



Managing Bronchoscope Quality and Cost: Results of a Real-world Study



Bronchoscopes are used to establish airways, obtain samples, perform lung biopsies and remove pus and tumors from vulnerable patients who are ill or immunocompromised.^{1,2} Bronchoscopy is often messy and cases can be quite lengthy; this allows residue to accumulate inside bronchoscopes, and delays in reprocessing can foster the growth of biofilm.³ Given these issues, it is essential that reusable bronchoscopes are adequately reprocessed to ensure they are free of contamination.

In 2015, a warning letter from the US Food and Drug Administration (FDA) about bronchoscopes described numerous reports of residual contamination and infections following bronchoscopy.⁴ The FDA noted that some infections were due to reprocessing breaches, while others occurred even when manufacturers' instructions for use (IFU) were followed.

In 2017, Ofstead's team evaluated the effectiveness of bronchoscope reprocessing in three large hospitals.⁵ Every bronchoscope had visible defects, and protein was detected on 100% of high-level disinfected (HLD) bronchoscopes. Bacteria or mold were found on 58% of these "patient-ready" bronchoscopes. Because HLD did not work, we recommended that study sites consider alternatives, including sterilization or use of single-use bronchoscopes.

Site personnel asked how much more these alternatives would cost. To find out, we designed this study to determine the time and cost of acquiring, maintaining and reprocessing bronchoscopes. Personnel from four hospitals participated, and several other experts from the International Association of Healthcare Central Service Materiel Management (IAHCSMM) and the Association for Professionals in Infection Control and Epidemiology (APIC) provided insights presented in this paper.



Data collection methods

Reprocessing and infection prevention (IP) managers in the field helped us develop 10 worksheets for collecting data about bronchoscope-related practices and costs. Based on the worksheets and phone calls with study site coordinators, we developed a cost model focused on five contributing factors:

- Bronchoscope acquisition;
- Bronchoscope maintenance and repair;
- Consumable reprocessing materials;
- Personnel time and wages for reprocessing; and
- Re-reprocessing due to exceeding “hang-time” policies.

Sites

Participating sites were diverse in terms of geographical location and size (Table 1). All sites were accredited by The Joint Commission (TJC) or Det Norske Veritas (DNV). Sites reported that they followed reprocessing standards published by one or more national organizations.

Bronchoscope use and storage

Unlike other types of endoscopes that are generally used only in urology or gastroenterology departments, we

Table 1: Study sites were diverse in size and geographic location

Characteristic	Site A	Site B	Site C	Site D
Location	Midwest	Midwest	West Coast	West Coast
Description	Urban medical center	Small-town hospital	Small-town medical center	Urban medical center
Number of beds	500	200	180	110

Table 2: Bronchoscopes were used and stored in numerous departments

Location	Site A	Site B	Site C	Site D
Bronchoscope use				
Endoscopy unit	♻️	♻️	♻️🚫	♻️
ICUs	♻️	🚫	♻️🚫	♻️
Operating room	♻️		♻️🚫	♻️🚫
Emergency room	♻️	🚫	♻️🚫	
Bronchoscopy lab	♻️		♻️	
Bronchoscope storage				
Procedure rooms	♻️	♻️		♻️
SPD	♻️			
Endoscopy unit				
RT lab	♻️		♻️	
OR	♻️		♻️	♻️
Storage room	♻️			♻️

♻️ reusable bronchoscopes 🚫 single use bronchoscopes

Table 3: Reprocessing commonly involved clinical personnel from multiple departments

Reprocessing step	SPD	Endo	Nurses	MAs	RTs	ATs
Pre-cleaning		A	A C D	A B C D	C	C
Leak testing	A C D	B C	C	B C	C	C
Manual cleaning	A C D	B C	C	B C	C	C
Visual inspection	A C D	B C	C	C	C	C
Cleaning verification	A D	B				
HLD	A C D	B C	C	B C	C	C
Sterilization	A					
Drying	A C D	B C	C	C	C	C
Storage	A C D	B C	C	A C	A C	C

A = Site A B = Site B C = Site C D = Site D



found that bronchoscopes are used and stored all over the hospital (Table 2). Site personnel were not always sure where their bronchoscopes were or even how many bronchoscopes they had in their institutions.

