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Comparison of automated and manual drying in the elimination of residual endoscope working channel fluid after reprocessing (with video)

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Abstract

Background and Aims: Residual fluid within endoscope working channels after reprocessing may promote growth of pathogens. Current reprocessing guidelines therefore recommend endoscope drying with administration of forced filtered air; however, the duration and modality of administered air are not specified. The new DriScope Aid device enables automated administration of filtered air at controlled pressure through all internal endoscope channels. We systematically compared, for the first time, the impact of manual drying and automated drying on retained working channel fluid and bioburden after reprocessing.

Methods: We assessed for residual working channel fluid after reprocessing and/or drying by using the SteriCam borescope. Drying was performed either manually (forced filtered air) or was automated (DriScope Aid) for either 5 or 10 minutes. Adenosine triphosphate (ATP) bioluminescence testing was performed on working channel rinsates after drying, to evaluate for residual bioburden.

Results: Significantly more fluid droplets were evident after manual drying (4.55 ± 6.14) than with automated device-facilitated drying for either 5 minutes (0.83 ± 1.29 ; $P = .007$) or 10 minutes (0 ± 0 ; $P = .001$). ATP bioluminescence values were higher for manual drying compared with automated drying at 48 hours ($P = .001$) and 72 hours ($P = .014$) after reprocessing.

Conclusions: We demonstrate significantly fewer water droplets and delayed ATP bioluminescence values within endoscope working channels after automated drying compared with manual drying. In particular, virtually no retained fluid was evident within endoscope working channels after automated drying for 10 minutes. These findings support recommendations for automation of as many reprocessing steps as possible. Automated drying may decrease the risk of transmission of infection related to endoscopy. (*Gastrointest Endosc* 2019;89:124–32.)

The reprocessing of flexible endoscopes after use is a complex, multi-step process. The broad steps include point-of-use pre-cleaning, manual cleaning, and high-level disinfection

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(HLD) followed by alcohol flushes and drying. Residual moisture within endoscope channels may promote retention and proliferation of waterborne pathogens, and inadequately dried endoscopes have been associated with growth of *Pseudomonas aeruginosa* and *Mycobacterium* species within endoscopes.¹⁻³ The 2016 multi-society guidelines on endoscope reprocessing recommend flushing endoscope channels with alcohol followed by the application of forced filtered air to facilitate drying, although the duration and modality of administration of forced filtered air are not specified.⁴ The extent to which alcohol flushes and application of forced filtered air accomplish endoscope drying remains undetermined. Additionally, the threshold at which retained fluid within endoscope working channels becomes a risk for bacterial proliferation remains undefined. Given these unknowns, the multi-society guidelines include redundant steps to promote endoscope drying after reprocessing and recommend that endoscopes be hung vertically during storage.

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There has previously been no direct method to confirm adequate drying of endoscope working channels after reprocessing. A recent advance has been development of small-diameter borescopes, and we and others have used these to visualize endoscope working channels.^{5-7,8} These studies have noted residual fluid in the working channels of 42% to 95% of reprocessed endoscopes despite alcohol flushing and drying steps, suggesting that current reprocessing protocols may be insufficient to ensure complete drying of endoscopes immediately after reprocessing.^{6,8} It is possible that the residual fluid noted in these studies is related to variability in drying protocols and their implementation. Several studies have indicated that human lapses and inattention during manual reprocessing steps remain a significant issue during endoscope reprocessing, and increased automation and standardization of the process is preferable.⁹

The DriScope Aid (Tricor Systems, Elgin, Ill) is an endoscope drying machine that has recently become commercially available. It enables automated administration of filtered air at controlled pressure through all internal endoscope channels for a programmable duration of time. In this study we compared the efficacy of automated drying by using this new device, with manual application of forced-filtered air in the elimination of residual fluid in endoscope working channels after reprocessing. We also measured adenosine triphosphate (ATP) bioluminescence to evaluate for associated residual bacteria and/or bio-burden after both drying approaches.

