Communication from the ASGE Quality Assurance in Endoscopy Committee

SOCIETY DOCUMENT

ASGE
American Society for Gastrointestinal Endoscopy

Video recording in GI endoscopy

Fateh Bazerbachi, MD,[1,2] Faris Murad, MD,[3] Nisa Kubiliun, MD,[4] Megan A. Adams, MD, JD, MSc,[5] Neal Shahidi, MD,[6] Kavel Visrodia, MD,[7] Eden Essex,[8] Gottumukkala Raju, MD,[9] Caprice Greenberg, MD, MPH,[10] Lukejohn W. Day, MD, MBA,[11] B. Joseph Elmunzer, MD, MSc[12]

The current approach to procedure reporting in endoscopy aims to capture essential findings and interventions but inherently sacrifices the rich detail and nuance of the entire endoscopic experience. Endoscopic video recording (EVR) provides a complete archive of the procedure, extending the utility of the encounter beyond diagnosis and intervention, and potentially adding significant value to the care of the patient and the field in general. This white paper outlines the potential of EVR in clinical care, quality improvement, education, and artificial intelligence–driven innovation, and addresses critical considerations surrounding technology, regulation, ethics, and privacy. As with other medical imaging modalities, growing adoption of EVR is inevitable, and proactive engagement of professional societies and practitioners is essential to harness the full potential of this technology toward improving clinical care, education, and research. (Gastrointest Endosc 2025;10:67-80.)

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INTRODUCTION

GI endoscopy relies on the visual interpretation of intraprocedural findings, which are relayed within a procedure report that is, by intent, a brief representation of the full endoscopic experience. Although the concise nature of endoscopic reporting is practical for routine clinical documentation and communication, substantial procedural information is lost in the process. Moreover, endoscopy reports may be affected by the narrator's descriptive capacity, inherent limitations in reporting technology, transcription fidelity and representativeness, and recall and time constraints. Procedure reports are often supplemented by key images intended to represent the salient findings and interventions; however, the nuances of visual and tactile observations and the complexities of endoscopic intervention might not be comprehensively captured in a written manner and by static images. Significant technological advances now allow for high-definition video capture of endoscopic footage with quasi-unlimited archiving capacity, minimal necessary infrastructure, and negligible brick-and-mortar footprint. Therefore, endoscopic video recording (EVR) may represent a practicable and scalable solution to address some of the deficiencies of traditional endoscopic reporting in a way that can be leveraged to maximize the quality of endoscopic care.

EVR has been most widely applied in the instructional and educational context, focusing primarily on postgraduate medical training and continuing medical education. For example, because recordings illustrate procedural steps and details better than a written manuscript, video case reports and series have been adopted as an effective form of communication in the medical literature with dedicated peer-reviewed journals housing these publications.[1,2] In addition, live endoscopy courses have provided a forum for real-time observation of and interaction with experts, aiming to augment attendees' technical and cognitive skills. However, the full potential of EVR—in routine clinical care, quality and performance improvement, education, training, and in fueling artificial intelligence (AI) applications—is yet to be realized.

Implementation and diffusion of EVR involves multiple stakeholders and poses unique challenges relating to its technological requirements and cost and associated medicolegal, ethical, privacy, and legislative concerns. In this white paper, we provide an assessment of the status and future potential of video recording in GI endoscopy, with an emphasis on addressing challenges and maximizing endoscopic quality.

MODERN VIDEO RECORDING TECHNOLOGY

EVR options have evolved significantly in the past few years regarding features, complexity, and technical requirements. Endoscopy unit directors, endoscopists, and healthcare administrators should consider their specific endoscopic recording needs along with various other factors when determining the ideal video capture option.

The current video quality standard is high definition (HD) with an image frame of a minimum of 1280 × 720 pixels. However, newer displays and emerging endoscopy processors can receive and transmit at a resolution of 4K (3840 × 2160 pixels). The number of discrete video inputs that a recording device can simultaneously accommodate may also be important, for example, if fluoroscopy, EUS, or an external in-room camera is needed in addition to the endoluminal footage. The capacity and method of the storage medium (eg, internal hard drive, external hard drive or USB, and cloud-based storage) should also be considered and may vary depending on whether every procedure is being recorded, the typical length of a procedure, and how many discrete inputs are needed. Compatibility and integration with existing hospital information technology systems, such as electronic medical records (EMRs) or picture archiving and communication systems (PACs), may be desirable to streamline workflow and enhance data management. On this basis, the involvement of the endoscopy unit's EMR and PACS teams before purchase and setup is advantageous.

The accessibility of video recordings can vary, with some platforms permitting remote access through a dedicated secure server and others requiring manual retrieval of recordings from the recording device. An optimal display interface, designed to be intuitive and user-friendly, may incorporate elements such as a touchscreen panel, buttons, or a combination of input methods. This interface facilitates setting changes, initiation and cessation of recording, and navigation through features, and allows for immediate review of footage.

