleaning and antisepsis.
- In contrast, endoscopes and ultrasound probes enter the body via non-sterile orifices:
  - Mouth: 200+ species
  - Large intestine: 1,000 species
- GI scopes contaminated with microbes during each use:
  - 1 million to 10 billion CFUs/mL
  - 1 billion to 100 billion bacteria in one gram of feces
Infections may go unrecognized (e.g. inadequate surveillance, long latent periods between exposure and the appearance, asymptomatic infections)

Biofilm growth inside endoscope channels
Studies demonstrated peracetic acid disinfectants can fix E. coli biofilm and blood on to silicone tubing

- Number of endoscopic procedures in the US per year: **24.4 million** [1,2]
- Incidence of infection associated with endoscopy: **1 in 1.8 million procedures** [3]

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Endoscopy related infections

Duodenoscope (ERCP)
Duodenoscope (ERCP)

Tainted scope

Duodenoscopes used in ERCP have been tied to several superbug outbreaks.

Annual number of U.S. ERCP procedures

<table>
<thead>
<tr>
<th>Year</th>
<th>Count in Thousands</th>
</tr>
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<tbody>
<tr>
<td>2010</td>
<td>583,700</td>
</tr>
<tr>
<td>2011</td>
<td>668,800</td>
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</tbody>
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What is a duodenoscope?

It’s a specialized endoscope put down a patient’s throat to treat gallstones, cancers and other digestive issues.

Controls

“Elevator” controls attachments like catheters or guide wires.

- Air-water nozzle
- Camera
- Light

Sources: Millennium Research Group, New England Journal of Medicine

@latimesgraphics
Duodenoscope related infections

Figure 1. Number of MDR reports\textsuperscript{1,2,3} received for duodenoscopes associated with patient infection, patient exposure or device contamination.

1: Each MDR may report events associated with one or more patients
2: 2015 year only includes data received as of February 17, 2015.
3: Reports received prior to 2010 (n=4) not shown in this figure.

FDA report. 2015
CRE, which stands for carbapenem-resistant Enterobacteriaceae, are a large family of Gram-negative bacteria that includes *Salmonella*, *Escherichia coli*, and *Klebsiella*, etc.

Types of CRE are sometimes known as KPC (*Klebsiella pneumoniae* carbapenemase) and NDM (New Delhi Metallo-beta-lactamase). KPC and NDM are enzymes that break down carbapenems and make them ineffective.
Endoscope related infections

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Epidemiologically Significant Pathogens

- 28,502 HAIs reported to NHSN b/w Jan 2006-Oct. 2007
- 621 U.S. hospitals

CDC 2010 report
Microbes and human

10 trillion human cells

10 trillion human cells

100 trillion microbial cells

20,000 human genes

20,000 human genes

2-20 million microbial genes
Culprits of HAIs: bacteria

Teresa Cardoso, et. al. *BMC Infectious Diseases* 2012, **12**:375 doi:10.1186/1471-2334-12-375

Cattaneo et. al. *Nature Reviews Microbiology* 6, 529-540 (July 2008) doi:10.1038/nrmicro1927
• **Virus size**
  - 17 nm – 3000 nm diameter

• **Basic shape**
  - Rod-like
  - “Spherical”

• **Protective Shell - Capsid**
  - Made of many identical protein subunits
  - Symmetrically organized
  - 50% of weight
  - Enveloped or non-enveloped

• **Genomic material**
  - DNA or RNA
  - Single- or double-stranded

Tuberculosis and Mycobacteria cell wall

- TB infection is currently spreading at the rate of one person per second
- “The single most lethal bacterial disease in the world”
Basic and clinical microbiology

More resistant

- Prions
- Endospores of bacteria
- Mycobacteria
- Cysts of protozoa
- Vegetative protozoa
- Gram-negative bacteria
- Fungi, including most fungal spores
- Viruses without envelopes
- Viruses with lipid envelopes

Less resistant

Peptidoglycan

Planktonic ≠ Biofilm

Reference: Gerald E. McDonnell.
A typical biofilm contains 85% polymeric substances and only 15% bacterial mass.


This photo shows the distal tip of the colonoscope contaminated with the biofilm mixture. The fluorescence permits better visualization of the biofilm.

Image source:
Scope Tip after Manual Cleaning
Biofilm Debris in Channel
Biofilm not only harbors pathogens, but also spreads

Biofilm not only harbors pathogens, but also spreads

95% bacteria live in biofilm. It only takes 30 minutes to form biofilm.

Biofilm is very resistant to antibiotics, disinfectants due to penetration (diffusion) barrier.

Mechanical brushing cannot eradicate biofilm.

