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Single-Use vs. Reusable Duodenoscopes: How Infection Knowledge Gaps Are Driving Environmental Harm and What Can Be Done

Matthew W. Smith, Lyndon V. Hernandez, Pamela Lee, Richard A. Martinello, Hardeep Singh, Jodi D. Sherman

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Title: Single-Use vs. Reusable Duodenoscopes: How Infection Knowledge Gaps Are Driving Environmental Harm and What Can Be Done

Short Title: Duodenoscope-associated infection knowledge gaps

Authors: Matthew W. Smith[1,2], Lyndon V. Hernandez*[3], Pamela Lee[4], Richard A. Martinello[5], Hardeep Singh[6,7], Jodi D. Sherman[8,9]

Affiliations:
1 Center for Access & Delivery Research and Evaluation (CADRE), Iowa City Veterans Affairs Healthcare System
2 Division of Infectious Diseases, University of Iowa Carver College of Medicine, Iowa City, Iowa
3 Division of Gastroenterology, Medical College of Wisconsin and GI Associates, Milwaukee Wisconsin
4 Division of Infectious Diseases, The Lundquist Institute at Harbor-UCLA Medical Center, Torrance, CA
5 Departments of Internal Medicine and Pediatrics, Yale School of Medicine, New Haven, CT Department of Infection Prevention, Yale New Haven Health, New Haven, CT
6 Center for Innovations in Quality, Effectiveness and Safety, Michael E. DeBakey Veterans Affairs Medical Center
7 Baylor College of Medicine, Houston, Texas
8 Department of Anesthesiology, Yale School of Medicine
9 Department of Environmental Health Sciences, Yale School of Public Health

***Corresponding author**:
Lyndon V. Hernandez, MD, MPH

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Background

More than 500,000 duodenoscopies are now performed annually in the United States.[1] Increased reports of duodenoscope-associated infections (DAI) following endoscopic retrograde cholangiopancreatography (ERCP) over the past decade have sparked discussions about how to reduce the incidence of DAI and propelled adoption of single-use duodenoscopes (SUDs) as an infection mitigation strategy. Meanwhile, potential downsides to SUDs, including increased environmental and public health impacts, costs, and supply chain risks, also warrant discussion especially because the true benefits of these devices remain unclear. A better understanding of DAI incidence is essential for rational use of SUDs. To address key information gaps and potential next steps, this paper highlights the environmental impact of single-use duodenoscopes and calls for the development of standard DAI case definitions and a reliable DAI data repository, similar to how case definitions have been developed for improving reporting and surveillance of ventilator-associated adverse events (VAE).[2] An accurate reporting system and supporting active surveillance infrastructure will enable evidence-informed discussions on how to weigh the risks and benefits of SUDs vs. reusable duodenoscopes. Implementing value-based incentive programs, wherein health system reimbursement are linked to standardized DAI reporting, could advance measurement and quality improvement activities related to DAI.

Environmental Impact and Cost of Single-use Duodenoscopes

A recent life cycle assessment comparing environmental impacts of SUD and reusable duodenoscopes found that SUDs generate 24-47 times more carbon dioxide emissions than reusable duodenoscopes on a per-use basis.[3] Switching to SUDs increases the net solid waste from ERCP by 40-400%, with high end estimates reflecting inclusion of ancillary supplies in the

calculation.[4] In addition to a larger carbon footprint and solid waste generation, reliance on SUDs can increase supply chain vulnerability to manufacturing shortages, such as those experienced during the COVID-19 pandemic.[5]

The US healthcare system is responsible for 8.5% of our country's greenhouse gas emissions and other toxic pollutants.[6] This connection between patient care and pollution is in direct tension with healthcare's responsibility to first, do no harm.[7] Gastrointestinal endoscopy is one of the highest waste-generating clinical specialties, behind perioperative services and intensive care,[8] highlighting the importance of sustainable practices in the gastroenterology community.[9] Thus, the growing concern stemming from increasing reliance on SUDs must be urgently addressed.