METHODS

Three drying protocols (manual drying, 5-minute automated drying, and 10-minute automated drying) were evaluated for their efficacy in eliminating residual fluid within the working channels of a variety of endoscopes after reprocessing in an automated endoscope reprocessor (AER). Evaluations were performed within 30 minutes of reprocessing and at 24 hours, 48 hours, and 72 hours (Fig. 1).

Endoscopes evaluated

Six standard and/or diagnostic gastroscopes, 6 adult and/or standard colonoscopes, 5 linear echoendoscopes, and 6 duodenoscopes were evaluated. Study endoscopes underwent

preliminary SteriCam inspection (Sanovas Inc, San Rafael, Calif) to evaluate working channel damage and were preselected to have endoscope working channel damage limited to minimal or mild on the scale we described previously.⁷ This range of wear-and-tear changes is typical of endoscopes in our endoscopy unit.⁷ All study endoscopes were evaluated in triplicate at each study time point for each study drying protocol.

Endoscope reprocessing protocol

At our institution, endoscope reprocessing is composed of point-of-use precleaning performed by an endoscopy unit technician. Manual cleaning and HLD are then performed by designated personnel in our centralized sterile processing department (SPD). HLD is performed by using a Medivators Advantage Plus (Minntech, Minneapolis, Minn) AER with per-acetic acid as the disinfectant. The HLD cycle culminates in isopropyl alcohol flushes followed by an automated 1-minute air purge within the AER. A subset of endoscopes was inspected immediately after this AER protocol and before either manual or automated drying.

ENDOSCOPE DRYING PROTOCOLS

Standard manual drying

After HLD in the AER, all endoscopes undergo manual drying of the endoscope working channel for 10 minutes with forced high-efficiency particulate filtered air, as per our institution's standard manual drying protocol. This is administered by using a forced-air administration apparatus (Safety Air Gun, LZR600; Guard Air Corporation, Chicopee, Mass). SPD personnel were aware that a drying study was underway but were not aware of the specifics of the study.

Automated drying

The DriScope Aid is a 20 × 15 × 16-cm endoscope drying device weighing 2 kg, which may be placed on countertops or may be pole and/or wall-mounted (Fig. 2A). The device uses disposable connectors and tubing (Fig. 2B) to deliver constant high-efficiency particulate filtered air to all internal endoscope channels, including the working channel, waterjet channel and handpiece. Manufacturer-specific adapters are available to facilitate drying of all major endoscope brands (Olympus, Pentax, and Fujinon). The device has a digital display with touchpad controls and drying times that are programmable to between 1 and 99 minutes. The cost of the DriScope Aid device used in this study is \$2995. Tubing maybe used for 24 hours; the tubing costs \$17, and the per-use connectors for each endoscope cost \$3.25 each (per manufacturer and/or distributor).

After HLD in the AER, study endoscopes were attached to the DriScope Aid device. The duration of drying was set for either 5 minutes or 10 minutes for the designated study arms.

Study design

Assuming that some fluid might be retained within the working and waterjet channels of endoscopes despite drying with either the manual or automated approach, we initially assessed for this qualitatively.

After completion of manual or automated drying, we connected 5 endoscopes dried by each method to the DriScope Aid device for 5 minutes to allow the automated air delivery device to force out residual fluid from all endoscope channels. A piece of carbon paper (Blulu Carbon Transfer Paper; Distributed by WillBond Shop) was positioned under the distal end of the endoscope to collect pooled expelled fluid.

An initial bench study was conducted to qualitatively visualize expelled fluid from the tips of endoscopes after completion of each drying protocol. For this qualitative study, the DriScope Aid device was connected to endoscopes to deliver automated forced air for 5 minutes to endoscope channels, and expelled fluid was collected on carbon paper.