Some systems are equipped with real-time transmission capacity, enabling endoscopists to broadcast the live endoscopic feed (including multiple inputs) during the procedure. This feature facilitates educational activities and remote training and coaching by allowing real-time feedback as the procedure progresses. In addition, the recorder's built-in software may allow for basic video editing and annotations. This functionality is valuable for real-time documentation of important procedural details such as anatomical landmarks, pathological findings, or critical maneuvers, contributing to a comprehensive record of the medical intervention.

Because of the sensitive nature of medical data, dedicated recording systems frequently incorporate advanced features such as data encryption, user authentication, and other robust security measures aimed at safeguarding patient information. Furthermore, backup and redundancy measures should be strongly considered to mitigate the risk of data loss.

VIDEO RECORDING OPTIONS

Various recording and storage technologies exist for capturing endoscopic video (Table 1): Digital Imaging and Communications in Medicine (DICOM)-based systems, electronic health record (EHR)-integrated systems, external data capture devices (DCDs), cloud-based platforms, personal computers (PCs), and emerging systems. Each option has merits and potential disadvantages that should be considered when determining the optimal approach for an endoscopy unit or practice.

PACS/vendor-neutral archive: DICOM-first integration (the "integrated operating room")

One option is a recording system aligned with the DICOM standard. Originally developed to facilitate interoperability and standardized data sharing among a diverse range of radiological applications, DICOM has become integral in managing the copious amounts of radiology-generated imaging data. In hospitals, it may be advantageous to retain and index video recorded casework alongside other medical images. These video recordings are typically stored in the DICOM format within a PACS or vendor-neutral archive (VNA). However, it is noteworthy that neither DICOM nor PACS/VNAs were initially designed with video in mind, impacting the functionality of a DICOM/PACS-first strategy for EVR.

Implementing a DICOM setup involves acquiring video-acquisition hardware, integrating software, and using on-premises software tools. In a DICOM/PACS-equipped GI procedure room, hardware is necessary to relay the video stream to an on-premises storage location, and software is required to manage the video file itself. Integrated operating room (OR) build-outs may include video-relay hardware connected directly to the endoscopic processor, which modulates video transmission and relays signals to a specific server location, sometimes needing fiberoptic routing. These systems typically feature an in-room touch panel to initiate and manage recording activities.

Several barriers hinder the widespread adoption of these systems such as cost, personnel training, limited awareness of system availability, and real-time logistical implementation in time-constrained environments.[3] Another critical consideration in evaluating a DICOM strategy is storage preference. Most systems were initially designed for "on-premises" installation, requiring the purchaser to budget for upfront and ongoing costs associated with onsite storage and managing a growing dataset. Although some vendors offer remote viewing tools, enabling offsite access, uptake may be restricted by cost and implementation complexities. Notably, these products often incorporate Health Level Seven (HL7) capabilities, facilitating the transmission of patient metadata to/from the EHR/PACS, enhancing context and query ability within each system. The "integrated OR" concept is gaining traction in gastroenterology, with some larger systems restructuring their endoscopy suites for full media integration and routing.

EHR-native video capture

A more accessible endoscopic video capture strategy may involve leveraging applications provided by EHR vendors. Currently, various vendors incorporate embedded video capture applications within their software. One example is ProVation (Minneapolis, Minn, USA), which offers video

TABLE 1. Overview of endoscopic video capture options

Feature	DICOM-based systems	EHR-native video capture	External DCDs	Standard computers	Cloud-based recording	Operating Room Black Box
Description	Stores recordings in DICOM format (PACS/VNA)	Leverages EHR vendor's applications	Separate digital management device paired with the processor	Uses desktop/laptop with video input port	Internet connectivity for remote storage/ analysis	Captures comprehensive OR data (video, audio, and vital signs)
Hardware	Video-acquisition hardware, fiber optic routing, and in-room touch panel	Server hardware, dedicated workstations, and high-fidelity video cards	Device often includes touchscreen display, storage	Computer with compatible video input port and cables	Compact device connected to the endoscope processor	High-resolution cameras, medical device integration
Software	Integrating software and on-premises management tools	Limited functionality (eg, low resolution and short clips)	May include basic content management features	OS-specific screen recording software (QuickTime, Game Bar, or third party)	HIPAA-compliant web portal, may have editing/ annotation tools	Sophisticated analysis software (potentially with AI)
Storage	On-premises (potential for remote viewing)	On EHR vendor's servers	Device's internal hard drive	Computer's hard drive or external storage	Cloud-based storage	Centralized storage (potentially cloud-based)
Integration	Designed for radiology image integration (DICOM)	Integration capabilities depend on the specific EHR vendor	Limited integration potential	No direct EHR integration	Software-driven, flexible integration with various processors	Integrates with medical devices for comprehensive data capture
Accessibility	May have limited remote access options	Accessible within the EHR environment	Content transfer/ management is user dependent	Accessible from configured computer	Remote access from any location	Primarily for postoperative review, limited real-time access
Features	May include basic editing tools	Functionality is vendor-specific	May include dual inputs, high-definition recording	Flexible, depends on chosen recording software	Remote streaming, editing, download. Some offer AI-assisted tools	Advanced analysis, event reconstruction
Cost	$$$$$ (high)	$$$$ (high)	$$$ (moderate)	$ (low)	$$-$$$ (variable)	$$$$$ (very high)
Advantages	Integration with other medical images	Accessible within EHR	Simple to set up, potential for basic editing	Affordable, customizable	Secure storage, remote access, potential for AI features	Comprehensive data capture, quality improvement focus
Disadvantages	High cost, complexity, and potential storage limitations	Limited features, vendor-dependent, may need server upgrades	No EHR integration, privacy risks, and content management burden	May require adapters, basic recording functionality	Reliance on internet, potential subscription fees	Cost, not primarily for endoscopic video recording