IAHCSMM experts and study sites coordinators described problems with tracking and managing their bronchoscope inventories:

- “We’ve found bronchoscopes in pillow cases on crash carts. If they go out on carts, you never know when or where they’re coming back, and it’s almost never in the correct time frame.”
- “At our facility, we would find scopes we had no purchase records for, and then we found out that doctors had purchased bronchoscopes on their own and stashed them in different parts of the hospital for easy access.”
- “We would lose scopes – they could be anywhere! We’d find them sitting somewhere, uncleaned, for a week.”
- “We have a mystery scope that shows up on our books and is extremely old, but it doesn’t appear to be in service anywhere. It does appear that we are paying for a service contract on it (but maybe not after this project).”

To ensure bronchoscopes were always available throughout the hospital, large numbers of diverse staff members were involved in reprocessing (Table 3). Substantial resources were required to provide training, competency testing and supervision for numerous clinical personnel who occasionally reprocess bronchoscopes. These medical assistants (MAs), nurses, respiratory therapists (RTs), and anesthesia techs (ATs) have other clinical priorities that frequently result in delayed reprocessing and skipped steps. In addition to the negative impact on quality, their involvement makes bronchoscope reprocessing more

Table 4: Cost of bronchoscope acquisition and ownership per use

Characteristic	Site A	Site B	Site C	Site D
Bronchoscope brands	Olympus, Karl Storz	Olympus	Olympus	Olympus
Age of scopes (years)	1-7	2	3-25+	1-4
Number of bronchoscopes	11	5	9	9
Annual bronchoscopies	175	130	420	240
Uses/scope/year*	16	26	47	27
Acquisition cost/scope**	\$30,000	\$33,000	\$26,000	\$30,000
Cost per use over 5 years	\$375	\$254	\$111	\$222

* Calculated by dividing # of procedures by # of bronchoscopes

** Average acquisition cost for reusable bronchoscopes purchased in last three years

Table 5: Annual service agreement and out-of-pocket repair costs per bronchoscope

Cost line item	Site A	Site B	Site C	Site D*
Service agreement (average)	—	\$3,800	\$2,350	\$0
Out-of-pocket repair cost (average)	\$5,064	\$0	\$1,000	\$0
Maintenance cost per use	\$317	\$146	\$71	\$0

* Site does not pay for repairs with their own budget (larger entity involved)

— Per unit cost for annual service agreement not readily available

Table 6: Variation in cost of reprocessing consumables by site

Consumable	Site A	Site B	Site C	Site D
Extended cuff gloves (2)	\$1.82	\$0.22	\$0.60	\$1.48
Aprons/gowns	\$0.23	\$0.69	\$1.05	\$0.88
Shoe covers (2)	\$1.08	\$0.26	\$0.18	\$0.14
Hair cover	\$0.03	—	\$0.05	\$0.06
Face shield	\$1.24	\$1.08	\$0.63	—
Syringes	\$1.00	\$0.62	\$0.06	\$0.28
Single-use cloths	\$0.28	\$0.10	\$2.40	\$0.60
Single-use brushes	\$2.29	\$1.50	\$2.60	\$1.50
Single-use transport liners	—	\$2.58	\$0.69	\$2.54
Disinfectant wipes	\$0.28	\$0.11	\$0.08	\$0.06
MEC test strips	—	\$0.70	\$0.86	\$0.91

— Not used

expensive because they are paid more than reprocessing technicians.

Number of employees with bronchoscope reprocessing roles:

- Site A: 15-20
- Site B: 1-5
- Site C: 30-35
- Site D: 30-35



Bronchoscope acquisition and maintenance

Acquisition cost

Sites had five to 11 flexible bronchoscopes and performed 130 to 420 bronchoscopy procedures per year. On average, each bronchoscope was used less than once per week (range 16 to 47 uses per year).