The best way to control biofilm is prevention and timely cleaning (point-of-use).
Organic debris inside endoscope channels

- Gastroscopy (N=543): 9.2%
- Colonoscopy (N=463): 6.9%
- Bronchoscopy (N=251): 4.0%
- ERCP scope (N=57): 12.3%
- Elevator guide wire (N=21): 19.1%
- Duodenoscope (N=15): 13.3%
- Sigmoidoscope (N=91): 2.2%
- Cystoscopy (N=48): 6.3%
- Total (N=1,489): 7.4%

Alfa et al., AJIC, 2012
Incomplete removal of the biofilm will allow it to quickly return to its equilibrium state, causing a rebound in biofilm growth following disinfection.
Endoscope related infections

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Proper high-level disinfection of endoscopes
- Cleaning is a prerequisite for effective high-level disinfection
- High-level disinfection
Basic steps to clean and perform high-level disinfection of gastrointestinal endoscopes

1) Pre-cleaning including bedside
2) Leakage testing
3) Cleaning including enzymatic and proper mechanical brush
4) Rinsing
5) Disinfection
6) Rinsing
7) Drying
8) Storage
Investigation of Transmission of Hepatitis B Virus (HBV) from 202 Confirmed Viraemic Patients to Gastrointestinal Endoscopes and Evaluation of the Efficacy of Current Cleaning and High-Level Disinfection Procedures

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DOI: http://dx.doi.org/10.1016/j.ajic.2016.04.029
HBV was detected from 21 endoscopes (10.4%) after the procedures. Patients with higher serum HBsAg level ≥145 ng/ml had a 4.75-fold higher risk to transmit HBV to the endoscopes (p=0.015, OR=4.75(95%CI: 1.35-16.70))
Basic steps in cleaning/disinfecting endoscopes

**Pre-cleaning**
- Cleaning outer surface
  - Flush the air/water channel*
  - Flush all other channels with enzymatic detergent

**Leak testing**
- Leak Testing*
  - Attach leak tester*
  - Ensure the endoscope is fully immersed in water. Do not use any detergent
  - Perform leakage test. Perform complete manipulation of buttons and lever

**Manual cleaning**
- Manual Cleaning & Rinsing
  - Fully immerse the endoscope in enzymatic detergent
  - Clean outer surface with lint free cloth or endoscope sponge
  - Brush all appropriate channels*
  - Ensure deflation of the endoscope before proceeding to the manual cleaning

**HLD & rinse**
- High Level Disinfection & Rinsing
  - Test High Level Disinfectant or sterilant*
  - Fully immerse endoscope in HLD or sterilant in dedicated basin
  - Fill all channels with HLD or sterilant and wipe the endoscope with a soft lint-free cloth to remove any bubbles on the surface of the endoscope*
  - Ensure adequate contact with all surfaces of the endoscope*

**Drying & storing**
- Drying & Storing
  - Fully immerse the endoscope in dedicated basin filled with rinse water
  - Rinse all channels with rinse water**
  - Remove the endoscope from the rinse water and purge all channels with air**
  - Purge all channels with alcohol followed with forced air as indicated***
  - Wipe the exterior surfaces of the endoscope with an alcohol moisten soft lint-free cloth
  - Store endoscope uncoiled in a vertical position (i.e., hang in closed, ventilated cabinet). Store detachable and reusable parts (e.g., valves and water resistant cap) separately from scope.
Effects of cleaning and disinfection on reduction of bioburden in endoscopes

A dirty instrument

3 log reduction (99.9%)

6 log reduction (99.9999%)

If STAGE 3 is skipped, waterborne microorganisms (e.g., *Pseudomonas*) may proliferate during storage and pose a serious risk of nosocomial infection, despite effective cleaning and high-level disinfection or "liquid sterilization."

If STAGES 1, 2 and 3 are performed properly, there is virtually no risk of nosocomial infection following endoscopy.

Cleaning + high-level disinfection: 3 + 6 = 9 log reduction of microorganisms
Outbreaks Associated with Contaminated Medical Device

New Delhi Metallo-β-Lactamase-Producing Carbapenem-Resistant *Escherichia coli* Associated With Exposure to Duodenoscopes

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**IMPORTANCE** Carbapenem-resistant Enterobacteriaceae (CRE) producing the New Delhi metallo-β-lactamase (NDM) are rare in the United States, but have the potential to add to the increasing CRE burden. Previous NDM-producing CRE clusters have been attributed to person-to-person transmission in health care facilities.

**OBJECTIVE** To identify a source for, and interrupt transmission of, NDM-producing CRE in a northeastern Illinois hospital.