Quantitative assessment was then performed. Every study endoscope was evaluated after each drying protocol (manual drying, 5-minute automated drying, and 10-minute automated drying) and at each time point (0 hours, 24 hours, 48 hours, 72 hours) (Fig. 1). Endoscopes were reprocessed before each of these individual evaluations. This primary evaluation included inspection by using a borescope and ATP bioluminescence testing on working channel rinsates. The order in which drying protocol and latency to evaluation were implemented for individual endoscopes was determined in a randomized fashion. These drying protocols and evaluations were repeated in triplicate for each endoscope.

In the interval after reprocessing and/or drying and before inspection, endoscopes were stored in air circulation cabinets, as is our institutional protocol, except as indicated below for the secondary evaluation of the impact of endoscope storage modality on retained fluid droplets. For this secondary assessment, single rather than triplicate endoscope evaluations were performed.

ENDOSCOPE EVALUATION

We used an ultra-slim flexible inspection borescope (SteriCam; Sanovas Inc, San Rafael, Calif) to inspect endoscope working channels for retained residual fluid and damage after reprocessing, as we have previously described.⁷ The SteriCam borescope was reprocessed immediately before each use, as recommended by the manufacturer, with disinfectant wipes (PDI Super Sani Cloth Germicidal Wipes Orangeburg, NY, USA) for a full 2 minutes of contact time, followed by air-drying for 10 minutes. Previously reported controls confirm that passage of the reprocessed SteriCam endoscope did not affect ATP bioluminescence values.⁷

We additionally evaluated ATP bioluminescence values on rinsates collected from the working channels of these endoscopes as previously reported.^{7,10,11} Working channel borescope inspections and rinsate collections were performed immediately (within 30 minutes) and at 24, 48, and 72 hours after endoscope reprocessing and/or drying, with a single inspection performed on each endoscope per reprocessing cycle (Fig. 1). This study was approved by the Stanford Institutional Review Board (Protocol no. 40603).

Impact of endoscope storage modality on retained fluid

For evaluation of the impact of storage modality on retained fluid within endoscope working channels, all endoscopes were randomly assigned to either vertical storage in air-circulation cabinets or to horizontal storage in transport bins as described below.

During the interval between endoscope reprocessing and/or drying and borescope evaluation, each study endoscope was stored vertically in air-circulation cabinets, which circulate air around endoscopes for the designated time after each drying protocol and before evaluation (24 hours, 48 hours, or 72 hours). Unlike drying cabinets, air-circulation cabinets do not have connectors to circulate air through endoscope channels. Similarly, study endoscopes were coiled and stored horizontally in standard transport bins immediately after endoscope reprocessing and/or drying for the designated time before evaluation (24 hours, 48 hours, or 72 hours).

Statistical analysis

Analyses were conducted by using SAS Enterprise Guide version 7.11 HF3 (SAS Institute Inc, Cary, NC) and Microsoft Excel (Microsoft, Redmond, Wash). Mean and standard deviation (SD) values are reported. Values were compared by using a 2-tailed *t* test assuming unequal variance. Reported *P* values are 2-sided, statistical significance was attained at *P* < .05, and adjustment was made for multiple comparisons by using the method of Bonferroni. Regression analysis was performed by using generalized linear models.

RESULTS

Qualitative assessment of retained fluid despite manual and automated drying

The amount of retained fluid within all endoscope channels after manual and automated drying was visually assessed on carbon paper. In all 5 evaluated endoscopes that were dried manually, drops of fluid that coalesced and created small pools were expelled from the endoscope tip (Fig. 3A). In contrast, after 5 minutes of automated drying, only rare single fluid droplets were observed in 4 of 5 evaluated endoscopes, and no fluid droplets were observed in the remaining evaluated endoscope (Fig. 3B). No fluid droplets were observed after 10 minutes of automated drying in any of the 5 evaluated endoscopes.

Quantitative assessment of working channels with borescope

Retained working channel fluid after AER cycle.—Alcohol flushes and the AER's programed 1-minute air purge were insufficient to dry endoscopes. Multiple coalescing shallow pools of residual fluid were visualized within the working channels of each endoscope inspected at this stage (Fig. 4A).