We calculated an average cost per use related to owning reusable bronchoscopes using information

about each site's reusable bronchoscope inventories, procedural volumes and acquisition costs (Table 4). The numbers below include EBUS (ultrasound) bronchoscopes, but not intubation scopes. Our calculations assumed reusable bronchoscopes were replaced every five years. *Note: The formulas used to calculate costs in this paper are available from the authors upon request.*

Maintenance and repair costs

Sites reported that they commonly identified damaged bronchoscopes when they conducted visual inspections as recommended in current guidelines.⁶⁻⁸ To manage the cost of routine maintenance and repairs, sites negotiated service agreements with manufacturers or third-party repair services. Sites frequently had to pay out-of-pocket repair costs, despite having service agreements because certain kinds of damage were not covered.

The annual cost of maintenance and repair was estimated (Table 5). Complete data were not available for Sites A and D. Thus, Table 5 likely underestimates the true costs associated with bronchoscope maintenance.

Table 7: Variation in multi-use product formulations and costs per jug

Consumable	Site A	Site B	Site C	Site D
HLD	\$728.00 (70 cycles/jug)	\$8.22 (single-use pod)	\$156.75 (20-23 uses/jug)	\$184.00 (58 cycles/8 jugs)
HLD cost/cycle	\$10.40	\$8.22	\$7.29	\$3.17
Enzymatic detergent	\$47.18 (70 cycles/jug)	\$41.43 (15 cycles/jug)	\$37.77 (64 cycles/jug)	\$64.00 (32 cycles/jug)
Enzymatic detergent cost/cycle	\$0.67	\$2.76	\$0.59	\$2.00
Non-enzymatic detergent	\$76.00 (70 uses/jug)	—	\$32.62 (45 cycles/jug)	\$28.00 (30 cycles/jug)
Non-enzymatic detergent cost/cycle	\$1.08	—	\$0.73	\$0.93
Alcohol	\$1.27 (16 fluid oz.)	\$1.03 (16 fluid oz.)	\$1.14 (13.7 fluid oz.)	\$17.50 (128 fluid oz.)
Alcohol cost/cycle	\$0.09	\$0.26	\$0.14	\$0.35

— Not used

Bronchoscope reprocessing

Consumable reprocessing materials

The cost of reprocessing supplies varied significantly by site due to volume discounts and use of different brands and types of products. Examples of the prices paid for select single-use items appear in Table 6.

Some reprocessing consumables, such as detergent and HLD, are purchased in bulk quantities, and a small amount is used during each cycle. The formulations and amounts used varied significantly (Table 7). We used the above data to estimate the total cost of consumable materials for each reprocessing cycle at each site (Table 8).

Table 8: Variation in costs for consumable supplies per reprocessing cycle

Task	Site A	Site B	Site C	Site D
PPE	\$4.56	\$2.37	\$4.37	\$6.69
Pre-cleaning	\$1.47	\$2.80	\$3.01	\$1.28
Transport container	—	\$2.58	\$1.38	\$5.08
Manual cleaning	\$5.63	\$6.19	\$7.96	\$7.75
Cleaning verification	\$0.88	\$7.50	—	\$10.50
HLD, MEC tests, alcohol, etc.	\$10.48	\$9.18	\$8.37	\$4.43
Drying indicator	\$2.50	—	—	—
Area/transport bin clean-up	\$0.28	\$0.22	\$0.37	\$0.99
Other	—	—	\$5.98	—
Total supply cost	\$25.80	\$30.84	\$31.44	\$36.72

— Not done or not applicable

Personnel expenses for reprocessing

Reprocessing time

Site personnel measured reprocessing time and there was significant variation in the time required at each site (Table 9). Bronchoscope turnaround times ranged from 41 minutes to nearly two hours, including AER cycle time and drying time. The time spent doing hands-on tasks ranged from 18 minutes to 55



minutes (Figure 1).

Institutional policies and practices affected efficiency. Technicians at Site B did not change personal protective equipment (PPE), perform hand hygiene, visually inspect, or dry bronchoscopes thoroughly. These shortcuts allowed them to finish in less than half the time required at other sites and reduced the cost of supplies required for reprocessing. However, their policies violated current reprocessing standards and Occupational Safety and Health Administration (OSHA) regulations. The coordinator at Site B reported that staff at her institution were proud of how quickly they could reprocess and turn around bronchoscopes. It did not occur to her that their short turnaround time could be an indicator of poor quality until she saw the findings from other study sites—which spent a lot more time on critical tasks.

