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A GLIMPSE AT THE TRUE COST OF REPROCESSING ENDOSCOPES: RESULTS OF A PILOT PROJECT

INTRODUCTION AND METHODS

In light of recent outbreaks of infection tied to contaminated flexible endoscopes, several national organizations have published more stringent reprocessing guidelines. The guidelines are intended to reduce the risk of infection and improve patient safety. Complying with these recommendations will require institutions to invest more resources into endoscope reprocessing.

The purpose of this pilot project was to explore the real-world impact of the new guidelines as it relates to reprocessing time and material costs. Our commitment to doing this research came from discussions with front-line personnel who are under fire to do more with less. The findings are intended to empower managers and technicians, so they can attain the resources they need to ensure patient safety.

This article provides an initial glimpse at the cost of reprocessing endoscopes. The focus is on endoscopes that are reprocessed using high-level disinfection (HLD) rather than sterilization. The estimates presented here are not comprehensive, in part because they do not include the cost of purchasing or leasing flexible endoscopes.

We included 17 tables in order to be transparent about how costs were calculated. Our goal is to provide a stepping stone for others to collect data and share findings to expand our collective knowledge about the true cost of endoscope reprocessing.

THE BOTTOM LINE

THERE ARE FOUR KEY TAKEAWAYS FROM THIS PILOT PROJECT:

1. Reprocessing one flexible endoscope requires approximately 76 minutes of hands-on staff time.
2. The cost of reprocessing one endoscope ranges from $114.07 to $280.71.
3. These findings likely underestimate the time and cost associated with endoscope reprocessing.
4. More research is needed to determine the true cost of endoscope reprocessing.

REVIEWING NATIONAL STANDARDS AND GUIDELINES

The authors compared the 2011 Multisociety Guideline on Reprocessing Flexible GI Endoscopes[1] with four new standards published in the U.S., including:

- ANSI/AAMI ST91 for Flexible and Semi-Rigid Endoscope Processing (2015)[2]
- AORN Guideline for Processing Flexible Endoscopes (2016)[3]
- SGNA Standard of Infection Prevention in the Gastroenterology Setting (2015)[4]
- SGNA Standards of Infection Prevention for Reprocessing of Flexible Gastrointestinal Endoscopes (2015)[5]

These standards are lengthy and complex. Collectively, they recommend more than 100 steps for reprocessing each endoscope. Although there are similarities between standards, some recommendations are not universal. This presents challenges for Central Service (CS) and endoscopy center personnel.

Table 1 provides an overview of recommended steps from the new standards. This table was developed by the authors of this pilot study, and does not represent everything in standards and manufacturers' Instructions for Use (IFU). The recommendations appearing in red are included in the 2015-2016 standards, but were not included in the 2011 Multisociety guidelines. Checkmarks indicate which standards recommend each step.

OBTAINING COST AND TIME DATA

After reviewing the standards, the authors spoke with several vendors of reprocessing products and reviewed published sources of cost information.[6-10] To help estimate real-world costs, CS and materials management personnel shared information about the time and cost associated with completing recommended tasks. The data presented in this article came from 14 healthcare institutions and five vendors. Pricing from vendors was used only when there was inadequate data available from the field.

HOW REPROCESSING IS PERFORMED

Methods used to reprocess endoscopes vary significantly between institutions, with different protocols, equipment, chemicals and other materials used. For example, some use commercial pre-cleaning kits, while others assemble their own pre-cleaning materials. Some institutions use syringes to flush channels, while others use automated irrigation systems. All data in this article came from institutions that use automated endoscope reprocessors (AERs) for HLD. In some cases, these AERs perform only the HLD step, while others have a cleaning cycle, as well.

KEY FINDINGS

Reports from individuals in the field revealed substantial variation in:

- How endoscope reprocessing is performed
- Time spent to complete reprocessing tasks
- Wages paid to reprocessing personnel
- Types of reprocessing materials used
- Cost of reprocessing materials used

Table 1: Overview of recommendations included in new reprocessing standards issued by SGNA, AORN, and ANSI/AAMI, compiled by Ofstead & Associates, Inc. Checkmarks indicate which organizations recommended each step, and new recommendations appear in **red**.

