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Borescope inspection of endoscope working channels: Why and how?

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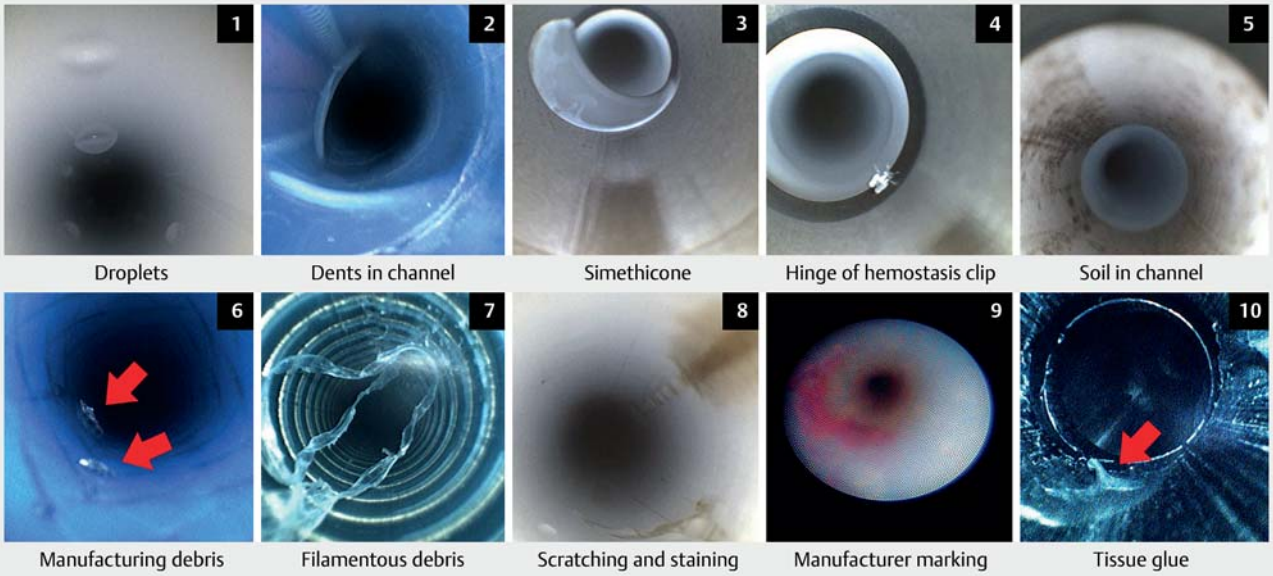
Borescopes are useful tools for inspecting endoscope channels and interior components, which are otherwise obscured due to being narrow and encased in opaque material. Their use is now recommended in many reprocessing guidelines. Our research team has conducted several studies on endoscope reprocessing effectiveness, during which we performed hundreds of borescope exams on a diverse array of endoscopes, including ureteroscopes, cystoscopes, bronchoscopes, endobronchial ultrasound endoscopes, gastroscopes, colonoscopes, duodenoscopes, and endoscopic ultrasound endoscopes. The interior architecture of various brands and models is diverse, with strikingly different appearance.

Over time, our team and others discovered that nearly 100 % of channels have visible defects, and the need for borescope inspections has become more apparent [1–4]. Myriad defects have been observed in patient-ready endoscopes, including fluid droplets, soil, staining, dents, scratches, shredding, debris, tissue glue, and fragments of accessories (▶ **Fig. 1**).

The clinical implications are sobering. Several peer-reviewed investigations have linked infections and deaths to visibly contaminated or damaged endoscopes (▶ **Table 1**) [5–7]. In one outbreak, two multidrug-resistant pathogens harbored inside a bronchoscope infected 19 patients before a borescope examination detected “proteinaceous debris” and a channel defect [5]. The authors hypothesized that retained debris “may have contributed to the establishment of a biofilm and subsequent contamination” and concluded that borescope examination is a “critical component of device reprocessing” [5]. Numerous adverse events linked to inadequately reprocessed endoscopes have been reported to the US Food and Drug Administration (▶ **Table 1**). These reports described retained tissue, stents, balloons, and reprocessing brush tips, which were discovered when they were expelled into another patient during a subsequent procedure.

Given our experience with borescope exams, we read with interest the new study by Barakat et al. on the use of artificial intelligence (AI) to assist with borescope examinations. We agree that human factors, including training, subjectivity, and the time and expertise needed to conduct borescope exams, can be barriers to implementation. We commend the authors for exploring how AI-supported borescope examinations could overcome these barriers. As Barakat et al. emphasized, endoscopes can be damaged during routine procedures, reprocessing, or transport, and as such, frequent borescope examinations would be beneficial. We have observed two approaches to implementing borescope inspections, namely using them for quality assurance during every reprocessing cycle or for periodic assessment of the endoscope fleet. Both approaches require careful consideration of program goals and logistics, such as what borescope sizes are needed; where, when and by whom exams will be performed; how exams fit into the reprocessing workflow; what will be done when defects are observed; and how to ensure that borescopes do not contribute to cross-contamination among the endoscope fleet or borescopist exposure to pathogens.

The value of inspections is dependent on image quality, which is impacted by the skill and technique used by the borescopist as well as the size and characteristics of the endoscope and whether soil, debris, fluid, lubricants, or simethicone are present and stick to the lens during the exam. The interpretation of observations by human borescopists or AI systems depends on their experience with diverse internal architecture of



▶ **Fig. 1** Diverse defects and retained debris in endoscope channels. Source: Ofstead & Associates, Inc.

▶ **Table 1** Patient exposure to endoscopes with damage or retained debris and contamination (2018–2020).

Endoscope type	Defects or retained material	Debris discovery and outcomes
Infections		
Bronchoscope [5]	Channel defects Proteinaceous debris	19 patients infected with superbugs; 10 died
Duodenoscope [6]	Cracked biopsy channel Brown staining around elevator	27 patients infected with superbug
Ureteroscope [7]	Surface cuts Non-intact channel lining	13 patients infected with superbug; 8 developed sepsis
Exposure to tissue retained in channels		
Bronchoscope [8]	Mesh or tissue	Pushed from channel into another patient's lung
Colonoscope [9]	Polyp	Pushed from channel into another patient
Gastroscope [10]	Foreign tissue	Pushed from channel into another patient
Exposure to retained devices		
Colonoscope [11]	Clip	Fell into another patient
Duodenoscope [12]	Pancreatic stent	Found in channel after several weeks; retrieved with tweezers
Gastroscope [13]	Banding device	Fell into another patient
Gastroscope [14]	Brush tip	Pushed out of channel during reprocessing
Colonoscope [15]	Clip	Fell into a patient two procedures later
Duodenoscope [16]	Sponge	Observed during procedure, pushed out of channel after scope extraction

various models of endoscopes, as well as various defects that may be present. Therefore, both technicians and AI systems require extensive training and competency testing before they can successfully perform borescope examinations and interpret the findings.

That said, our main criticism of the AI program described by Barakat et al. is that its accuracy was assessed only by three gastroenterologists whose opinions were deemed the "gold standard." Ideally, defects identified by either endoscopists or AI systems should be validated by experts in endoscope design, reprocessing, and repair. The ongoing development of such pro-

grams will undoubtedly require the collaboration of multidisciplinary teams including endoscope manufacturing experts, repair technicians, reprocessing personnel, infection preventionists, researchers, AI software developers, and clinicians. As the technology progresses, it is hoped that borescope examinations will become widely adopted as a proactive method for screening endoscopes to identify those in need of routine maintenance, repair, or refurbishment akin to colon cancer screening programs that identify patients with conditions that benefit from early identification and treatment.

Competing interests

Ofstead, Hopkins, and Eiland have received research grants, study materials, educational materials, or consulting contracts from 3 M Company, Ambu, Auris Health, Advanced Sterilization Products, Boston Scientific Corporation, Laborie/Cogentix, Convergascent, Fortive, Healthmark, Cantel/Medivators, Pentax, and Steris. These companies were not involved in drafting this editorial.

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