The financial viability of SUDs is also concerning. SUD costs have recently been estimated to range from $1995-$4400 per procedure, depending on facility volume and negotiated procurement discounts,[10] whereas the cost of reusable duodenoscopes (including decontamination and refurbishment) ranges from $1,110-$2,685 per procedure.[11] Bang et al. estimated that a high-volume US-based center switching all of their duodenoscopes to SUDs would incur a cost of $367,200 over a three-year period, a ten-fold increase in cost per patient.[12] Additionally, cost calculations for reusable duodenoscopes change based on the estimated rate of DAI. For example, Bang et al. estimated that post-ERCP cholangitis added $125,000 in costs to patient care, so the cost of one ERCP using a reusable duodenoscope rose $600-$1400 assuming DAI rates of 0.4% and 1.0%, respectively.[12] A different study by Das et al. showed that reusable duodenoscope costs are also affected by reprocessing technique, with high-level disinfection being less costly than culture-and-quarantine and ethylene oxide sterilization methods.[13] The

performance characteristics of various reprocessing measures for duodenoscopes are still not fully understood, further complicating the cost discussion.[1]

Uncertainty of the Actual Rate of Duodenoscope-Associated Infections

Concern for DAI is the cornerstone of the movement towards SUDs. However, there is great uncertainty regarding the true rate of infections following ERCP, suggesting current risk-benefit calculations are insufficiently supported.[14] Early estimates ranged from one infection per 1,800,000 ERCPs to one infection per 276,000 ERCPs: this variability arose from inconsistencies in defining the number of infections (i.e., the numerator) as well as the number of procedures that occur (i.e., the denominator).[15] It is commonly theorized that the actual rates of DAI are higher than reported in the literature, as existing studies typically rely on case reports. A recent study of the Dutch health system estimated DAI rates to be one infection per 10,000 ERCPs (0.01%), a much higher rate than previously reported.[16] Understanding the number of ERCPs performed annually is challenging given that, in the US, the estimated annual number of endoscopies performed varies by a factor of seven depending on whether the estimate came from a government agency or an endoscopy society.[14] In the absence of a national health registry, denominator numbers will continue to remain elusive. Adding to the confusion, many cost-assessment papers use a DAI rate of 1% for their estimates, a 100-fold higher rate than supported by current literature. Even when considering the possible sevenfold variation in procedures performed, this leads to a potential bias towards over-estimating the cost of reusable endoscopes.[10, 12]

Current State of Reporting Duodenoscope-Associated Infections

To understand why DAI rates are poorly understood, we must examine the history of DAI reporting in the United States. Prior to 1990, there were 281 reported episodes of pathogen transmission from general endoscopy found in the scientific literature.[17] Most of these healthcare-associated infections were attributable to inadequate cleaning, insufficient decontamination standards, and equipment malfunction.[18] In 1990 the Food and Drug Administration (FDA) gained oversight of medical device adverse event reporting in the United States. Prior to this there was no standard definition of DAI. Subsequently, a device-related adverse event was defined as any undesirable experience associated with the use of a medical product in a patient.[19] DAI is now one of many types of device-related adverse events that are reportable to the FDA.

There are hundreds of thousands of medical device-associated events reported each year through the FDA MedWatch reporting website, of which only a small portion are related to duodenoscopes. This data is publicly available and downloadable through the FDA Manufacturer and User Facility Device Experience (MAUDE) database.[20] Per the FDA, event reporting is mandatory for both device manufacturers and facilities (including hospitals, outpatient diagnostic/treatment facilities, and ambulatory surgical facilities). A critical limitation of the FDA's medical device reporting system is that it is passive and lacks oversight to ensure the completeness of reports. This means the actual incidence of events is unknown, as many events likely go unreported given that facilities have no incentive to report. Also, limited information is provided in these reports and their accuracy is unvalidated, so it is difficult to obtain meaningful clinical information about presumed cause and effect.

DAI incidence rates were not investigated for many years given the challenges in obtaining reliable data from the MAUDE database. In the 2010s, reports of DAI outbreaks emerged from large-volume endoscopy centers.[21] In 2015, the FDA issued an advisory about the risk of duodenoscope contamination related to design issues involving parts of duodenoscopes that were difficult to clean.[22] They subsequently published guidance in collaboration with the Centers for Disease Control and Prevention (CDC) regarding reprocessing procedures. This guideline, which includes details about disinfection, sterilization, and cleaning, serves as a cornerstone of DAI mitigation. In addition, the CDC has published surveillance sampling and culture protocols.[23] Since these documents were published, the FDA has noted an 82% decrease in DAI reports (Figure 1), from a peak of 250 reports in 2015, down to 45 reports in 2019, suggesting that the FDA guidance was effective at significantly reducing the incidence of DAI.[24] Notably, the downward trend started prior to the recent push towards SUDs over reusable duodenoscopes, as the first fully disposable duodenoscope was approved by the FDA in December 2019.[25]