AI, Artificial intelligence; *DCD*, data capture device; *DICOM*, Digital Imaging and Communications in Medicine; *EHR*, electronic health record; *HIPAA*, Health Insurance Portability and Accountability Act; *OR*, operating room; *OS*, operating system; *PACS*, picture archiving and communication system; *VNA*, vendor-neutral archive.

capture capabilities in a limited manner, allowing users to record short clips in low resolution (approximately 680p). Other examples include Modernizing Medicine (Boca Raton, Fla, USA) and eClinicalWorks (Westborough, Mass, USA), both of which provide "video processor integration" capabilities. Other endoscopy EHRs do not inherently offer video or image capture functionalities. Instead, these systems may integrate third-party imaging acquisition systems to ensure the capture of images and videos during usage.

Like PACS limitations, adopting an EHR-first approach requires budgeting for server storage, dedicated image-viewing PC workstations, and high-fidelity video cards for these workstations, all of which may need intermittent servicing and replacement, with associated costs. Overall, the EHR-native option may be a good option for some practices but is suboptimal for endoscopists and units that aim to capture large amounts of complex (ie, multiple inputs) video.

External DCDs for medical use

Various manufacturers of endoscopy video processors offer a separate digital management device that can be acquired independently for pairing with the processor.

Further, third-party devices are also commercially available with different compatibilities between processors.

In 2014, the American Society for GI Endoscopy (ASGE) technology committee reviewed two external DCDs: the SDC3 (Stryker, Kalamazoo, Mich, USA) and Olympus IMH-20 (Center Valley, Pa, USA).[4] The SDC3 system features a color touchscreen display, dual inputs, picture-in-picture or picture-by-picture recording, 1080p recording capability, 1 TB storage (capacity to save 500 cases), the input of patient data, storage, and editing using Studio3, Stryker Endoscopy (San Jose, Calif, USA) and the option to save to USB or hospital network. The IMH-20 system offers dual-channel recording in full HD, a 500 GB hard drive, a touch-panel display, and network compatibility.

Although DCD options may be the path of least resistance to initiating an EVR program, these modalities present essential challenges. First, these systems do not provide a streamlined content management system or strategy, and thus the end user is responsible for managing and transferring content on their own and editing video with separate dedicated software. In addition, these systems do not typically integrate with EHRs; therefore, direct video upload to the medical record for clinical purposes is not possible. Lastly, these systems pose privacy challenges as they are often unsecured and non-HIPAA (Health Insurance Portability and Accountability Act) compliant; external drives can be lost and accessed by nonauthorized individuals if not properly encrypted.

Standard computers

Endoscopists lacking access to the aforementioned technologies can leverage readily available PCs as an alternative solution for EVR. This approach offers flexibility, as both desktop computers and laptops equipped with a compatible video input port (high-definition multimedia interface [HDMI], digital visual interface [DVI], or displayport) can be configured into recording stations.

Hardware requirements.

- Endoscopy platform compatibility: the endoscopy platform, regardless of manufacturer (eg, Olympus, Pentax, and Fujinon), should feature a video output port, typically HDMI or DVI.
- Computer compatibility: a standard desktop or laptop computer with a compatible video input port (HDMI, DVI, or DisplayPort) is required. If the computer lacks a matching port, an appropriate adapter (eg, HDMI to USB-C and DVI to Thunderbolt) can bridge the gap.
- Video cable: a cable of appropriate type (HDMI, DVI, and DisplayPort) is needed to connect the endoscopy platform to the computer.

Operating system options.

- macOS: For Apple computers running macOS, users can use the preinstalled QuickTime Player application to initiate screen recording. The desired recording area should be selected to capture the live endoscopic feed displayed on the screen.
- Windows: for Windows-based computers, the built-in Windows Game Bar (available on Windows 10/11) or a suitable third-party screen recording software can be used. The chosen software should be configured to capture the live endoscopic feed displayed on the computer screen.

Although using standard PCs is a low-cost, flexible, and readily available EVR option, several important limitations should be considered. PC hard drives may have limited storage capacity, requiring frequent video transfers or external storage solutions. In addition, they might be more vulnerable to security breaches compared with dedicated systems, making robust security measures such as encryption and strict access controls a necessity. Furthermore, using PCs does not offer seamless integration with EHRs or other medical record systems. Lastly, consumer-grade PCs might be less reliable for long-duration recordings or demanding clinical environments, increasing the potential for technical issues.