However, longer turnaround times do not automatically indicate better quality. The total reprocessing time at Site C was more than double the time at Site B, but that was not entirely due to better quality. The study coordinator at Site C reported that they have problems with water flow and the sinks fill very slowly. This resulted in lengthy times for leak testing and manual cleaning and greatly reduced overall efficiency.

Hourly rates varied substantially between sites (Table 10). All steps requiring hands-on staff time were included in our cost calculations.

Costs associated with routine re-reprocessing

Current guidelines recommend that institutions establish policies for re-reprocessing bronchoscopes that have not been used within a certain amount of time.⁶⁻⁸ Maximum “hang-time” storage policies at study sites varied considerably, ranging from seven to 30 days.

Initially, we assumed all bronchoscopes

Table 9: Turnaround time for reprocessing of bronchoscopes using HLD (minutes:seconds)

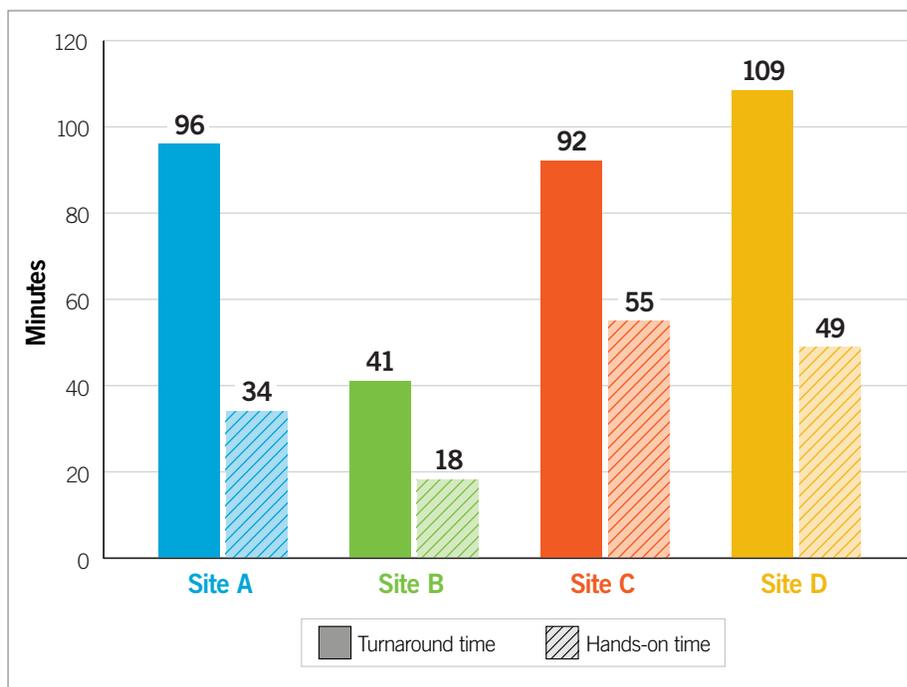
Task	Site A	Site B	Site C	Site D
Hand hygiene/Don PPE	3:15	0:05	1:45	2:15
Pre-cleaning	3:00	2:15	2:15	4:30
Transport to decontam	5:00	0:45	5:15	8:00
Leak testing	1:00	1:45	12:15	3:00
Manual cleaning	2:00	6:45	10:15	4:30
Visual inspection	1:00	—	2:00	2:00
Cleaning verification	2:00	3:45	—	4:00
Load AER/Test MEC	2:00	0:45	7:45	12:30
AER cycle length*	32:00	23:00	26:00	55:00
Drying after HLD**	30:00	2:15	10:45	5:00
Transport to storage	5:00	—	8:00	8:00
Other	10:00	—	5:15	—
Total turnaround	96:15	41:15	91:30	108:45

* AER cycle time not included in hands-on reprocessing time/salary cost

** Drying time not included in hands-on reprocessing time/salary cost at Sites A, C, and D because it was performed in AER or drying cabinet. Site B used an air pistol which requires hands-on staff time

— Not done

Figure 1: Time required for reprocessing bronchoscopes using HLD





were used equally. Study sites would have needed to re-reprocess bronchoscopes 0 to 3 times per week (Table 11); however, we learned that physicians strongly preferred certain bronchoscopes. This meant that most bronchoscopes were rarely used and needed to be re-processed frequently.