Step	Recommendations	Organization		
		SGNA 2015*	AORN 2016	AAMI 2015
PPE	Wear fluid-resistant face masks, eye protection (e.g., face shields), impermeable gowns, shoe covers, head covers, and gloves when reprocessing endoscopes	✔	✔	✔
	Wear clean gloves to handle reprocessed endoscopes		✔	✔
Bedside pre-cleaning	Begin immediately after the procedure ends	✓	✓	✓
	Inspect visually for damage	✓	✓	✓
	Wipe exterior and flush solution through all channels	✓	✓	✓
	Transport to reprocessing area in closed container	✓	✓	✓
Leak testing	Pressurize endoscope to recommended pressure	✓	✓	✓
	Maintain pressure for time specified in IFU (30+ seconds)	✓	✓	✓
	Manipulate all moving parts	✓	✓	✓
	Watch for a drop in pressure or bubbles indicating a leak	✓	✓	✓
Manual cleaning	Prepare detergent solution and soak endoscope	✓	✓	✓
	Scrub exterior surfaces	✓	✓	✓
	Clean removable parts and accessories	✓	✓	✓
	Brush channels multiple times using correct-size brushes	✔	✔	✓
	Flush channels with detergent and rinse with water	✔	✔	✔
	Reprocess reusable brushes after each use	✓	✓	✓
	Clean and disinfect transport containers after each use		✔	✔
	Perform biochemical cleaning-verification tests	✔	✔	✔
Visual inspection	Inspect endoscope visually *after every use*	✓	✓	✓
	Use lighted magnification for visual inspection	✔	✔	✔
HLD using an AER	Complete manual cleaning before loading AER (even when the AER has a cleaning cycle)	✓		✓
	Perform MEC test of disinfectant *before each use*	✔	✔	✔
	Attach channels, initiate cycle, and ensure completion	✓	✓	✓
	Unload AER promptly after cycle completion	✔		✔
Drying	Completely dry the endoscope *before* storage	✔		✔
	Flush alcohol through channels	✓		✓
	Dry channels using pressurized, filtered air	✓	✓	✓
	Dry exterior using a lint-free towel or wipe	✔	✔	
	Dry all accessories (valves, caps)	✔	✔	✔
	Transport to storage using a clean container		✔	✔
Storage	Store endoscope in a clean, well-ventilated area	✔	✔	✔
	Store accessories with their assigned endoscope	✔	✔	✔
	Use a positive pressure cabinet that circulates filtered air		✔	
Documentation	Use biohazard labels on dirty transport containers	✓	✓	✓
	Use a system (tag or label) to verify reprocessing occurred	✔	✔	✔
	Maintain records linking patient to endoscope	✓	✓	✓

Items marked as "new" reflect recommendations made in the 2015 SGNA standards, the 2016 AORN guidelines, and/or the 2015 ANSI/AAMI ST91 that did not appear in the 2011 Multisociety guidelines. *SGNA 2015 reflects two different sets of guidelines.

TOTAL COST FOR REPROCESSING

The overall cost of reprocessing one flexible endoscope ranged from $114.07 to $280.71 (Table 2).

REPROCESSING TIME AND WAGES

The average hands-on time to reprocess one endoscope was 76 minutes (Table 3). Personnel who reprocess endoscopes included CS, surgical and patient care technicians, registered nurses (RNs), respiratory therapists and others. In 2015, CS technicians nationally were paid an average of $16.80 per hour, with most earning $11.07 to $23.79 per hour.[11] National average wages were higher for surgical technicians ($22.09/hour)[12] and RNs ($34.14/hour).[13] These estimates do not include benefits beyond wages. Cost of personnel time was based on the average time for a CS technician to perform tasks (total $21.27). The cost for other personnel to reprocess endoscopes is higher ($43.22 for an RN) (Table 3).

COST FOR REPROCESSING MATERIALS

In the examples, the minimum cost uses the least expensive combination of materials, and the maximum cost uses the most expensive materials.

Table 2: Total estimated cost for reprocessing one flexible endoscope*

Reprocessing step	Minimum cost	Maximum cost
PPE for reprocessing personnel	$5.06	$17.78
Bedside pre-cleaning	$4.45	$19.14
Leak testing	$2.27	$5.28
Manual cleaning	$11.12	$37.11
Visual inspection, cleaning verification, and re-cleaning 20% of endoscopes	$14.62	$49.69
HLD in an AER	$10.74	$17.21
Drying and storage	$1.88	$6.45
Repairs needed due to issues identified by reprocessing technicians	$63.93	$128.05
Total	$114.07	$280.71

*Assumptions used to build these estimates are described in detail in each section to follow. These estimates do not include all costs associated with purchasing, reprocessing, and maintaining endoscopes (see Limitations section and Table 16).

Table 3: Staff time and wages paid to complete basic reprocessing activities for one endoscope

Reprocessing step	Average time required* (minutes)	Cost of staff time for reprocessing tasks**		
		CS Tech $16.80/hr	Surgical Tech $22.09/hr	RN $34.14/hr
PPE changes and hand hygiene†	9.1	$2.54	$3.34	$5.16
Bedside pre-cleaning	5.8	$1.61	$2.12	$3.27
Transport to reprocessing room	5.5	$1.54	$2.02	$3.13
Dry leak testing	2.1	$0.59	$0.77	$1.19
Wet leak testing	5.5	$1.54	$2.02	$3.13
Manual cleaning	17.3	$4.85	$6.38	$9.86
Sinks and counter clean-up	6.0	$1.68	$2.21	$3.41
Visual inspection	3.0	$0.84	$1.10	$1.71
Performing cleaning verification tests	5.4	$1.52	$1.99	$3.08
Re-cleaning & re-testing‡	4.5	$1.26	$1.66	$2.56
Setting up AER§	4.0	$1.12	$1.47	$2.28
Drying endoscope & accessories	7.3	$2.03	$2.67	$4.13
Transport to storage	0.5	$0.15	$0.20	$0.31
Total time and wages for reprocessing one endoscope	76 minutes	$21.27	$27.95	$43.22

*Time estimates provided by CS and endoscopy center staff from several institutions; **Average wages obtained from the United States Bureau of Labor Statistics. †Time for donning/doffing PPE includes two complete changes of PPE, donning gloves two more times, and performing hand hygiene twice. ‡Assumes 20% of endoscopes require re-cleaning due to results of visual inspection and cleaning verification tests. §Time for setting up AER includes loading endoscope, connecting channels, entering data, testing MEC, removing endoscope, and documentation. It does not include time for running the cycle.