Cloud-based recording

Emerging cloud-based solutions may improve the recording process during endoscopy by using internet connectivity for remote storage, analysis, management, and sharing of video data. Other potential advantages of this approach include centralized storage, accessibility from different locations, and collaborative potential.

In this paradigm, a compact device connects to the endoscopy processor and remains operational continuously. Some of these devices possess the capability to detect procedure activity, initiating and concluding recording automatically. The recorded video undergoes compression and encryption, and is then stored on a HIPAA-compliant web portal. This portal facilitates remote streaming, editing, or downloading from any location. The use of cloud storage addresses concerns related to physical storage limitations, allowing for the efficient storage and management of large volumes of data. Cloud-based platforms may also provide tools for editing, annotating, and documenting endoscopic videos; some incorporate built-in AI software to help with these tasks.

Cloud solutions, being predominantly software-driven, exhibit homogeneous expansion scalability. Furthermore, they are device/processor/input agnostic. This allows access from a range of devices, including computers, tablets, and smartphones, thereby enhancing the usability and accessibility of recorded endoscopic content, which could be shared directly with the patient after the procedure. Typically operating on a subscription or pay-as-you-go model, cloud-based solutions are a viable EVR option and may be particularly beneficial for smaller endoscopy units.

Emerging system: the “Operating Room Black Box”

The “Operating Room Black Box” or “medical data recorder” is a novel technology developed to enhance patient safety and elevate surgical outcomes, with potential implications for the future of EVR.[5] Inspired by aviation black box recorders, this system aims to capture and analyze comprehensive data during surgical procedures. It encompasses various data inputs, including video recordings of the operation itself, audio from the OR, patient physiological parameters, and information from medical devices.

Strategically placed high-resolution cameras record the entire surgical theatre during the whole operation, offering valuable material for postoperative analysis, training, and quality improvement (QI), leveraging AI deep learning algorithms. Beyond video, the inclusion of audio recording capabilities may provide insights into communication dynamics and other factors influencing surgical outcomes. The Operating Room Black Box integrates with medical devices, capturing vital signs, anesthesia events, and other relevant parameters, presenting a holistic view of the surgical environment.

With precise timestamps and synchronization across different data sources, the system aims to ensure accurate correlation between video footage, audio recordings, and other data streams. This facilitates the reconstruction and analysis of critical events. Postoperatively, the recorded data undergo analysis for QI, training, and research purposes. Surgeons and medical teams can review procedures to identify areas for enhancement or understand factors contributing to specific outcomes, and event reconstruction for QI is possible when unexpected adverse events occur. This system is designed in compliance with medical regulations and privacy standards and seeks to prioritize the ethical handling of sensitive data. Although this system is not considered a first-line option for EVR, it does provide a glimpse into the future potential of EVR to improve the quality of endoscopic care.

VIDEO RECORDING IN CLINICAL PRACTICE AND PATIENT CARE

Video recording of endoscopic procedures can play an essential role in optimizing patient care, especially in complex cases in which multiple physicians are involved or when a second opinion is needed. In these scenarios, endoscopic evaluation is critical in multiple downstream decisions. Such referrals for second opinions or to render specialized services in tertiary centers may benefit from accurate video documentation of the issue at hand. For example, referrals for large polypectomy or to repeat an unsuccessful ERCP may benefit from a provisional review of the index procedure by specialists for determination of the best therapeutic approach, preplanning to ensure that needed devices are available, and troubleshooting.[6] Similarly, many endoscopic procedures require surveillance or interval follow-up (eg, polyp resection and inflammatory bowel disease) and that follow-up procedure may be performed by a different physician or conducted after a lengthy delay. The availability of index procedural details in the form of video recording may provide improved context for comparison purposes in such cases. Lastly, EVR may be valuable in multidisciplinary conferences, which convene medical professionals from different disciplines to discuss cases and propose optimal treatment plans.[7]

In addition to such practical applications, the very act of video recording may improve clinical performance. Studies in different disciplines, including surgery and emergency medicine, have demonstrated that the performance of medical providers may improve when video recording of interventions is undertaken.[8] Rex et al[9] showed substantial improvement in colonoscopy quality measures after notifying the endoscopists that their procedures were being recorded. Similarly, a comparative study of 2 cohorts of patients undergoing colonoscopy showed an increase in polyp detection rate in the recorded group.[10] Additional research is imperative to delineate the proportion of this effect attributable to intraprocedural observation[11] versus an independent EVR effect. If EVR alone can enhance adenoma detection rate (ADR), a critical quality metric, widespread adoption of EVR stands as a potentially implementable tool across GI practices, presenting a viable avenue for quality enhancement.