Retained working channel fluid after manual drying.—After manual drying, a mean ($\pm$ SD) of 4.55 ($\pm$ 6.14) fluid droplets were evident in endoscope working channels on evaluation immediately ($\leq$ 30 minutes) after drying. As expected, we subsequently noted decreasing numbers of fluid droplets when groups of endoscopes were evaluated over increasing time intervals. A mean of 1.62 fluid droplets was noted in endoscopes evaluated at 24 hours, 0.51 fluid droplets in those evaluated at 48 hours, and none in those evaluated at

72 hours after drying (Table 1), (Supplementary Table 1, available online at www.giejournal.org), (Fig. 4B), (Video 1, available online at www.giejournal.org).

Retained working channel fluid after automated drying.—Automated device-facilitated drying for 5 minutes resulted in a smaller number of retained fluid droplets than manual drying, with a mean of only 0.83 ($\pm$ 1.29) fluid droplets evident in endoscope working channels on evaluation immediately ($\leq$ 30 min) after drying. Again, decreasing numbers of fluid droplets were noted when groups of endoscopes were evaluated over increasing time intervals, with 0.20 droplets noted in endoscopes evaluated at 24 hours, 0.04 droplets in those evaluated at 48 hours, and none at 72 hours after drying (Table 1), (Supplementary Table 1) (Fig. 4C). Automated drying for 5 minutes resulted in significantly fewer mean fluid droplets relative to manual drying immediately (4.55 vs 0.83; $P = .007$), at 24 hours (1.62 vs 0.20; $P < .001$), and at 48 hours (0.51 vs 0.04; $P = .003$) after endoscope reprocessing.

Automated drying for 10 minutes resulted in the smallest number of retained fluid droplets. Standard HLD followed by 10 minutes of automated drying resulted in a mean of 0 ($\pm$ 0) fluid droplets in endoscopes evaluated immediately after drying, 0.01 fluid droplets in endoscopes evaluated at 24 hours, and none in endoscopes evaluated at either 48 or 72 hours after drying (Table 1), (Supplementary Table 1).

Automated drying for 10 minutes resulted in significantly fewer fluid droplets relative to manual drying in endoscopes evaluated immediately (mean of 4.55 vs 0; $P < .001$), at 24 hours (1.62 vs 0.01; $P < .001$), and at 48 hours (0.51 vs 0; $P = .001$) after HLD. Automated drying for 10 minutes also resulted in significantly fewer fluid droplets relative to automated drying for 5 minutes immediately after endoscope reprocessing (0.83 vs 0; $P = .004$) and at 24 hours after endoscope reprocessing (0.20 vs 0.01; $P = .014$). There was no significant difference in the number of residual fluid droplets between 5 minutes and 10 minutes of automated drying at 48 (0.04 vs 0; $P = .08$) or 72 hours (0 vs 0; $P = 1.0$) after endoscope reprocessing (Table 1), (Supplementary Table 1).

Impact of endoscope storage modality on retained fluid.—Vertical endoscope storage in accordance with the multi-society recommendations appeared beneficial after manual drying, but storage modality did not affect fluid retention after automated drying.

After manual drying, endoscope storage in vertical air circulation cabinets for the intervals studied resulted in significantly fewer fluid droplets in endoscope working channels at 24, 48, and 72 hours compared with endoscopes stored coiled within transport bins ($P < .001$).

In contrast, after automated drying, there was no significant difference in the number of fluid droplets based on endoscope storage modality after 5 minutes of automated drying ($P = .450$ at 24 hours, no droplets at 48 or 72 hours) or 10 minutes of automated drying ($P = .611$ at 24 hours, no droplets at 48 or 72 hours).

ATP bioluminescence values after manual and automated drying

ATP bioluminescence values from endoscope working channel rinsates collected immediately after drying did not differ significantly from endoscopes undergoing either manual or 5-minute automated drying (8.65 vs 9.01 relative light units; $P = .696$). However, 10-minute automated drying was associated with significantly lower endoscope working channel ATP bioluminescence values immediately after drying, compared with both manual and 5-minute automated drying (6.04 relative light units; $P = .007$; $P = .005$, respectively) (Table 2), (Supplementary Table 2, available online at www.giejournal.org).