Materials used to reprocess one endoscope

PPE used to reprocess one flexible endoscope

Table 4: Amount paid for PPE materials

PPE materials	Quantity	Minimum price paid	Maximum price paid
Bouffant hair covers	100	$3.12	$4.86
Drop-down face shields	50	$51.00	$137.50
Pop-up face shields	25	$10.77	$14.74
Surgical masks	50	$3.70	$4.48
Fluid-resistant gowns or aprons	20	$10.02	$65.00
Exam gloves	200	$4.13	$26.00
Extended cuff gloves	50	$6.40	$19.00
Shoe covers	100	$4.64	$9.57
Scrubs (laundry cost)	1 pound	$0.20	$0.88

Table 5: Examples of costs for PPE used to reprocess one endoscope

PPE materials	Minimum cost			Maximum cost		
	Price/unit	Quantity	Total	Price/unit	Quantity	Total
Hair cover	$0.03	2	$0.06	$0.05	2	$0.10
Pop-up face shield	$0.43	2	$0.86	NA	NA	NA
Drop-down face shield	NA	NA	NA	$2.75	2	$5.50
Surgical mask	NA	NA	NA	$0.09	2	$0.18
Exam gloves (pair)	$0.04	4	$0.16	$0.26	7	$1.82
Extended-cuff gloves (pair)	$0.26	1	$0.26	$0.76	1	$0.76
Impermeable gown or apron	$0.50	2	$1.00	$3.25	2	$6.50
Shoe covers (pair)	$0.09	2	$0.18	$0.19	2	$0.38
Materials cost			**$2.52**			**$15.24**
Personnel cost			**$2.54**			**$2.54**
Total PPE cost			**$5.06**			**$17.78**

Note: "NA" indicates not used. **Assumptions:** The maximum cost includes wearing double gloves for manual cleaning, with two additional glove changes. The cost for laundering hospital-issued scrubs is not included.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

The new standards state that personnel should wear full personal protective equipment (PPE) [hair covers, eye protection, face masks, impermeable gowns, gloves, and shoe covers] when reprocessing endoscopes (Table 1). They state that personnel should don (put on) entirely fresh PPE and perform hand hygiene at least twice during the course of reprocessing each endoscope. In addition, eyes and skin should be protected whenever handling hazardous chemicals (e.g., when doing the MEC test). Exam gloves are permissible for bedside pre-cleaning and handling disinfected endoscopes. Extended-cuff gloves or utility gloves should be worn for manual cleaning.

The purpose of PPE

- Endoscopes are highly contaminated during every use.
- PPE protects healthcare personnel and patients.
- Changing PPE and washing hands after manual cleaning reduces the risk of contamination.
- Wearing gloves when handling reprocessed endoscopes prevents endoscope contamination.

The cost of PPE

There was variation in prices paid for PPE (Table 4). The cost of recommended PPE ranged from $5.06 to $17.78 (Table 5), including personnel time for changing PPE. This does not include the cost of purchasing and laundering scrubs, which are essential components of PPE.

BEDSIDE PRE-CLEANING

The new standards emphasize the importance of immediate bedside pre-cleaning. This involves wiping the outside of the endoscope and flushing channels before transporting the endoscope to the reprocessing room.

The purpose of bedside pre-cleaning

- The number of bacteria on an endoscope can double every 20 to 30 minutes after it is used.
- Pre-cleaning washes away debris and prevents residue from drying out.
- Once biofilm begins to grow, it can be difficult or impossible to remove.
- Outbreaks of infection have been blamed on a failure to pre-clean endoscopes.

The cost of bedside pre-cleaning

The cost to perform bedside pre-cleaning and transport one endoscope to the reprocessing room ranged from $4.45 to $19.14 (Tables 6, 7a, 7b). Institutions that self-assemble materials for pre-cleaning and reuse transport containers tend to pay less for materials than facilities that use commercial kits containing detergent and sponges with single-use transportation containers; however, self-assembly may require more time.

LEAK TESTING

The new standards recommend leak testing every endoscope each time it is reprocessed. When an endoscope fails a leak test, it requires further evaluation and, possibly, repair. Guidelines recommend reviewing the IFU for each endoscope to ensure the correct leak testing equipment and pressure specifications are used.

The purpose of leak testing

- Tiny holes or leaks could allow blood, fecal matter, patient secretions or reprocessing chemicals to invade the endoscope lining.
- Catching leaks early reduces damage that could occur when the endoscope is immersed in cleaning solution or HLD.
- Identifying a leak when it first occurs reduces the cost of repairs.

Table 6: Amount paid for materials used to pre-clean, manually clean, and transport endoscopes

Cleaning materials	Quantity	Minimum price paid	Maximum price paid
Bedside pre-cleaning kit (detergent and sponge)	25	$46.80	$155.00
Bedside pre-cleaning kit with transport container	10	$90.00	$150.00
Detergent	1 gallon	$12.00	$33.31
Container for cleaning solution	200	$14.00	$49.00
Lint-free cloth	150	$51.85	$219.95
Lint-free sponge	100	$60.00	$145.00
Single-use brushes for ports and valves	25	$27.50	$156.25
Single-use channel brush	25	$20.00	$122.50
Single-use valves and caps (set)	50	$300.00	$761.00
Single-use suction canister	40	$58.16	$181.20
Syringe (30 - 60 cc)	40	$7.58	$30.00
Single-use transportation container	100	$116.00	$320.00
Liner for reusable transport containers	50	$6.57	$137.50
Disinfectant wipes for reusable transport containers	300	$6.20	$25.25

- Endoscopes tested during outbreaks have failed leak tests by investigators.