Future Desired State of Reporting Duodenoscope-Associated Infections

Standardizing and Expanding Definitions to Facilitate Accurate Reporting

The most feared form of DAI is a highly drug-resistant organism transmitted from an inadequately reprocessed duodenoscope; however, DAI can arise from the external environment or from disruption of the patient's endogenous flora during the procedure. Post-procedural infections include bloodstream infections, hepatobiliary infections, and intraabdominal infections, typically defined as occurring within 30 days after the procedure. In addition, a patient can become colonized with exogenous flora following ERCP with a contaminated duodenoscope. Colonization, while usually benign, can result in delayed infections which are

difficult to link to the procedure. Risk factors unique to DAI include complex device design, biofilm formation on duodenoscopes, and suboptimal duodenoscope disinfection,[26] in addition to common risk factors including poor hand hygiene (with or without gloves) and weakened host immune health status.[5]

Proving that a post-procedural infection was secondary to a contaminated duodenoscope is challenging. Definitive proof of DAI utilizes molecular epidemiology, comparing the DNA of the bacteria causing the infection with bacteria present on the duodenoscope and proceduralist staff prior to the procedure. In addition, there should be evidence that the patient was not already colonized with the offending organism prior to the procedure. In practice, this resource-intensive investigation is not feasible, so alternative means of culture and surveillance are suggested by the CDC, including liquid culture/standard plating methods and duodenoscope surveillance sampling protocols post-procedure.[23] However, many institutions do not perform duodenoscope sampling post-procedure due to costs and the burden of adhering to challenging decontamination protocols, and only half of centers perform routine cultures after high-level disinfection (pre-proceduralist handling).[27] Moreover, there is wide variation of culture methods and definition of contamination, and current duodenoscope culture techniques may fail to grow a pathogen even when a duodenoscope is highly implicated as the source of an outbreak.[28] Of note, no formal grading system of DAI currently exists.

The challenge of understanding device-related infections is not unique to gastroenterology. Pulmonologists struggle to adequately categorize and define infections arising from intubated patients, and for many years described this condition as ventilator-associated pneumonia (VAP).

Over time, however, it was recognized that etiologies of poor health outcomes related to intubation were heterogeneous, and the VAP label was too narrow. This led to development of a new framework in 2012, with VAP broadened to ventilator-associated events (VAE). The VAE framework is more nuanced, with additional criteria for ventilator-associated conditions, including infection-related factors, and a distinct category of ventilator-associated pneumonia, which is subcategorized as possible and probable.[2] With these expanded criteria, physicians have the flexibility to better categorize infectious and non-infectious risk factors of respiratory failure. Furthermore, reporting is now streamlined as the definitions are based on standardized, objective data.

DAI could benefit from a similar attribution approach to better account for vulnerability and associated risks. The creation of a "duodenoscope-associated events (DAE)" framework could serve to differentiate infectious and non-infectious contributors and parse out device-related events. Non-infectious contributors could include pancreatitis, bleeding, perforation, and other known post-procedural complications. Infections could be subcategorized as probable DAI, possible DAI, post-procedural infection unrelated to duodenoscope contamination, and duodenoscope-associated contamination (an event where post-procedural surveillance reveals duodenoscope contamination).

The VAE framework culminated from a multi-year interdisciplinary workgroup process, including stakeholders from pulmonary, critical care, and infectious diseases societies.[2] Similarly, comprehensive framework and definitions of DAI will require collaboration between leading organizations in gastroenterology and infectious diseases, such as the American

Gastroenterological Association (AGA), American College of Gastroenterology (ACG), American Society for Gastrointestinal Endoscopy (ASGE), Infectious Disease Society of America (IDSA), Association for Professionals in Infection Control and Epidemiology (APIC), Society for Healthcare Epidemiology of America (SHEA), and the CDC.