At 24 hours after reprocessing, no significant difference was evident in ATP bioluminescence values after automated drying (for either 5 or 10 minutes) and manual drying ($P = .050$; $P = .982$). However, ATP bioluminescence values were significantly lower after 5-minute and 10-minute automated drying compared with manual drying at both 48 hours ($P = .001$; $P < .001$) and 72 hours ($P = .030$; $P = .014$) after reprocessing (Table 2, Supplementary Table 2).

Impact of endoscope type and working channel damage on retained fluid and bioburden

After manual drying, colonoscopes were associated with more residual fluid droplets in comparison with other endoscope types immediately ($P = .020$) and at 24 hours ($P = .010$) after drying, but at 48 and 72 hours, endoscope type did not predict greater fluid retention. After automated drying, endoscope type (colonoscopy vs gastroscopy vs echoendoscopy vs duodenoscopy) did not predict the number of residual fluid droplets ($P = .310$) at any time point in our regression analysis. Regression analysis also revealed that the working channel damage rating (within the range of mild damage evaluated in this study) did not predict residual fluid or ATP bioluminescence values for either manual or automated drying.

DISCUSSION

Adequate endoscope drying after HLD is important, because residual moisture within endoscope working channels may facilitate bacterial proliferation during endoscope storage.² After alcohol flushes, the range of options for endoscope drying include 1 or a combination of vertical storage alone, a post-HLD air purge in the AER, manual drying by using a handheld forced air delivery apparatus, storage in air circulation cabinets that circulate air throughout the cabinet but not directly into the endoscope channels, or storage in drying cabinets that deliver forced filtered air directly into endoscope channels.

There is a paucity of data regarding the necessity of, and optimal modalities for, drying of flexible endoscopes after reprocessing. Additionally, endoscope reprocessing and/or drying recommendations from different sources vary. Alcohol flushes are recommended by some for their antimicrobial activity¹² and to promote drying,^{4,13,14} whereas the British Society of Gastroenterology recommends against alcohol flushes because of concerns that the fixative properties of alcohol may, over time, promote pathogen retention within endoscopes.^{15,16} Similarly, although some emphasize the importance of thoroughly drying endoscopes after each reprocessing cycle,¹⁷ others indicate that drying is not necessary if an endoscope is

used within 3 to 4 hours of disinfection and recommend drying only before prolonged storage.^{16,18,19}

Given the lack of firm regulatory and/or societal guidance regarding the best approach for drying of endoscopes after HLD, it is not surprising that the range of drying practices varies widely between institutions, even within the same healthcare system. In a recent duodenoscope reprocessing survey, only 47.8% of the 249 responding centers reported using the AER air purge cycle or any post-reprocessing drying such as administration of manual forced air to the working channel.²⁰ In a study of 3 hospitals within the same healthcare system, drying practices varied from only alcohol flushes and vertical endoscope storage, to alcohol flushes followed by pressure-regulated forced-air drying.⁸ The study noted residual fluid in 47% of endoscope working channels examined after 24 to 48 hours of storage.⁸ Similarly, we previously reported residual fluid droplets after drying in 42% of endoscope working channels examined within 24 hours of reprocessing,⁷ despite our institution's formal standardized SPD protocol of alcohol flushes and air purges in the AER followed by manual administration of forced filtered air for 10 minutes.

Human lapse or error in the manual steps of cleaning may contribute to endoscopy-associated infections.²¹ Standardization and automation of processes minimizes the impact of human deficiencies. A 2010 multi-site observational study reported only 1.4% adherence to reprocessing guidelines when endoscopes were reprocessed using manual cleaning methods and 75.4% adherence to guidelines when an AER was used.²¹ Based on this principle, the Center for Disease Control issued a statement indicating that automation of reprocessing is beneficial in "reducing the likelihood that an essential reprocessing step will be skipped."⁹ However, even when an AER is used, the automated reprocessing steps are straddled by manual cleaning steps before, and manual drying steps after HLD, which remain susceptible to human lapses.