The cost of leak testing

The average time to complete dry and wet leak tests was 7.6 minutes. Leak testing equipment used for 4,000 tests costs $0.14 to $3.15 per use. Including personnel time, the cost per leak test is $2.27 to $5.28. Additional costs accrue when an endoscope fails the leak test and needs to be repaired. This occurs 1% to 10% of the time. It takes 20 minutes to complete paperwork and package an endoscope before sending it out for repair.

MANUAL CLEANING

Manual cleaning is considered the most important reprocessing step. Disinfection or sterilization will not be effective if endoscopes are still dirty.[2,3,5] New standards recommend passing brushes down endoscope channels multiple times. It is not possible to see inside an endoscope while it's being cleaned; therefore, standards recommend performing biochemical tests to verify cleaning effectiveness.

During manual cleaning, sinks and counters are exposed to bodily secretions, fecal matter and tissue fragments that remain in endoscopes. Counters and sinks should be cleaned after manually cleaning each endoscope to prevent cross contamination.

Table 7a: Examples of costs for pre-cleaning and transporting one endoscope using self-assembled materials and a reusable transport container

Bedside pre-cleaning materials	Minimum cost			Maximum cost		
	Price/unit	Quantity	Total	Price/unit	Quantity	Total
Detergent solution	$0.00	200 cc	$0.00	$0.01	200 cc	$0.01
Cloth: Lint-free	$0.02	1	$0.02	NA	NA	NA
Sponge: Lint-free	NA	NA	NA	$1.45	1	$1.45
Container for solution	$0.07	1	$0.07	$0.25	1	$0.25
Disinfectant wipes	$0.02	2	$0.04	$0.17	2	$0.34
Transport container liner	$0.13	1	$0.13	$2.75	1	$2.75
Reusable transport container	$5.00	1 use	$0.05	$134.35	1 use	$1.34
Materials cost			**$0.31**			**$6.14**
Personnel cost			**$4.14**			**$4.14**
Total pre-cleaning cost			**$4.45**			**$10.28**

Note: "NA" indicates not used. **Assumptions:** Reusable transport containers are used 100 times before being replaced. The cost of reusable lint-free cloths includes only the cost of laundering. Personnel cost is based on pre-cleaning and transport being performed by a surgical technician.

Table 7b: Examples of costs for pre-cleaning and transporting one endoscope using a commercial pre-cleaning kit and single-use transport container

Bedside pre-cleaning materials	Minimum cost			Maximum cost		
	Price/unit	Quantity	Total	Price/unit	Quantity	Total
Pre-cleaning kit	$1.50	1	$1.50	NA	NA	NA
Pre-cleaning kit with transport container	NA	NA	NA	$15.00	1	$15.00
Single-use transport container	$1.16	1	$1.16	NA	NA	NA
Materials cost			**$2.66**			**$15.00**
Personnel cost			**$4.14**			**$4.14**
Total pre-cleaning cost			**$6.80**			**$19.14**

Note: "NA" indicates not used. **Assumptions:** The bedside pre-cleaning kit includes detergent solution and a sponge. Personnel cost is based on pre-cleaning and transport being performed by a surgical technician.

The purpose of manual cleaning

- Protein, blood or carbohydrates left inside endoscopes can provide shelter and food for bacteria.
- Any remaining soil or bodily fluids can decrease the concentration of HLD or liquid sterilant.
- Diluted HLD is not as effective, and bacteria can survive reprocessing.
- Numerous outbreaks of infection have been blamed on failing to adequately clean endoscopes.

The cost of manual cleaning

The cost of manual cleaning, including materials and personnel time, ranged from $11.12 to $37.11 (Table 8).

VISUAL INSPECTION

The Association of periOperative Registered Nurses (AORN) and the Society of Gastroenterology Nurses and Associates Inc. (SGNA) now state that visual inspection is a separate step that should be performed before HLD or sterilization. New standards recommend using magnifying glasses with extra lighting, so technicians can see debris remaining on external surfaces after cleaning. Although handheld magnifying glasses may be used, many institutions are purchasing visual inspection stations with lighting and mounted magnifying glasses.

To examine inside ports and channels, it is necessary to use a borescope. These tiny endoscopes allow technicians to view internal surfaces using lighted magnification. It is important to use borescopes of correct dimensions (diameter and length) for the endoscopes being inspected.[2] Careful inspection can identify damage or debris that could impact patient safety or procedural success.