VIDEO RECORDING FOR QI INITIATIVES

There is considerable potential to expand the role of EVR to harness its capabilities for QI.[12-15] The efficacy of colonoscopy screening for preventing colorectal cancer (CRC), for example, is intricately linked to procedural quality, which can be comprehensively evaluated through various metrics feasibly captured and analyzed during video recording. Current assessment of quality in endoscopy relies on the retrospective review of measures such as adequate bowel preparation, ADR, and cecal intubation rate, which are documented in the procedure report. Although valuable, this approach is limited by the lack of efficient measurement and reporting tools and is subject to recall and documentation variability. Indeed, a recent study of the video-based assessment of adherence to quality indicators during surveillance endoscopy for Barrett's esophagus observed considerable discrepancy between clinical documentation and what actually occurred during these endoscopic procedures.[16]

One potential application of EVR technology is to improve our existing approach to QI by allowing automatic and accurate capture, reporting, and standardized assessment of measurable intraprocedural quality indicators (such as ADR or the use of Seattle protocol biopsies) and intraprocedural adverse events. Automating these processes through EVR-based technology would have a significant favorable impact on the uptake and accuracy of quality assurance activities.

Successful cecal intubation represents another aspect of quality colonoscopy. The U.S. Multi-Society Task Force on Colorectal Cancer recommends a cecal intubation rate of at least 95% for screening colonoscopies and 90% for all colonoscopies.[17] Photo documentation of the ileocecal valve and appendiceal orifice is expected to establish the completion of the colonoscopy. Despite real-time assessment during a procedure, definitive evidence with static photographs of cecal landmarks can be challenging to obtain. Rex[18] investigated the anatomic variations and photographic factors associated with convincing cecal photographs, concluding that EVR consistently served as a compelling and effective means of documenting cecal intubation.

Bowel preparation quality significantly impacts colonoscopy effectiveness, influencing cecal intubation and withdrawal times as well as polyp detection.[19] Current recommendations stipulate that over 85% of outpatient examinations exhibit adequate bowel preparation. Although validated scoring systems such as the Boston Bowel Preparation Scale exist, they suffer from interobserver variability and practical limitations in clinical practice.[20] EVR has been investigated as a means to improve bowel preparation documentation, with videos used to develop deep learning–based systems for standardized reporting.[21,22]

Beyond automated capture and standardization of measurement, EVR also may improve endoscopic performance as it pertains to quality indicators through qualitative assessment. Disparities in adenoma and CRC detection rates between endoscopists have been widely documented, but the underlying reasons for this observation are more elusive. However, as far back as the year 2000, a study of video-recorded colonoscopy withdrawals, evaluated by experts, revealed an association between a better withdrawal technique and a diminished adenoma miss rate.[23] This study highlights how EVR can be used in QI because only through the review of video footage, as opposed to still images, were experts able to qualitatively evaluate the withdrawal technique and its relationship to adenoma detection.

VIDEO RECORDING IN REPORTING AND STANDARDIZATION OF PROCEDURE-RELATED EVENTS

Quality assurance in endoscopy is contingent upon implementation of a standardized endoscopic reporting system. The assessment of procedural quality and key endoscopy metrics becomes inherently challenging without such systems in place, hindering effective benchmark tracking over time. The literature substantiates that a well-structured reporting system contributes significantly to enhanced completeness in endoscopy reports. However, it is noteworthy that reporting practices among clinicians exhibit high variability and often fall short of optimal standards.[24]

Studies have identified significant variations in the completeness of endoscopic text reports and adherence to standard terms, and this inconsistency leads to differences in disease definition and technical descriptions during procedures.[25] Efforts to standardize endoscopic reporting have focused on identifying key elements for inclusion in electronic reports. However, current procedure writing software and dictated notes lack actionable information on procedural technical quality, compromising their utility in QI. Despite the development of validated scales for specific findings, such as the Prague classification for Barrett's or the Forrest classification for peptic ulcer disease, interobserver variability might compromise the accuracy of procedure reports. Drawing from the surgical literature, van de Graaf et al[14] highlighted the value of operative videos, demonstrating that standardized video reports more effectively capture technical details than narrative reports. They found that traditional operative reports documented only 52.5% of essential technical steps, increasing to 85.1% with the addition of EVR.[14]

EVR can also augment QI in assessing intraprocedural adverse events. Consider an EMR with perforation risk factors, such as inadequate submucosal cushion, failure to recognize deep submucosal invasion, and improper electrocautery. These variables are often absent in procedural reports. Video recording surpasses current reporting tools with its objectivity and lack of recall bias, enabling a nuanced understanding of adverse event factors such as submucosal cushion adequacy and snare placement precision. The value of EVR lies in its ability to capture intricacies not evident in static images, making it a pivotal tool for comprehending endoscopic adverse events.

VIDEO RECORDING FOR TRAINING, POSTGRADUATE COACHING, AND CREDENTIALING

Video analysis for the evaluation and instruction of technical skills in laparoscopic surgery has emerged as a productive and scalable approach to enhancing performance and clinical outcomes. In 2013, a seminal article featured in the *New England Journal of Medicine* (*NEJM*) showed substantial between-surgeon variation in technical skill levels based on video assessment of Roux-en-Y gastric bypass operations. Importantly, this variation in skill correlated with risk-adjusted adverse event rates.[26] This study was one of the first to demonstrate a direct link between technical proficiency and clinical outcomes using video analysis, suggesting that video-based interventions to measure and augment skill could improve the quality of care.