Therefore, we used the actual number of re-reprocessing cycles reported by sites to calculate the cost of the total number of times each bronchoscope was reprocessed between procedures. Then we multiplied that figure by the cost of reprocessing supplies and staff time at each site to estimate the total cost of reprocessing performed between bronchoscopy procedures, including all the times it was re-reprocessed due to hang time (Table 11).

Overall cost summary

Total cost for reusable bronchoscopes

To calculate the total cost per use for reusable bronchoscopes, we added the acquisition and maintenance costs to the reprocessing costs (including wages, consumable materials and re-reprocessing). The total cost ranged from \$281 to \$803 per use (Figure 2).

These numbers greatly underestimate the total because we did not include any costs associated with essential equipment such as leak testers, irrigation systems, AERs and drying cabinets. In addition, the costs illustrated in Figure 2 do not include personnel time for routine tasks that could not be attributed to a single bronchoscope reprocessing cycle.

Sterilization

One site regularly sterilized bronchoscopes. The study coordinator reported that sterilization involved several extra steps, including thorough drying, packaging, and loading and initiating the cycle. The turnaround time for a sterilized bronchoscope was 142

Table 10: Cost of hands-on staff time for reprocessing bronchoscopes

	Site A	Site B	Site C	Site D
Proportion certified	100%	0%	0%	100%
Hourly salary by position				
CS/SPD tech	\$15-\$20	—	\$18-\$19	\$29-\$35
SPD manager	\$35-\$36	—	—	\$35-\$55
RT	—	—	\$29-\$30	—
Endo tech	—	\$15-\$20	\$20-\$25	—
Anesthesia assistant	—	—	\$20-\$21	—
Staff time per reprocessing cycle				
Hands-on reprocessing time	34m (.57hr)	18m (.3hr)	55m (.92hr)	49m (.82hr)
Average hourly salary*	\$17.50/hr	\$17.50/hr	\$24.00/hr	\$32.00/hr
Average salary cost per cycle**	\$10	\$5	\$22	\$26

* Bold dollar ranges within the hourly salary by position portion of the table indicate data used to calculate average hourly salary, which was based on staff who reprocessed bronchoscopes most frequently

** “Hands-on reprocessing time” (in hours) x “Average hourly salary” = “Average salary cost per cycle” (rounded to the nearest whole number)

— Not involved in hands-on reprocessing

Table 11: Impact of “hang-time” policies and practices on reprocessing cycles

	Site A	Site B	Site C	Site D
Site statistics				
Maximum storage time	14 days	7 days	7 days	30 days
Annual uses per scope	16	26	47	27
Re-reprocessing expected if bronchoscopes used equally				
Annual re-reprocessing cycles	111	130	45	0
Actual re-reprocessing cycles due to hang-time limits				
Annual re-reprocessing cycles	726	36	364	63
Total reprocessing cycles per procedure	3.1	1.28*	1.87	1.26
Total reprocessing costs including re-reprocessing				
Consumable supplies**	\$80	\$40	\$58	\$47
Hands-on staff time***	\$31	\$6	\$41	\$33
Total	\$111	\$46	\$99	\$80

* Upon review, site discovered that scopes were not being re-reprocessed according to policy

** “Total reprocessing cycles per procedure” x “Total supply cost” (from Table 8) = “Consumable supplies”

*** “Total reprocessing cycles per procedure” x “Hands-on staff time” (from Table 10) = “Hands-on staff time”



minutes, which was 46 minutes longer than their turnaround time for HLD. This site reported that sterilization requires machines that are more expensive than AERs (Table 12), as well as additional supplies, including sterilization trays, wraps, dust covers, sterilant, and chemical and biological indicators.