Distal ends of two gastroscopes (top one intact; bottom one damaged)

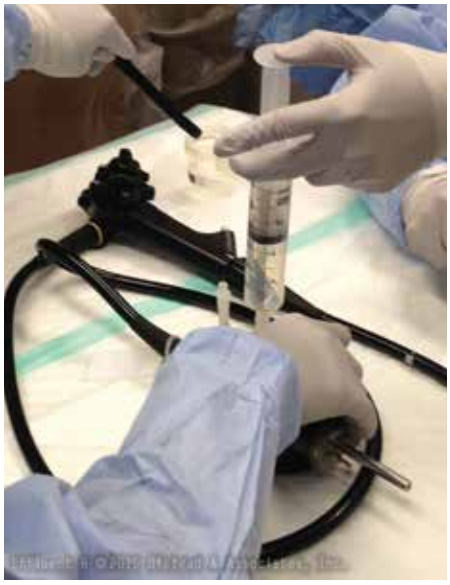
Table 8: Examples of costs for manual cleaning

Manual cleaning materials	Minimum cost			Maximum cost		
	Price/unit	Quantity	Total	Price/unit	Quantity	Total
Detergent	$0.13	5 ounces	$0.65	$0.26	5 ounces	$1.30
Detergent solution beaker	$0.07	1	$0.07	$0.25	1	$0.25
Reusable lint-free cloth	$0.02	3	$0.06	$0.07	3	$0.21
Single-use lint-free sponge	NA	NA	NA	$1.45	1	$1.45
Single-use port/valve brush	$1.10	1	$1.10	$6.25	1	$6.25
Single-use channel brush	$0.80	1	$0.80	$4.90	1	$4.90
Syringe	$0.19	2	$0.38	NA	NA	NA
Suction canister	$1.45	1	$1.45	NA	NA	NA
Commercial irrigation system	NA	NA	NA	$1,935.00	1 use	$0.32
Single-use buttons/valves	NA	NA	NA	$15.22	1	$15.22
Disinfectant wipes for sinks and counters	$0.02	4	$0.08	$0.17	4	$0.68
Materials cost			**$4.59**			**$30.58**
Personnel cost			**$6.53**			**$6.53**
Total manual cleaning cost			**$11.12**			**$37.11**

Note: "NA" indicates not used. **Assumptions:** The minimum cost is based on the use of suction and syringes for irrigation and reusable buttons/valves. The maximum cost is based on using a commercial irrigation system 6,000 times before replacement. The cost of reusable lint-free cloths includes only the cost of laundering.

Distal tip of a colonoscope with a scratched and cloudy lens

Inside a colonoscope suction/biopsy channel showing scratches and brown staining



Two technicians conducting an ATP test of a colonoscope biopsy port

The purpose of visual inspection using lighted magnification

- It is very difficult to see defects or residual debris with the naked eye.
- Good lighting and magnification can illuminate scratches, cracks, tissue fragments, fecal matter or blood that is not visible under normal room lighting.
- Outbreaks have been linked to damage and debris found when investigators inspected the endoscope using a borescope or took the endoscope apart.[14-16]

CLEANING VERIFICATION TESTS

It is possible to verify cleaning effectiveness by using rapid tests for protein, blood or adenosine triphosphate (ATP). ATP indicates the presence of living cells. Cleaning verification can be done by swabbing surfaces or flushing sterile water down channels and testing the swabs or water for residue. The new standards state that tests should be performed on a regular basis (every reprocessing cycle or daily).[2,3] ANSI/AAMI ST91 recommends testing the suction/biopsy channel, at a minimum.[2] Most tests provide results within a couple of minutes—allowing a dirty endoscope to be re-cleaned right away. After it has been re-cleaned, personnel should repeat the test to ensure the contamination is removed because residual contamination can harden in the endoscope when it is exposed to chemicals during HLD or sterilization, making it more difficult to remove.

Scientific studies have found that cleaning is often ineffective. Tests have revealed that 10% to 92% of endoscopes don't come clean with the first round of manual cleaning.[17-22,25] This was true even when technicians followed the standards.[17,21,25] It is particularly difficult to remove protein, especially if there are scratches in the channels.[23,24] HLD is not effective when used on dirty endoscopes.[17,21,25]

When tests for residual contamination fail even after vigorous attempts were made to clean the endoscope, the instrument should be sent out for repair. Researchers in one study sent out endoscopes that had visual defects or high levels of residual contamination after multiple rounds of cleaning. The manufacturer found defects requiring repair or refurbishment for every endoscope.[25]

The purpose of cleaning verification tests

- Measuring the impact of cleaning on components that cannot be easily seen or dissembled.
- Detecting residue that could interfere with HLD or sterilization.
- Preventing cleaning failures that have allowed germs to survive and cause infections.[26-29]
- Identifying dirty endoscopes so they can be re-cleaned right away.

The cost of visual inspection and cleaning verification

The cost to perform cleaning verification tests and visually inspect endoscopes ranged from $14.62 to $49.69 (Table 10). This does not count costs related to multiple rounds of cleaning and repairs. The cost for lighted magnification stations ranges from $45 to more than

$400. Borescopes typically cost several thousand dollars. These are fragile devices that may require frequent repair, depending on usage and types of endoscopes being inspected. Luminometers used to measure ATP cost several thousand dollars. They require annual calibration and must be handled carefully to prevent damage.

Once cleaning verification materials are purchased, the main cost is the time it takes to carefully perform examinations and re-clean endoscopes with residual contamination or visible debris. Additional time is required when repeated rounds of cleaning fail to reduce contamination levels or when damage requiring repair is found.

HIGH-LEVEL DISINFECTION

When flexible endoscopes were first invented, they were less complex and used for less invasive procedures. Experts believed that endoscopes should be sterilized between uses, but the materials used to make them were not compatible with available sterilization systems; therefore, in the 1960s, experts decided that endoscopes could be cleaned and high-level disinfected instead.