Recent research in endoscopy has corroborated these findings. A randomized controlled trial demonstrated that video-based interventions, particularly when combining self-review with benchmark comparisons, can significantly enhance endoscopists' ability to accurately assess their own performance. This research underscores the value of recorded endoscopic videos in promoting self-reflection and improving self-assessment capabilities among practitioners.[27]

Additional evidence has affirmed this association,[28] as well as the potential role of video analysis in surgical training and postgraduate coaching.[29-31] Among practicing surgeons, coaching programs are feasible and well-regarded by both participants and coaches, and appear to improve the surgeons' self-assessment abilities. Still, their impact on clinical outcomes remains under investigation.[32-34] This surgical experience highlights the potential role video analysis might play in endoscopic training, postgraduate coaching, quality assurance, and credentialing.

In contrast to validated assessment tools that require direct observation,[35,36] video analysis has far-reaching implications. First, video-based coaching is scalable and can be performed remotely, which may be valuable for smaller and lower-resourced centers where local expertise and mentorship are limited.[37,38] Second, video analysis allows assessors as much time as needed to rate and coach performance and removes this process from the clinical setting, where educational focus could be compromised by competing responsibilities.[39] Third, the anonymous nature of video analysis mitigates rater bias[40] and reduces hesitancy by established practitioners to be judged.[41] Last, by defining the basic parameters that simulators will ultimately use to enhance performance, video analysis is the logical first step in the process that leads to the development of intelligent simulator technology and augmented reality platforms that can provide scalable coaching through automated and synchronous feedback during the conduct of a simulated or real-world procedure.

In the *NEJM* study above, surgical videos were rated by untrained peers according to a modified version of the Objective Structured Assessment of Technical Skills (OSATS) tool, which is commonly used to assess surgical performance across a range of operations. Subsequently published studies have also used such generic assessment tools,[42] although procedure-specific instruments have been developed for some operations.[43,44] Although an agnostic rating scale, or a generic tool, may provide valid assessment for credentialing or maintenance of certification, a procedure-specific assessment tool might add value in coaching, as it allows for clear milestones for precise and actionable feedback. From a psychometric point of view, specialized tools may mitigate rater bias and variability and be better at discriminating skill levels.[45]

In keeping with these considerations, procedure-specific tools for video-based assessment of technical skills in endoscopy have been developed and initially validated, and more are under development.

One of the pioneering instruments in this domain is the GI Endoscopy Competency Assessment Tool (GiECAT) for colonoscopy. This tool has shown promising results, with a prospective study demonstrating excellent agreement between live and blinded video-based assessments, as well as similar psychometric characteristics in both settings. This finding provides strong support for the use of video-based assessments as a viable alternative to live evaluations of endoscopic skill.[46]

In addition, the Cold Snare Polypectomy Assessment Tool (CSPAT),[47] the Bethesda Endoscopic Retrograde Cholangiopancreatography Skill Assessment Tool (BESAT),[48] and the Peroral Endoscopic Myotomy Assessment Tool (POEMAT)[49] have all been initially validated and have demonstrated performance characteristics comparable to equivalent laparoscopic tools. The CSPAT was initially developed through modification of a previously validated tool designed primarily for direct observation.[35,47] In contrast, the BESAT and POEMAT were created de novo through expert analysis and deconstruction of ERCP and POEM videos to construct an initial framework.[48] All 3 scales were refined through the Delphi method before establishing validity evidence via expert ratings of larger samples of videos using the respective tools. The CSPAT was primarily evaluated based on inter-rater agreement, which was moderate to high (kappa: 0.52-0.63) for most domains. The BESAT was assessed primarily on the basis of G-analysis—the ability to reliably differentiate between endoscopists based on their technical performance as observed on video. The G-coefficient for BESAT was found to be in the range of 0.7, the threshold at which a tool is considered reliable and for which most of the observed variance is attributable to the performance of the endoscopist, as opposed to other factors, such as the rater. Similarly, in preliminary testing, the POEMAT demonstrated a G-coefficient of 0.6 to 0.7 for most of its component domains.

The CSPAT was subsequently studied in a randomized trial of 22 gastroenterology fellows who were assigned to video-based versus conventional feedback for cold snare polypectomy of lesions <1 cm.[50] In this trial, video feedback was associated with a modest improvement in learning curves compared with the conventional approach, preliminarily suggesting that such tools may play a growing role in endoscopic training. The Colon EMR Assessment Tool (CESAT) for video assessment of large polyp EMR remains under development.