Single-use bronchoscopes

Three sites had obtained single-use Ambu bronchoscopes for procedures done in certain departments, after hours, or in emergency situations (Figure 3). These bronchoscopes are sterilized and shipped to customers in single-use packaging that maintains sterility. Institutions must also purchase a compatible computer monitor from the manufacturer. Sites reported the following costs:

- Single-use bronchoscopes: \$290 to \$315 each
- Reusable computer monitors: \$2,000 to \$3,150 each

Others in the field have obtained single-use bronchoscopes for \$220 to \$270. They attributed their lower costs to manufacturer discounts related to higher procedural volume.

Additional costs related to reusable bronchoscopes

The cost of expensive equipment that is necessary for reprocessing could not be attributed solely to bronchoscopes. Although these costs were not included in the aforementioned calculations, we included details about equipment acquisition costs to support institutions and researchers interested in evaluating their own programs (Table 12).

When site coordinators were measuring bronchoscope reprocessing time, they also tracked the time required for routine tasks that are not specific to

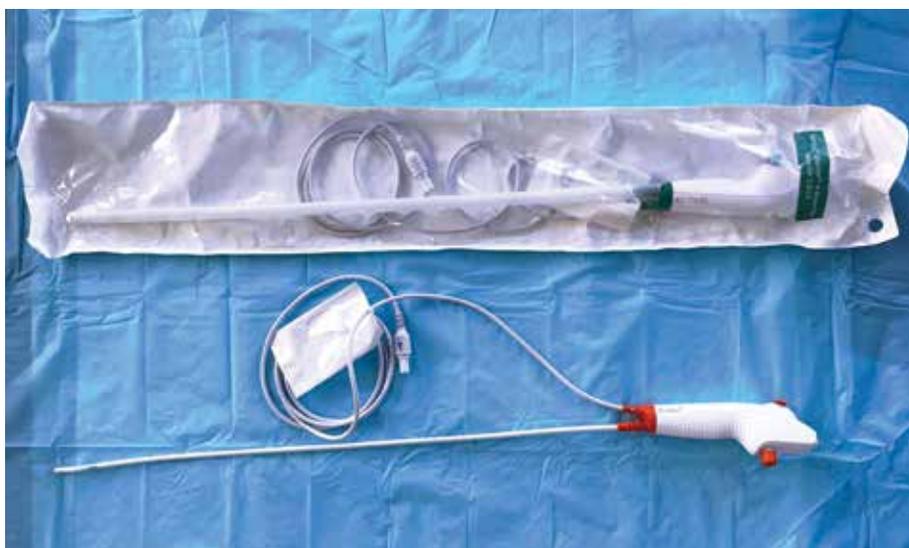
The Bottom Line

- Cost of using high-level disinfected (HLD) bronchoscopes: \$281 to \$803 per procedure
- Cost of purchasing each single-use bronchoscope: \$220 to \$315
- Reprocessing turnaround time for disinfected bronchoscopes: 41 to 109 minutes
- Increase in turnaround time when bronchoscopes are sterilized: 46 minutes more than HLD

Figure 2: Total cost per use for reusable bronchoscopes



Figure 3: Ambu single-use bronchoscope



Photograph taken by Ofstead & Associates, 2018



bronchoscopes. There was substantial variation in the approaches used and frequency of tasks, such as cleaning reprocessing and storage areas and disinfecting transport bins (Table 13). At all sites, these responsibilities added to the burden on reprocessing staff.

In addition to routine tasks done by technicians, managers and supervisors invested numerous hours on administrative tasks and other responsibilities related to reprocessing endoscopes (Table 14). The time required to prepare for inspections by accreditation agencies, address

reprocessing breaches or respond to potential outbreaks varies based on circumstances and could be substantial.

Due to time and resource constraints, we were unable to gather data on several other important cost factors, including worker benefits and training; preparing for and conducting audits; space for reprocessing and storage; water; electricity; and costs and materials associated with failed cleaning verification tests or AER cycles. As such, this paper underestimates the true cost of performing procedures with reusable bronchoscopes.