In theory, HLD will kill any bacteria, fungi or viruses that remain after cleaning, with the exception of small numbers of bacterial spores that may survive exposure to the chemicals. For HLD to kill germs, it must be in contact with the endoscope for a specified period of time, and the solution must be kept at the correct temperature—generally higher than room temperature.

In recent years, it has become possible to sterilize certain flexible endoscopes using gases or liquid chemical sterilants. Many endoscopes that are fairly simple and short (e.g., bronchoscopes, cystoscopes, ureteroscopes) are now routinely sterilized. Sterilization may not be as effective for longer, more complex endoscopes; therefore, most institutions still use HLD for colonoscopes, gastroscopes and duodenoscopes.

The purpose of high-level disinfection

- Eliminating microbes that remain

Table 9: Amount paid for single-use materials used for cleaning verification and visual inspection

Cleaning verification and visual inspection materials	Quantity	Minimum price paid	Maximum price paid
Hemoglobin test kit	12	$74.65	$120.95
Protein test kit	12	$87.05	$120.95
ATP swab (requires luminometer)	100	$184.50	$275.00
ATP water (requires luminometer)	100	$300.00	$535.00

Table 10: Examples of costs for cleaning verification and visual inspection for one endoscope

Cleaning verification materials	Minimum cost			Maximum cost		
	Price/unit	Quantity	Total	Price/unit	Quantity	Total
ATP water effluent test	$3.00	1	$3.00	NA	NA	NA
Protein test	NA	NA	NA	$10.08	1	$10.08
Syringe with sterile water	$0.19	1	$0.19	$0.75	1	$0.75
Container for channel effluent	$0.07	1	$0.07	$0.25	1	$0.25
Luminometer purchase price	$2,673.00	1 use	$1.34	NA	NA	NA
Magnifying glass with lighting purchase price	$45.00	1 use	$0.01	$409.35	1 use	$0.07
Borescope purchase price	$1,500.00	1 use	$3.75	$6,397.00	1 use	$15.99
Re-cleaning/re-testing materials	$12.95	20%	$2.59	$57.72	20%	$11.54
Materials cost			**$10.95**			**$38.68**
Personnel cost			**$3.67**			**$11.01**
Total cleaning verification cost			**$14.62**			**$49.69**

Note: "NA" indicates not used. **Assumptions:** 20% of endoscopes fail visual inspections or cleaning verification tests and require re-cleaning and re-testing. A luminometer is used 2,000 times before needing replacement or repair. A magnifying glass with lighting is used 6,000 times before needing to be replaced. A borescope is used 400 times before needing replacement or repair. The maximum cost includes triple personnel cost because additional time is needed to conduct a protein test and use a borescope.

after cleaning, so endoscopes can be safely used
- Providing relatively quick turn-around time compared to gas sterilization
- Preventing the transmission of pathogens

The cost of high-level disinfection

The cost of performing HLD for one endoscope ranged from $10.74 to $17.21 (Table 13). Purchasing and maintaining AERs is costly, with purchase prices ranging from $24,000 to $56,000. AER life expectancy is estimated to be eight to 10 years.[8] Maintenance costs $4,000 to $11,000 per AER annually (Table 11). Other expensive items that require regular replacement (water filters, tubing, connectors) have not been included in the cost estimates.

DRYING AND STORAGE

Under old guidelines, it was permissible to hang up wet scopes and let them drip dry in storage cabinets. New standards state that endoscopes should be completely dry before storing them.

Table 11: Purchase price and annual maintenance costs for commonly-used AERs*

AER brand	List price	Quoted price	Annual maintenance
ASP Evotech	$61,686	$55,798	$10,920
Medivators DSD	$49,144	$36,642	$5,100
Olympus OER-Pro	$33,911	$30,473	$4,295
Average prices	$48,247	$40,971	$6,772

*Prices from 2014 article by ECRI[8]

Table 12: Amount paid for materials used during HLD and transport to storage cabinets

HLD, drying and storage materials	Quantity	Minimum price paid	Maximum price paid
HLD	1 gallon	$22.67	$47.50
Detergent — for cleaning cycle	1 gallon	$16.88	$27.00
Isopropyl alcohol	16 ounces	$1.00	$1.50
MEC test strips	100	$47.50	$69.58
Mesh bag for valves and buttons	100	$25.00	$195.00
Labels indicating reprocessing time	100	$17.45	$67.50
Disinfectant wipes for AER	300	$3.10	$25.25
Reusable transport container	1	$5.00	$134.35

Table 13: Examples of costs for performing HLD for one endoscope in an AER that has a cleaning cycle

AER materials	Minimum cost			Maximum cost		
	Price/unit	Quantity	Total	Price/unit	Quantity	Total
Detergent	$0.13	1 use	$0.13	$0.70	1 use	$0.70
HLD (6 gallons)	$136.02	1 use	$2.27	$285.00	1 use	$4.75
Isopropyl alcohol	$0.002	30 mL	$0.06	$0.003	30 mL	$0.09
MEC test strips	$0.48	1	$0.48	$0.70	1	$0.70
Disinfectant wipes for AER	$0.01	4	$0.04	$0.17	4	$0.68
Annual AER maintenance cost	$6,772.00	1 use	$3.39	$6,772.00	1 use	$3.39
AER purchase price	$36,000.00	1 use	$3.00	$46,000.00	1 use	$3.83
Mesh bag	$0.25	1	$0.25	$1.95	1	$1.95
Materials cost			**$9.62**			**$16.09**
Personnel cost			**$1.12**			**$1.12**
Total AER cost			**$10.74**			**$17.21**

Assumptions: The HLD value is the cost of 6 gallons of HLD divided by 60 uses over 14 days. The maintenance value is the average annual cost for maintenance divided by 2,000 annual uses. The purchase prices used are $5,000 below and above the average published prices quoted. The cost for AER usage reflects 12,000 uses during an 8-year period.