**DESIGN, SETTING, AND PARTICIPANTS** Outbreak investigation among 39 case patients at a tertiary care hospital in northeastern Illinois, including a case-control study, infection control assessment, and collection of environmental and device cultures; patient and environmental isolate relatedness was evaluated with pulsed-field gel electrophoresis (PFGE). Following identification of a likely source, targeted patient notification and CRE screening cultures were performed.

**MAIN OUTCOMES AND MEASURES** Association between exposure and acquisition of NDM-producing CRE; results of environmental cultures and organism typing.
Uses and Risks Associated with Duodenoscopes

- More than 500,000 procedures performed in the U.S. each year
- Unlike other endoscopes, duodenoscopes have a movable “elevator” mechanism at the tip
- Intricate design creates challenges for cleaning and high-level disinfection
- Brushing may not remove residual body fluids and organic materials from microscopic crevices in elevator area
- If microbial contamination present, subsequent patients may be exposed
Reprocessing of Endoscopes Using Metricide OPA Plus Solution

- Active ingredient is ortho-phthalaldehyde (OPA)
- Broad spectrum activity against *Mycobacterium tuberculosis*, Hepatitis A Virus, Hepatitis B Virus, HIV, Polio Virus Type 1
- Fast and effective
- Long lasting – may be used for up to 30 days (manually); up to 14 days in an AER
- Ready to Use – does not require activation or dilution
Quarterly Culturing of Endoscopes

- Duodenoscopes at all four NorthShore hospitals are cultured every 3-months: January, April, July, and October
- Cultures are obtained after duodenoscopes have been reprocessed and dried
- During each sampling period, one endoscope is cultured before enzymatic cleaning and one after enzymatic cleaning as a quality control of the sampling methodology
- Endoscopes containing organisms of “high concern” are sequestered pending further action
Quarterly Culturing of Endoscopes
Quarterly Culturing of Endoscopes

Clean the outer surface of the duodenoscope tip with a sterile alcohol pad, taking care not to wipe the "elevator" mechanism and lens face.
Sample the elevator mechanism in (a) the lowered/closed position, (b) the raised/open position, and (c) the lens face.
Results of Quarterly Culturing of Endoscopes
Interpretation of Culture Results

- **Low Concern Bacteria**
  - Coagulase-negative Staphylococci
  - Micrococci
  - Diphtheroids, Bacillus species and other Gram-positive bacilli

- **High Concern Bacteria**
  - Staphylococcus aureus
  - Enterococcus species
  - Pseudomonas aeruginosa
  - Klebsiella species
  - Salmonella species, Shigella species
  - Other Enteric Gram-negative bacilli
High-Level Disinfection (HLD) and Sterilization BoosterPak

1. PRECLEANING

- Wipe exterior of scope with endoscopic detergent. *Note: Use a detergent formulated for use with endoscopes. Do not use household or dish detergent.*

- Suction scope with endoscope detergent until fluid is clear and end by suctioning air to clear fluid from scope. Flush auxiliary water channel even if it was not used. *Note: Two channel endoscope require aspiration of detergent through both channels.*

- Clear the air and water channels according to the manufacturer's instruction.

- Place fluid-tight video cap on scope and bring scope to reprocessing area in covered container.
High-Level Disinfection (HLD) and Sterilization BoosterPak

3

MANUAL CLEANING

Scrub, brush, soak and rinse all removable parts in fresh endoscope detergent.

For the suction valve depress button to clean valve channel opening.

Immerse and thoroughly clean exterior of the endoscope in endoscope detergent using a lint free sponge or cloth.

Brush all accessible channels.

Note: Clean brush each time it exits distal tip and umbilical cord. Brushing should be repeated until no debris is visible on the brush.

Attach cleaning adapters to endoscope. Immerse and soak the endoscope and its internal channels for the period specified by the label. Flush detergent solution through all of the following channels (suction, biopsy, air/water, accessory and elevator wire) until clear of debris.
High-Level Disinfection (HLD) and Sterilization BoosterPak

4. RINSE AFTER CLEANING

Rinse the Endoscope and removable parts thoroughly under running water to remove residual detergent. Flush all channels with water.

Purge all channels with air. Note: Dry the exterior of the endoscope with a soft, lint-free cloth to prevent dilution of the HLD used in subsequent steps.
Immerse the cleaned, rinsed and air-purged endoscope and all removable parts in a high-level disinfectant or sterilant. Using the cleaning adapters, fill all channels with the high-level disinfectant or sterilant until no air bubbles are seen.