A potential reason for the presence of residual fluid despite a rigorous drying protocol may be the human element inherent in manual drying of endoscopes. Manual application of forced air requires holding the air delivery device to the working channel for a set time. However, tasks requiring protracted human attention may be susceptible to truncation in the setting of a busy SPD. In institutions without a centralized SPD, it is possible that these demands on the time of nurses and technicians performing reprocessing and/or drying may be even greater, further increasing the potential for human lapses. In contrast to administration of manual forced air, which requires sustained human attention and can dry the working channel only, the DriScope Aid device offers an automated approach to the administration of forced air for a programmed duration of time and accomplishes drying of all endoscope channels.

Our study lends further support to the broad principle that when standardized operations and reliable outcomes are desired, automation is preferable to manual processes. We demonstrate for the first time that automated endoscope drying by using the DriScope Aid is associated with significantly fewer residual fluid droplets within endoscope working channels than after manual drying. After the brief AER air purge cycle and before either manual or automated drying, we saw coalescing pools of residual fluid within endoscope working channels. After

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manual administration of forced air to the working channel per our institution's SPD standard protocol, scattered fluid droplets were nevertheless evident in endoscope working channels. Automated drying by using the DriScope Aid for 5 minutes resulted in significantly fewer fluid droplets immediately after drying in comparison with manual drying. Importantly, after automated drying for 10 minutes, no fluid droplets were seen in any endoscope working channel.

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Fluid within endoscope working channels diminishes over time when endoscopes are hung vertically in air circulation or drying cabinets.^{22,23} Consistent with this, we demonstrated fewer working channel fluid droplets at sequential time points in the 72 hours after manual drying. We also found that endoscope working channels had significantly lower ATP bioluminescence values after 48 and 72 hours of endoscope hang time after automated drying, in comparison with manual drying. This may reflect bacterial proliferation in residual moisture that remains within endoscope working channels after manual drying. The thorough drying achieved with automated drying may minimize this bacterial proliferation and thereby lower the risk of transmission of infection related to endoscopy.

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Additionally, the thorough drying of endoscope working channels achieved with the automated approach potentially makes the need for subsequent vertical storage less critical. After automated drying, we noted no significant difference in working channel fluid droplets between endoscopes that were stored vertically and those that were stored horizontally, coiled in compact transport bins.

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As drying times may vary from one endoscope type to another, based on endoscope length and working channel diameter, it may be best to simplify automated drying protocols by having a standardized drying time for all endoscopes. Streamlining drying routines in this manner may result in better compliance with drying protocols. We have demonstrated that after automated drying for 10 minutes no fluid droplets were seen in any endoscope working channel. The optimal duration for automated drying with the DriScope Aid may therefore be at or near 10 minutes. If additional studies of automated drying confirm that definitive and predictable drying can be achieved consistently, short-term storage of endoscopes may be accomplished in space-saving and cost-efficient storage bins rather than in expensive and bulky vertical air circulation cabinets.

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Limitations of our study include that it was conducted at a single institution. Our manual drying data reflect current standard reprocessing practices at our institution, and we did not audit each reprocessing cycle for technique or duration of forced air administration during manual drying. SPD personnel were aware that a drying study was underway, thus their manual drying performances may have been enhanced because of the Hawthorne effect. Due to the borescope caliber, we evaluated only endoscope working channels and could not inspect waterjet channels for retained fluid. We measured ATP bioluminescence values to assess for microbial residue instead of bacterial cultures, and these values were low for the endoscopes studied. ATP bioluminescence has been validated previously as a method for surveillance of flexible endoscopes after manual cleaning^{11,24} and HLD.^{10,25,26} Although low ATP bioluminescence values are reassuring, they do not unequivocally indicate that endoscope working channels are free of microbial residue.^{11,27} Similarly, high ATP

bioluminescence values do not directly correlate with bacterial burden and are thus not reliably predictive of the potential for endoscope-transmitted infection.²⁸ Nevertheless, endoscope cultures for microbial surveillance also remain controversial, are not endorsed in the 2016 multi-society guidelines for endoscope reprocessing,⁴ and are susceptible to environmental contamination.²⁹