The standards emphasize that drying is as important as cleaning and HLD.[2,5] SGNA states that endoscopes that are wet after storage should be re-reprocessed before use.[5] This is because bacteria and fungi can replicate rapidly inside wet endoscopes. One or two bacteria that survive reprocessing can turn into thousands or even millions of bacteria when a wet endoscope is stored overnight.[3] Any evidence that fluid has leaked out of endoscopes after they've been hung in cabinets indicates they were not sufficiently dried before storage.

The new standards recommend drying external surfaces with a lint-free cloth, flushing channels with alcohol and then purging them with filtered, instrument-grade forced air. After reprocessing, endoscopes should be handled only with gloved hands. Gloves should be worn when removing endoscopes from AERs, taking them to storage, and setting them up in procedure rooms. Endoscopes should be placed in clean containers before transporting them to storage cabinets and to procedure rooms.

AORN recommends that reprocessed endoscopes be stored in drying cabinets that continuously circulate HEPA-filtered air around endoscopes and through channels. This removes residual moisture and helps endoscopes stay dry. When this type of cabinet is not available, AORN recommends using cabinets that circulate HEPA-filtered air around the outside of endoscopes.[3]

SGNA states that the maximum storage time should be seven days before being re-reprocessed.[5] Documenting the date and time of reprocessing allows technicians to determine which endoscopes have reached their seven-day limit, and ensures only fully-reprocessed endoscopes are used for procedures. The cost estimates do not take into account the need to re-reprocess endoscopes that are still wet after storage or haven't been used after seven days of storage.

The purpose of drying and storage

- Any moisture that remains inside endoscopes can foster the growth of bacteria and fungi.
- Several outbreaks of infection have been attributed to inadequate drying.
- Many germs that cause infections die when they are dried out.
- Storage in cabinets that circulate filtered air through channels helps endoscopes remain dry.

The cost of drying and storage

The cost for drying and storing endoscopes ranged from $1.88 to $6.45 per reprocessing cycle (Table 14).

PURCHASING, MAINTAINING AND REPAIRING EQUIPMENT

Along with expenses for single-use materials, institutions need to purchase and maintain equipment such as AERs, irrigation systems, luminometers, borescopes and drying cabinets. These expensive items add to the cost of reprocessing endoscopes (Table 15).

Endoscope repairs

Endoscopes are typically sent out for repair only when they fail leak tests or have functional failures that negatively impact their use during procedures; however, scientific studies and reports from outbreak investigators suggest that

Table 14: Examples of costs for drying and storing one endoscope

Drying and storage materials	Minimum cost			Maximum cost		
	Price/unit	Quantity	Total	Price/unit	Quantity	Total
Reusable lint-free cloth	$0.02	2	$0.04	$0.07	2	$0.14
Towels to line counter	$0.04	2	$0.08	$0.14	2	$0.28
Alcohol	$0.002	30 mL	$0.06	$0.003	30 mL	$0.09
Syringe	$0.19	1	$0.19	$0.75	1	$0.75
Label	$0.17	1	$0.17	$0.68	1	$0.68
Storage cabinet purchase price	$3,450.00	Daily use	$0.12	$20,687.47	Daily use	$0.71
Reusable transport container	$5.00	2 uses	$0.10	$134.35	2 uses	$2.68
Materials cost			**$0.76**			**$5.33**
Personnel cost			**$1.12**			**$1.12**
Total drying and storage cost			**$1.88**			**$6.45**

Assumptions: The storage cabinet cost is the daily cost for storing one endoscope in a 10-endoscope cabinet used continuously for 8 years (purchase price/2,920 days/10 endoscopes). Reusable transport containers are used 100 times before being replaced.

endoscopes may require more frequent maintenance to ensure they can be safely used.

In a recent study, researchers found visible damage and contamination that could not be removed with multiple rounds of reprocessing. Based on study findings, 17 of 20 gastrointestinal endoscopes were sent out for repair.[25] The manufacturer confirmed that every endoscope had defects requiring repair or refurbishment. In several outbreaks of infection linked to contaminated endoscopes, investigators discovered visible damage or debris inside most endoscopes.[15,16,30] In at least two cases, leak tests by the manufacturer failed.[16,30] Together, these findings suggest that when visual inspections and tests for residual contamination are performed, a high proportion of endoscopes may require repair.

Nevertheless, conservative estimates (1% to 2%) were used to create cost estimates for endoscopes needing repair due to problems discovered during reprocessing (leak test failures, damage detected during visual inspections, and repeated failures of cleaning verification tests). The cost models do not include repairs requested by clinicians.

Many factors impact repair costs, including the extent of damage and whether the endoscope requires repair or refurbishment. Overall, the average cost of repairs was $5,833, with 20 minutes of personnel time needed to complete paperwork associated with sending an endoscope out for repair. These expenses totaled $63.93 to $128.05 per endoscope.