Although several surgical training programs have incorporated video-based coaching into their educational curricula based on solid evidence, ongoing studies are establishing whether postgraduate surgical coaching programs will have a meaningful impact on clinical outcomes and quality, and if so, how best to implement such programs. Similarly, now that video-based coaching tools in endoscopy are available, it will be essential to develop an evidence base to support their use in both educational and postgraduate settings. In these contexts, additional research on discriminative validity (the ability of the tools to differentiate skill between endoscopists of varying levels of experience) and predictive validity (the ability of the tool to predict clinical outcomes based on observed endoscopic skill) is needed. In addition, methodologically rigorous investigation, ideally in the form of randomized trials, will be necessary to understand the effect of video-based coaching on performance and outcomes. Ultimately, the ability to implement and scale video-based coaching programs must be demonstrated. As this evidence evolves, the ASGE has interest in piloting video-based coaching programs that aim to emulate those that already exist such as the Academy for Surgical Coaching (https://surgicalcoaching.org).[51]

In addition to teaching and coaching, there has been interest in using video analysis for endoscopic procedure credentialing and privileging, which remains highly unstructured and variable.[52] Video analysis could represent a more objective, reproducible, and verifiable approach to credentialing. Current evidence, however, suggests that the performance characteristics of existing tools in both surgery and endoscopy are promising for formative assessment (the ability of the tool to guide coaching interventions and improve performance) but are thus far inadequate for summative assessment (the ability of the tool to determine whether a trainee has achieved adequate skill for independent practice or whether a practicing endoscopist has maintained such skill). For reference, a reliability level of $\geq$0.9 is generally considered the minimum standard for summative assessment; as mentioned, the BESAT, for example, has a reliability level in the range of 0.7. Similarly, existing surgical tools do not appear to have the performance characteristics to be used reliably in summative assessments.[53] Additional research is necessary to achieve reliability levels that allow credentialing based on video alone and to determine whether video analysis can play an adjunctive role as part of a more structured credentialing framework.

VIDEO RECORDING FOR GRADUATE AND POSTGRADUATE EDUCATION THROUGH PUBLICATIONS AND LIVE COURSES

EVR permeation in clinical practice has allowed for the rise of video-based education, communicated by several peer-reviewed publications.[1,2] Video-based endoscopy journals play an essential role in endoscopic knowledge dissemination and learning. First, they provide a platform for sharing the latest procedures, techniques, and innovations in endoscopic practice. Through video-based presentations, endoscopists can visually convey and grasp intricate procedural concepts or maneuvers, enhancing collaboration, understanding, and proficiency. Second, these journals promote continuing learning by showcasing real-life case studies, allowing endoscopists to learn from diverse clinical scenarios and challenges.

In addition, EVR plays an important role in gastroenterology conferences through dedicated video forum sessions that highlight high-quality videos demonstrating novel techniques, varying approaches to managing endoscopic challenges, and management of endoscopic adverse events. These are some of the best-attended sessions as they demonstrate endoscopy concepts in a relatable format that cannot be fully captured with still images or in manuscript text.

Similarly, live endoscopy courses have become popular as a platform to showcase high-quality endoscopic performance and state-of-the-art endoscopic techniques, more efficiently disseminating valuable lessons and advancements while allowing attendees to interface in real-time with nationally and internationally recognized faculty. Attendees can observe expert decision-making and troubleshooting during procedures, contributing to a practical understanding that may be applied in one's practice. Such courses may offer a unique avenue to develop complex decision-making skills above and beyond published cases, which lack the dynamic nature of real-life scenarios. The ASGE oversees some of these courses, with a strong emphasis on patient safety.[54] The ASGE has demonstrated foresight in promoting video recording and editing skills among endoscopists. In 2004, the Digital Atlas of Video Endoscopy (DAVE) project was introduced, as reported in *GI Endoscopy*.[55] This initiative pioneered the first internet-based, comprehensive educational video atlas in gastroenterology, integrating various endoscopic imaging modalities with relevant surgical, pathological, and radiological data. Building on this foundation, the ASGE collaborated in 2007 to establish the annual "Advanced Fellows Video Editing Scholarship Program." Led by DAVE project founders, this workshop culminated in the selection of the top 3 videos for publication in the DAVE repository, further emphasizing the importance of multimedia skills in endoscopic education.[56]

VIDEO RECORDING FOR CLINICAL RESEARCH AND AI DEVELOPMENT

EVR represents a distinct category of patient-related data that will play an emerging role in endoscopic research. The evolving ubiquity of high-resolution video platforms positions video-based endoscopic research for substantial expansion. Although EVR has played a role in some limited research capacities, such as blinded review of endoscopic endpoints in inflammatory bowel disease studies,[57] myriad future research applications for video recordings could be envisioned, such as in inferring causality of endoscopy-related adverse outcomes[58] and providing mechanistic insights into critical events that are traditionally difficult to study, such as delayed perforation and interval cancer development.

Research to drive the development of AI applications represents another opportunity to reshape the endoscopy landscapes, with a focus on computer vision. This technological advance could be further catalyzed by routine video recording of endoscopic procedures.[59] Computer vision refers to technologies that can process and analyze high-dimensional visual data to inform accurate procedural decision-making. Existing applications include computer-aided detection and diagnosis of GI lesions,[60-63] endoscopic disease activity classification,[64,65] bowel preparation and capsule endoscopy assessment,[22,66] as well as enhancing more complex applications such as ERCP[67] and third space endoscopy.[68] It is anticipated that routine EVR that informs computer vision and other similar technologies will represent the next frontier of research in endoscopic diagnostics.