*Note: If an automated reprocessor is used, place the endoscope in the reprocessor and attach all channel adapters according to the manufacturer’s instructions. Place valves and other removable parts into the soaking basin of the reprocessor unless the reprocessor has a dedicated space for the accessories, reprocess these items separately.*
Summary of advantages and disadvantages of chemical agents used as sterilants or HLDs

<table>
<thead>
<tr>
<th>Sterilization method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Peracetic acid/hydrogen peroxide | - No activation required  
- Odor or irritation not significant  
- Material compatibility concerns (lead, brass, copper, zinc) both cosmetic and functional  
- Limited clinical experience  
- Potential for eye and skin damage  
- Respiratory irritation from glutaraldehyde vapor  
- Pungent and irritating odor  
- Relatively slow mycobactericidal activity (unless other disinfectants added such as phenolic, alcohol)  
- Coagulates blood and fixes tissue to surfaces  
- Allergic contact dermatitis  
- Material compatibility concerns (brass, zinc, copper, and nickel/silver plating) both cosmetic and functional  
- Serious eye damage with contact |  |
| Glutaraldehyde               | - Numerous use studies published  
- Relatively inexpensive  
- Excellent material compatibility | - Stains protein gray (e.g., skin, mucous membranes, clothing, and environmental surfaces)  
- Limited clinical experience  
- More expensive than glutaraldehyde  
- Eye irritation with contact  
- Slow sporicidal activity  
- Anaphylactic reactions to OPA in bladder cancer patients with repeated exposure to OPA through cystoscopy  
- Potential material incompatibility (e.g., aluminum anodized coating becomes dull)  
- Used for immersible instruments only  
- One scope or a small number of instruments can be processed in a cycle  
- More expensive (endoscope repairs, operating costs, purchase costs) than high-level disinfection  
- Serious eye and skin damage (concentrated solution) with contact  
- Point-of-use system, no sterile storage  
- An AER using 0.2% peracetic acid not FDA-cleared as sterilization process but HLD |  |
| Hydrogen peroxide            | - No activation required  
- May enhance removal of organic matter and organisms  
- No disposal issues  
- No odor or irritation issues  
- Does not coagulate blood or fix tissues to surfaces  
- Inactivates Cryptosporidium  
- Use studies published |  |
| Ortho-phthalaldehyde         | - Fast acting high-level disinfectant  
- No activation required  
- Odor not significant  
- Excellent materials compatibility claimed  
- Does not coagulate blood or fix tissues to surfaces claimed |  |
| Peracetic acid               | - Rapid sterilization cycle time (30-45 min)  
- Low temperature (50°C-55°C) liquid immersion sterilization  
- Environmental friendly by-products (acetic acid, O₂, H₂O)  
- Fully automated  
- Single-use system eliminates need for concentration testing  
- Standardized cycle  
- May enhance removal of organic material and endotoxin  
- No adverse health effects to operators under normal operating conditions  
- Compatible with many materials and instruments  
- Does not coagulate blood or fix tissues to surfaces  
- Sterilant flows through scope facilitating salt, protein, and microbe removal  
- Rapidly sporicidal  
- Provides procedure standardization (constant dilution, perfusion of channel, temperatures, exposure) |  |

High-level disinfection or sterilization?

- **Common HLDs**
  - Glutaraldehyde
  - OPA
  - Peracetic acid
  - Combination chemistries

- **Pros**
  - Effective against most pathogens
  - Short exposure times
  - Staff familiarity

- **Cons**
  - Achieves a 3-6 log reduction
  - Does not kill all spores
  - Prone to user error
  - Residues can harm patients

- **Common sterilants**
  - Steam
  - EtO
  - H₂O₂
  - Peracetic acid

- **Pros**
  - Much larger log reduction
  - Effective against all microbes
  - Typically offers verification

- **Cons**
  - Conditions for effectiveness
  - Long process and aeration times
  - Materials compatibility issues
  - Toxicity concerns
FDA 关于环氧乙烷灭菌的最新评论

Dr. William Maisel

FDA Deputy Director and Chief Scientist:

• EtO sterilization is “not something that we routinely recommend”

• “...There can be ethylene oxide residual levels on the products that can be harmful to patients.”

• “[Eto] can damage the scopes themselves. And so we are not, at this time, recommending routine ethylene oxide sterilization.”
High-Level Disinfection (HLD) and Sterilization BoosterPak

**DRYING**

Purge all channels with air.  
*Note: Avoid excessively high air pressure.*

Flush all channels with 70-80% alcohol to facilitate drying. Purge all channels with air.
Hang endoscopes vertically in a clean, well-ventilated and dust-free area.

Note: Caps, valves and other detachable components removed per manufacturer’s instructions.
Biofilm and instrument reprocessing

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