Our data represent the first systematic comparison of manual and automated drying approaches, attest to the superiority of automated drying, and add credence to recommendations for automation of as much of endoscope reprocessing as possible. Implementation of automated drying in endoscopy units that already use an AER for HLD would result in automation of all major steps in endoscope reprocessing other than manual cleaning. Our results suggest that vertical storage in an air circulation cabinet may not be necessary after the consistently thorough drying achieved by automation. The effectiveness of automated drying will minimize bacterial proliferation and protect against transmission of infection related to endoscopy.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Abbreviations:

ATP	adenosine triphosphate
AER	automated endoscope reprocessor
HLD	high-level disinfection
SPD	sterile processing department

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Figure 1.

Study flow diagram: Working channel visual inspections and rinsate collections were performed at baseline (*within 30 minutes*) and at 24, 48, and 72 hours after endoscope reprocessing and/or drying. *ATP*, Adenosine triphosphate bioluminescence.

Figure 2.
A, Image of the DriScope Aid device. **B,** Disposable tubing and/or connectors.

Figure 3.

A, Qualitative visual assessment of fluid expelled from the endoscope tip when the DriScope Aid device was connected for an additional 5 minutes of drying after manual drying. **B,** Qualitative visual assessment of fluid expelled from the endoscope tip when the DriScope Aid device was connected for an additional 5 minutes of drying after 5 minutes of automated drying was performed. The scale bar on each image represents 1 cm.

Figure 4.

A, Borescope examination demonstrating a coalescing pool of fluid (*long arrows*) and individual fluid droplets (*short arrows*) after high-level disinfection and 1-minute air purge in the automated endoscope reprocessor. **B,** Discrete fluid droplets after high-level disinfection, 1-minute air purge in the automated endoscope reprocessor, and 10 minutes of manual drying. **C,** Rare, discrete fluid droplet (*arrow*) after high-level disinfection, 1-minute air purge in the automated endoscope reprocessor and 5 minutes of automated drying.

TABLE 1.

Quantification of residual fluid droplets at time points after manual and automated drying

	Baseline no. droplets (SD)	24 hours no. droplets (SD)	48 hours no. droplets (SD)	72 hours no. droplets (SD)
Standard manual drying	4.55 (6.14)	1.62 (1.61)	0.51 (0.70)	0 (0)
5 Min automated drying	0.83 (1.29)	0.20 (0.34)	0.04 (0.11)	0 (0)
10 Min automated drying	0 (0)	0.01 (0.07)	0 (0)	0 (0)
P values droplets	Manual vs 5 min automated	Manual vs 10 min automated	Manual vs 5 min automated vs 10 min automated	
Droplets-24 h	.0002	< .0001	.0136	
Droplets-48 h	.0032	.0012	.0761	
Droplets-72 h	-	-	-	

TABLE 2.

Quantification of ATP bioluminescence values at time points after manual and automated drying

	Baseline ATP value in RLU (SD)	24 h ATP value in RLU (SD)	48 h ATP value in RLU (SD)	72 h ATP value in RLU (SD)
Standard manual drying	8.65 (3.89)	5.52 (2.71)	9.01 (3.30)	7.94 (3.92)
5 Min automated drying	9.01 (2.10)	7.01 (2.29)	6.25 (1.81)	6.00 (1.45)
10 Min automated drying	6.04 (2.09)	5.51 (1.47)	5.81 (1.54)	5.70 (1.58)
	Manual vs 5 min automated		Manual vs 10 min automated	
ATP baseline	0.6955		0.0069	
ATP 24 h	0.0494		0.9828	
ATP 48 h	0.0010		0.0001	
ATP 72 h	0.0310		0.0144	

ATP, Adenosine triphosphate, *RLU*, relative light units.