LIMITATIONS

This article describes the findings from a small pilot project that only begins to scratch the surface in determining the true cost of endoscope reprocessing. The findings may not be applicable nationwide, as the types of endoscope used, personnel salaries, and reprocessing materials and methods vary tremendously.

CS and endoscopy center personnel in the field mentioned numerous costs associated with reprocessing. We were unable to obtain sufficient data for the tasks and resources described in Table 16, and these costs are not included in the cost estimates. In addition, the estimates do not include the cost of purchasing and routine maintenance for flexible endoscopes. The research team decided to exclude this data due to the complexity of determining costs for numerous endoscope brands and models.

Lastly, technicians pointed out that reprocessing one endoscope generates an enormous amount of trash. Calculating the cost of disposing single-use materials was beyond the scope of the pilot project, but merits attention when others conduct research on endoscope reprocessing costs.

DISCUSSION

The results of this pilot study reveal a glimpse of the time and effort it takes to reprocess endoscopes in accordance with the new standards. Despite being unable to account for every aspect of reprocessing, the costs are staggering—from $114.07 to $280.71 for one endoscope.

We encourage readers to use this article as a launching pad for designing and conducting their own cost evaluations.

Table 15: Amount paid for capital equipment

Capital equipment	Minimum price paid	Maximum price paid
Leak tester	$570.00	$12,586.00
Irrigation system	$1,071.70	$1,935.00
AER machine	$30,473.00	$55,798.00
Internal water filter for AER	$45.60	$389.38
Reusable transport container	$5.00	$134.35
Storage cabinets	$3,450.00	$20,687.47
Luminometer (for reading ATP tests)	$2,673.00	$8,475.00
Magnifying glass with lighting	$45.00	$409.35
Borescope for inspecting channels and ports	$1,500.00	$6,397.00

Trash generated from reprocessing one flexible endoscope

Waste and soiled linen generated from reprocessing one endoscope

In the meantime, we hope the evidence from this pilot project will support reprocessing personnel who need adequate time and resources to effectively reprocess scopes. This is essential to protect employees and ensure patient safety.

ACKNOWLEDGEMENTS

We appreciate the support provided by the numerous contributors who shared their knowledge about endoscope reprocessing and the real-world effort it takes to do it properly. Five vendors provided information and costs related to reprocessing. The research team received an unrestricted research grant from invendo medical. The sponsor did not participate in identifying sources, collecting data, compiling results, interpreting findings or drafting this article. We appreciate the editorial assistance of Miriam Amelang and the expertise of Joseph O'Connor, who reviewed numerous drafts and formatted all of the tables.

CONTRIBUTING EXPERTS

Several highly-respected IAHCSMM leaders shared their insights for this article, including Steven J. Adams, RN, CRCST (President, IAHCSMM); Julie E. Williamson (Communications Director and *Communiqué* Editor, IAHCSMM); Natalie J. Lind, CRCST, CHL, FCS (Education Director, IAHCSMM); Karen A. Nauss, CRCST (President, Massachusetts Chapter for Central Service Professionals and Secretary/Treasurer, IAHCSMM); Sheila M. Kritta, CRCST, CIS, CHMMC, CHL (Member, IAHCSMM); and several other sterile processing department and Central Service (CS) managers. These experts also helped recruit peers from other institutions nationally who were able to provide real-world time and cost data, which was used to build the time and cost estimates for reprocessing endoscopes. The costs described in this article reflect our compilation of data provided by 14 healthcare institutions and five vendors.

Table 16: Examples of reprocessing tasks and resources not included in the cost models in this article*

Tasks requiring personnel time	Resources needed
$ Cleaning and disinfecting: – Leak testing equipment – Channel irrigation systems – AERs – Reprocessing room surfaces – Storage cabinets $ Filling or changing fluids in AERs: – Detergent – HLD – Alcohol $ Monitoring AERs and handling cycle failures $ Changing water filters $ Re-reprocessing endoscopes after 7 days storage $ Additional rounds of cleaning after repeated failures $ Additional cleaning for delayed reprocessing $ Documentation for equipment maintenance $ Packaging endoscopes and handling documentation for repairs requested by clinicians $ In-service education for new endoscopes or equipment $ Annual training for reprocessing personnel $ Annual competency testing $ Documentation of training and competency testing $ Certification courses or conferences $ Drafting policies $ Conducting internal audits $ Responding to breaches or outbreak investigations	$ Scrubs for personnel $ Laundry service for scrubs $ Reusable items: – Wash clothes – Towels – Brushes for channels – Brushes for ports – Connectors – Tubing $ Thermometers – Fluid temperature – Room temperature $ Room humidity meter $ Leak tester maintenance unit $ Chemical spill kits $ O-rings for AER basins $ Software for tracking endoscope identifiers and status $ Paper for AER printouts $ Batteries $ Suction systems $ Water filters external to AERs $ Water – Tap/potable – De-ionized or reverse osmosis – Sterile $ Eye wash stations $ Lighting $ Electricity $ Air filtration systems and air filters – Reprocessing room – Storage cabinets $ Square footage for reprocessing room $ Shelving and cabinets $ Sinks $ Trash disposal

*The cost associated with purchasing or leasing flexible endoscopes is not included in this list or the cost models in this article. Costs associated with obtaining loaner scopes (reportedly $200.00 per day) are also not included.

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URO-476421-AA
MAY 2017