Crucial to the advancement of AI clinical decision support solutions (AI-CDSS) is big data availability. Proof-of-concept and early AI platforms have predominantly relied on still images, given their standardized inclusion in procedure documentation. However, these images are inherently limited by quality and scalability. It is anticipated that subsequent iterations of AI-CDSS, built on high-quality video datasets, will surpass the performance of their image-based predecessors. Unfortunately, the development of AI solutions has been hindered by the historical scarcity and subpar quality of existing video datasets. Developing transformative AI-CDSS involves the establishment of universal automated high-resolution video capture within a HIPAA-compliant video repository. This framework enables AI solutions to undergo training, validation, and testing using a robust representation of the target population. Robust metadata are essential, and integrating video repositories with existing hospital- or practice-based EHR platforms facilitates efficient video retrieval and outcome correlation.

In addition, although EVR can fuel the development of AI-based technologies, the reciprocal is also true; a symbiotic relationship between video and endoscopy can facilitate the development of technologies that improve endoscopic processes. For example, AI-based tools that generate high-fidelity procedure reports in real-time based on endoscopic video footage could improve endoscopic practice efficiency and endoscopist satisfaction. Automated tools could also assist with video recording, labeling, editing, and review in real-time. Lastly, AI is likely to play a major role in virtual and augmented reality platforms that hold great potential for immersive training experiences and precise navigation during procedures.

PRACTICAL CHALLENGES IN THE IMPLEMENTATION OF VIDEO RECORDING IN DAILY PRACTICE

The integration of EVR in endoscopic practice presents various challenges, primarily related to scalability, costs, and infrastructure. Scalability is a critical concern because healthcare facilities endeavor to deploy EVR systems across multiple endoscopy units. The substantial volume of daily procedures mandates a scalable solution capable of efficiently recording and storing high-quality video data without impeding workflow. Ensuring uniformity and compatibility across diverse endoscopic equipment and settings further complicates scalability, demanding standardized systems adaptable to varied procedural environments.

Cost considerations also pose a significant barrier to widespread adoption, encompassing expenses for recording equipment, storage solutions, and information technology infrastructure. Healthcare institutions grapple with financial constraints while striving to incorporate innovative technology for improved patient care and training. These costs extend beyond the initial setup to cover maintenance, upgrades, and the management of big data generated in each procedure. Allocating resources for training medical staff in using and interpreting recorded video data adds to the financial burden. The cost of EVR should ideally not be passed on to patients or insurers directly, but rather absorbed into the endoscopy unit or center's operating budget, bundled into the cost of endoscopic equipment. At some institutions, the costs of EVR may also be incorporated into the IT budget. It is important to consider that although the implementation of EVR will incur additional costs, there is the theoretical potential for long-term cost savings resulting from more improved patient outcomes and more efficient and effective training. Additional research is needed to better understand the financial impact of EVR on the healthcare system.

Infrastructure hurdles further impede the easy adoption of EVR in GI endoscopy, comprising physical hardware, storage systems, and the development of secure and efficient data transfer protocols. Ensuring patient information privacy and security within a complex healthcare network is imperative, requiring robust data management practices compliant with regulatory standards. The integration with EHRs and interoperability across diverse healthcare systems adds complexity to infrastructure requirements. Addressing these challenges is crucial to fully realizing the potential of EVR for enhanced patient care, medical education, and research.

MEDICOLEGAL AND JURIDICAL CONSIDERATIONS

An essential step in the implementation and dissemination of EVR in endoscopy is addressing pressing legal and ethical considerations related to the collection and use of such data. These concerns and lack of familiarity with the legal principles governing EVR in healthcare may hamper the widespread adoption of systematic video recording. Although unanswered questions remain about the ethical, legal, and logistical consequences of video recording in

TABLE 2. Principles for beneficial, responsible, and ethical use of video recording data in healthcare

Domains	Description
Informed consent	Patients are entitled to a clear, explicit, and documented agreement for the collection, use, and storage of their video recording data. The consent process should clearly outline the following: • Purpose(s) of data collection (eg, clinical care, education, and research) • How the data will be used, including any sharing with third parties • Storage and security measures • Duration of data retention • Right to view or request copies of recordings • Right to withdraw consent at any time • Clarity regarding any potential commercial application of individual and aggregated data. *The consent should include explicit language regarding potential monetary benefits to participants if such commercialization occurs.
Addressing power imbalances	Providers and practices should acknowledge the inherent power differential between physicians and patients. The consent process and related policies should strive for equipoise, making clear that participation in video recording is truly voluntary and will not negatively impact ensuing care.
Restrictions on redisclosure	The informed consent process should explicitly address whether and under what conditions the anonymized video data may be reshared with other researchers, institutions, and other entities.
Cultural sensitivity	When using video recordings for research or educational purposes, it is critical to be mindful of potential cultural insensitivities and unconscious biases.
Early anonymization/ deidentification	Techniques like image blurring, voice alteration, and concealment of metadata should be used to remove personally identifiable information as soon as possible. Ideally, this should occur synchronously with video capture.
Data minimization	The minimum amount of video data necessary should be collected to achieve the intended purpose. If only parts of the procedure are essential, the video should be edited accordingly.
Aggregation	Whenever feasible, video data should be aggregated for analytic or educational purposes. