The Value of Borescopes in Detecting Damage, Soil, Fluid, and Foreign Objects in Flexible Endoscopes

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Importance of Visual Inspection During Endoscope Processing

Endoscope manufacturers recommend performing visual inspection every time an endoscope is used, in order to ensure that it is clean and free of damage.¹,² Guideline-issuing bodies, including the Association for the Advancement of Medical Instrumentation, Association of periOperative Registered Nurses, and the Society of Gastroenterology Nurses and Associates recommend using good lighting and magnification for this step.³–⁵ Visual inspection should be done every time because endoscopes are heavily contaminated during procedures, and organic soil and bioburden (microbes) must be removed prior to high-level disinfection or sterilization for those processes to be effective. In addition, endoscopes are fragile and commonly sustain damage that can harbor contamination during routine use.

Recent studies have found that endoscope processing is not reliably effective, with bacteria or mold found in more than half of tested endoscopes.⁶–⁸ Microbes have been detected even after enhanced processing methods (e.g., double high-level disinfection,⁹,¹⁰ sterilization¹¹,¹²) were used. In many cases, these failures have been associated with inadequate cleaning that was detected via the use of biochemical tests for organic soil (protein, hemoglobin, and adenosine triphosphate).

The Food and Drug Administration has received numerous reports of patient exposures and infections that occurred when processing did not remove tissue, blood, or accessories from previous procedures (Table 1). This is concerning even for healthy individuals who are undergoing a procedure. However, many endoscopy patients are at high risk for infection and other complications due to their medical conditions, and flexible endoscopes are increasingly used for advanced therapeutic procedures. In one institution, 19 bronchos-
copy patients were infected with superbugs and 10 died after exposure to a contaminated bronchoscope. During the outbreak investigation, visual inspection of the channel with a borescope identified “proteinaceous debris” and other defects.13

Damaged endoscopes have also caused significant patient injuries, including lacerations and tissue damage.14,15 In two cases, ureteroscopes with damaged distal ends got stuck inside the patients’ kidneys and their ureters (kidney tubes) were torn out when the ureteroscopes were removed.16,17 These incidents underscore the importance of visual inspection to identify problems that could injure patients.

**Visual Inspection Using Borescopes**

In recent years, many facilities have obtained borescopes for processing personnel to use during visual inspection of endoscopes. Borescopes are tiny flexible endoscopes that can be used to look inside the small areas of medical instruments, and they are particularly well suited to inspect the interiors of ports and lumens. The utility of borescopes in visual inspection was initially established during an investigation of surgical site infections linked to contaminated instruments used in knee and shoulder surgery. When investigators used a borescope to look inside arthroscopic shavers, they found retained debris, including bone fragments and brush bristles.27 In a foundational study by Azizi et al.,28 visible residue or debris was detected inside 95% of 350 lumened surgical instruments.

**Ofstead Studies Involving Borescope Examinations**

After learning about the potential value of borescopes for identifying retained soil and debris, our team designed a study where the ports and channels of 20 colonoscopes and gastroscopes were carefully inspected three times during a seven-month period.7 Our goals were to determine whether damage and debris accumulated over time and whether more rigorous processing could completely eliminate contamination. This was the first time a borescope was used to prospectively monitor endoscope cleanliness and damage over time, so we had to develop our own protocol and reference materials.

First, we familiarized ourselves with the normal appearance of endoscope ports and lumens (Figure 1). During the baseline assessment, we inspected the inside of ports and channels and took photographs at specified points inside each endoscope. That way, we could compare the appearance of each component at baseline with how it looked at follow-up assessments. We were also able to compare each colonoscope or gastroscope with others in the fleet, which helped determine whether what we saw were normal features of the channels or ports or irregularities that required assessment by an endoscope maintenance technician.

During these inspections, a variety of unexpected observations suggested the patient-ready endoscopes were not sufficiently cleaned or dried, had retained debris or device fragments, or were seriously damaged. Figure 2 provides examples of irregularities we have observed inside of endoscopes at study sites.

By the end of that first study, we observed...
visible damage or soil/biofilm inside every endoscope. We also observed fluid droplets inside 95% of endoscope channels (Figure 2, photos 5–8). Most of the fluid appeared to be water or alcohol droplets, but we also saw fluid that was cloudy, white, shimmery, and viscous (photos 8 and 11 [at the top of the channel]). An assessment of captured samples revealed the fluid to be simethicone, which is a silicone-based product that is used to reduce foam and bubbles so the endoscopist can see well. It is not water soluble29,30 and cannot be completely removed by manual cleaning with water and detergent. We also saw a metallic object stuck in the channel of one endoscope, and a gastroenterologist said it looked like a hinge from a hemostasis clip (photo 17). Ultimately, 17 of 20 endoscopes were sent for repair based on the findings. The manufacturer found defects in every endoscope, including forceps passage damage, clogged nozzles, and chemical damage to the channel.

During the past several years, we have performed studies where we used smaller borescopes to inspect the ports and lumens of other types of endoscopes, including duodenoscopes,6 echoendoscopes, cystoscopes,6 ureteroscopes,12 and bronchoscopes.31 In every study, most of the endoscopes had internal damage that would have been undetected if borescopes were not used.

In one of our studies, we identified another factor that may be damaging endoscopes and influencing processing effectiveness and patient safety—the use of tissue glue during endoscopic procedures.6 Photo 18 shows a three-dimensional mass of tissue glue adhered to the interior of the biopsy port in an endoscopic ultrasound (EUS) endoscope. Processing staff at the study site had previously observed tissue glue on the outside of endoscopes and reported having difficulty removing it.

Research by Others
Since then, research teams at the University of California, Los Angeles and Stanford have performed borescope inspections of numerous endoscopes.30,32,33 Their findings echo ours: Nearly 100% of endoscopes had visible defects or retained fluid. Their work with borescopes provided new insights:
- New endoscopes were damaged after only 19 uses (median).32
- The longer endoscopes are used, the more damage and debris they accumulate.32
- Residual moisture is often present in patient-ready endoscopes but can be reduced with more robust drying methods.32,33
- Simethicone is widely administered via water bottles or directly through the working channel,30,33 and it is not removed by processing even when the lowest dose is used.30

We recommend collaborating with internal stakeholders from sterile processing, infection prevention, endoscopy, and specialty departments to develop protocols for inspecting endoscopes and assessing risk. That way, frontline personnel will be empowered to perform visual inspection and make decisions about recleanning endoscopes, sending them for repair, and involving other departments as necessary.

Setting up a Borescope Inspection Program
What Should You Do Before Starting Borescope Inspections?
When you begin inspecting ports and channels, you will probably notice issues that need to be addressed through recleanning or repair. In some cases, the results can be used for on-site quality improvement like recleanning a scope with retained soil or enhancing the protocol for drying endoscope lumens. In other cases, the endoscope should undergo assessment by the manufacturer or a qualified repair technician. Sometimes, the findings are concerning enough that other stakeholders should be notified.

To determine how to respond to findings from borescope examinations, we recommend collaborating with internal stakeholders from sterile processing, infection prevention, endoscopy, and specialty departments to develop protocols for inspecting endoscopes and assessing risk. That way, frontline personnel will be empowered to perform visual inspection and make decisions about recleanning endoscopes, sending them for repair, and involving other departments as necessary.

When developing a visual inspection protocol, consider the following:
1. Flexible endoscopes
   a. When will endoscopes be inspected?
   b. Where will endoscope inspection take place?
   c. Who will perform the inspections?
   d. How will they be trained?
## Fluid droplets

<table>
<thead>
<tr>
<th>Image</th>
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<tbody>
<tr>
<td>5</td>
<td>Droplets</td>
</tr>
<tr>
<td>6</td>
<td>Droplet and scratches</td>
</tr>
<tr>
<td>7</td>
<td>Droplets and channel shredding</td>
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<tr>
<td>8</td>
<td>Simethicone</td>
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</tbody>
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## Debris and discoloration

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<tr>
<th>Image</th>
<th>Description</th>
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<tbody>
<tr>
<td>9</td>
<td>Soil near distal end</td>
</tr>
<tr>
<td>10</td>
<td>Soil in channel</td>
</tr>
<tr>
<td>11</td>
<td>Staining or soil and simethicone</td>
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<tr>
<td>12</td>
<td>Manufacturer marking</td>
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## Channel damage

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<tr>
<th>Image</th>
<th>Description</th>
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<tbody>
<tr>
<td>13</td>
<td>Dents in channel</td>
</tr>
<tr>
<td>14</td>
<td>Scratches and staining</td>
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<tr>
<td>15</td>
<td>Filamentous debris</td>
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<tr>
<td>16</td>
<td>Filamentous debris and soil/biofilm</td>
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## Retained objects and material

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<thead>
<tr>
<th>Image</th>
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<tr>
<td>17</td>
<td>Hinge of hemostasis clip</td>
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<tr>
<td>18</td>
<td>Tissue glue</td>
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<tr>
<td>19</td>
<td>Retained material</td>
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<tr>
<td>20</td>
<td>Manufacturing debris</td>
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</tbody>
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*Figure 2.* Defects and damage commonly observed inside endoscopes. Images copyrighted 2020 by Ofstead & Associates, Inc. Used with permission.
e. How will findings be documented, and who will review them?
f. What will happen when problems are identified?
   i. When should endoscopes be recleaned or sent for repairs?
   ii. Who will be responsible for making decisions about recleaning or sending for repair?
   iii. Will endoscopes be reinspected after they have been recleaned or repaired?
   iv. When will other stakeholders be consulted (e.g., infection prevention, risk management, biomedical engineering)?
g. What will be done to maintain productivity when endoscopes need to be sent for repairs (e.g., encourage providers to use different endoscopes, acquire loaners or single-use scopes)?

2. Borescopes
   a. Which borescope will be used for each type of endoscope?
   b. How will borescopes be processed after use?
   c. Where will borescopes be stored between uses?
   d. What will be done when a borescope needs to be maintained or sent for repair?

Although we believe borescopes should be used for visual inspection, organic soil and debris can be difficult to see. When developing a quality management protocol, consider incorporating both visual inspection and cleaning verification tests that can detect invisible organic soil.

How Do You Use a Borescope?

Borescopes come in a range of lengths and diameters. Larger borescopes may provide a better image, but they will not fit in small lumens. Therefore, it may be beneficial to obtain two or three different sizes of borescopes so you can use the biggest diameter that will fit into the components you want to inspect. To conduct a borescope exam:

1. Select an endoscope and determine what channels and ports can be inspected
2. Decide which borescope is needed to inspect the targeted components
3. Take a photo of the serial number or endoscope ID
4. Inspect the rim and interior of each port or distal end
5. Gently insert the borescope into a channel from a port or the distal end
6. Inspect the channel carefully as you slowly advance the borescope
7. Consider rotating the borescope or backing up and changing the angle when you encounter resistance or see something unexpected, keeping in mind that:
   a. Forcing the borescope through any areas of resistance can cause damage
   b. Entering the channel from the other direction to see what is wrong may be necessary
   c. Advancing the borescope through debris, mucous, or thick fluid is risky, as they can damage the borescope or get on the lens and make it difficult to get a clear picture
8. Document findings by taking photographs and writing notes about what was observed

Resources

To support frontline personnel as they embark on visual inspection, our team has developed webinars with detailed instructions for using magnifying glasses and borescopes to inspect flexible endoscopes. These webinars provide information about what to expect and strategies for responding to the findings.

Educational resources for borescope inspections include:
   a. Conducting visual examinations of flexible endoscopes: a focus on channels and ports (borescope inspections)
   b. Conducting visual inspections of flexible endoscopes using lighted magnification
   c. The endoscope drying imperative: what, why, when, where, and how?
   d. Performing biochemical tests to verify cleaning effectiveness for flexible endoscopes


4. Olympus. The use of borescopes to inspect channels of Olympus flexible endoscopes

5. Kovach et al. Enhanced Visual Inspection of Medical Devices

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References


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