Improving and Mandating Reporting

There are several current structural obstacles to effective DAI reporting. Insufficient personnel available to do contact tracing as well as a lack of front-line clinician familiarity with the FDA MedWatch reporting infrastructure may hamper the initial detection and reporting of infections. Inadequate and unclear case definitions further impede outbreak investigations. The FDA MedWatch reporting requirement itself is minimal – presently, the only mandatory submission information is the product name and an event description which is entered in an unstructured free text box.[29] Thus, there are multiple reasons why a DAI might not be reported or might be reported inaccurately or with missing information.

Our present understanding of DAI is based on case reports in medical literature. Many of these reports lack any standardized DAI definitions or case descriptions, lack description of contact tracing methods, and fail to examine potential breaches in cleaning/reprocessing of the device.[30, 31] Reports from the early 2010s typically relied solely on patient and device cultures without gene sequencing.[32, 33] Multiple reviews on DAI outbreaks have been published in the past several years, and these reviews highlight the heterogeneity of case outbreak reporting that makes meta-analysis impractical.[21, 26, 34]

A more comprehensive reporting system (see table 1) would greatly expand our understanding of DAI. Taking lessons from VAE, a joint task force consisting of appointees from the AGA, ASGE, CDC, IDSA, APIC, and SHEA could work together to develop expert consensus on necessary components of device-related definitions and a reporting system. This could provide a foundation for a new centralized data repository for researching DAI prevention and guide development of best practices.

Mandatory reporting would help ensure the ability to quantify and reduce healthcare-associated infections. Central line-associated bloodstream infections (CLABSI) and catheter-associated urinary tract infections (CAUTI) demonstrated a 35-55% reduction in the decades following mandatory reporting, due to the development of infection control measures and value-based incentive programs.[35] A similar program for DAI could inform an evidence-based approach to DAI prevention and assist in determining the optimal circumstances when reusable duodenoscopes vs. SUDs should be considered. The ideal initiative would balance patient safety with resource conservation, decreased healthcare costs, and minimize the negative environmental impact of healthcare.

Conclusion

Single-use vs. reusable duodenoscopes have sparked widespread discussion in the gastroenterology community, but progress has been slow due to significant information gaps surrounding DAI. Obtaining reliable information about DAI epidemiology is vital. Clear case definitions are needed to appropriately categorize adverse events following ERCP, and accurate surveillance methods help to identify these events. These processes require interdisciplinary

collaborations for their development. DAI reporting should be standardized, mandatory, and involve the use of a centralized database, similar to reporting of other healthcare-associated infections to the CDC's National Healthcare Safety Network. To ensure data is sufficiently complete, mandatory reporting would need to be incentivized, akin to value-based incentive programs of CLABSI/CAUTI where health system reimbursement is linked to DAI numbers. This approach would allow a more accurate analysis and provide evidence for enhancing DAI prevention and developing best practices around appropriate use of alternative devices. Adoption of single-use duodenoscopes harms environmental health, increases costs, and increases supply chain vulnerability, so we must first understand DAI to appropriately compare the benefits and harms of alternative ERCP devices.

Figures and Tables

Figure 1: Duodenoscope-associated infection reports received by the FDA through MedWatch over time.

Table 1: Components of an ideal reporting system for DAI, and their presence/absence in existing systems

Suggested data inputs of ideal reporting system		**Mandatory in MedWatch reporting?**	**Included in Outbreak/case series reporting?**
Background	Location	Yes	Yes
	Date of positive culture	Yes	Yes
	Date of procedure	No	Yes
	Demographics (e.g. age, sex, race)	Yes	Yes
Duodenoscope	Manufacturer	Yes	Variable
	Type of instrument (e.g. Single-use vs reusable, reposable (disposable elevator component)	No	Variable
	Pre-existing damage? If yes, where?	No	Variable
Pathogen	Organism name	No	Yes
	Isolated from patient?	No	Yes
	Isolated from duodenoscope?	No	Variable

	Type of Infection (e.g. cholangitis, bloodstream infection)	No	Variable
	Patient Outcome (e.g. readmission, 30-day survival)	No	Yes
Epidemiology	Number of infected patients	No	Yes
	Number of patients exposed to contaminated duodenoscope	No	Yes
	Attack rate (infected / exposed)	No	Yes
Facility	Use of duodenoscope surveillance cultures?	No	Variable
	Adherence to reprocessing measures?	No	Variable
	Cause of contamination identified?	No	Variable
	Corrective measures taken?	No	Variable

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