Summary and recommendations

Key findings

- Bronchoscopes must be available 24 hours per day in bronchoscopy labs, ERs, ORs and ICUs.
- To ensure availability, large inventories of bronchoscopes were obtained and maintained, which were significant drivers of cost per procedure.
- Reprocessing was commonly performed by personnel who lacked certification or adequate training.
- Reprocessing practices vary widely and do not meet current standards and guidelines.
- Substantial resources were spent re-reprocessing bronchoscopes that reached hang time limits.
- The real-world cost for procedures with reusable bronchoscopes (\$281 to \$803) was comparable or higher than the cost of single-use bronchoscopes (\$220 to \$315).
- Quality management systems are needed to improve personnel competence, bronchoscope inventory management, maintenance, reprocessing effectiveness, and storage.

Based on our bronchoscope reprocessing effectiveness study⁵ and this cost study, we recommend that all

Table 12: Examples of costs for equipment used at study sites

Item	Site A	Site B	Site C	Site D
AER	\$50,000	\$19,500	\$40,000	\$40,000
Sterilizer	\$135,000	\$116,000	—	—
Leak tester	\$3,500	\$510	\$900	\$800
Detergent dispenser	\$1,500	—	—	—
Magnification station	\$1,500	—	\$125	\$60
Borescope	\$5,100	—	—	\$2,800
Luminometer	—	\$1,500	—	\$2,500
Storage cabinet	—	\$2,900	\$3,500	\$4,800
IFU software	\$4,000	—	—	—
Tracking software	\$150,000	—	—	—

— Data not provided or site does not use equipment

Table 13: Hands-on time spent on routine tasks related to reprocessing

	Site A		Site B		Site C		Site D	
	Time per task	Frequency						
Cleaning decontam area	15:00	3/day	4:15	Daily	0:45	1/cycle	3:30	3/day
Wiping down clean side	10:00	3/day	3:30	Daily	0:45	1/cycle	3:00	1/cycle
Ordering supplies	75:00	Weekly	3:00	2/week	1:15	1/week	—	—
Cleaning storage cabinets	3:30	Monthly	12:00	Weekly	6:45	Weekly	3:00 20:00	Daily Weekly
Prepping for repair	195:00	As needed	—	—	2:45	As needed	60:00	As needed
Taking garbage out	5:00	4/day	2:00	Daily	3:15	As needed	—	—
Disinfecting transport bins	—	—	0:10	1/cycle	1:30	1/cycle	2:30	1/cycle

— Data not provided

**Table 14:** Time spent by managers in charge of endoscope reprocessing

Task	Site A	Site B	Site C	Site D
Endoscope meetings	2	2	3	5
Endoscope training	4	—	4	27
Tracking endoscope data	8	1.5	3	8
Verifying PM schedules	4	1.5	—	1.5
Supervising reprocessing	40	2	4.5	9
Managing HR issues	8	—	3	3
Infrastructure issues	4	—	5.5	1
Developing educational tools	—	—	2	—
Literature review	8	—	2	—
Total hours per month	78	7	27	54.5

— Data not provided

institutions consider:

- Reviewing regulations, standards and manufacturers' IFU;
- Evaluating bronchoscope inventory and retiring old or infrequently-used bronchoscopes;
- Centralizing reprocessing activities in the Central Service/Sterile Processing department;
- Sterilizing bronchoscopes that are compatible with available sterilization systems;
- Obtaining single-use bronchoscopes for after hours and emergency situations and any procedures that do not require advanced bronchoscopy capabilities; and
- Arranging for experts to perform periodic audits and provide consultation to ensure that regulations and standards are being followed.

Evaluating bronchoscopy programs and making the appropriate changes is critically important. Recent research shows that current reprocessing methods (generally with HLD) are not effective enough to ensure that bronchoscopes are free of contamination after reprocessing^{3,5,9-11}; therefore, alternatives are not only economical but critical to

improving quality and ensuring patient safety.

Acknowledgements

We appreciate the support provided by personnel at study sites. In addition, several reprocessing experts provided consultation for this project, including Phillip Van Gorp, CRCST; Petra M. Richards, CFER, CSPDT; John H. Erickson, BS, CRCST; and Katherine E. Lucht, RN, BSN. We also appreciate the editorial assistance of Brandy Buro and Melissa Anderson and the graphic design expertise provided by Joseph O'Connor. This study was supported by an unrestricted research grant from Ambu. The study sponsor did not participate in designing the study, identifying sites, collecting data, compiling results, interpreting the findings or writing this article. ©

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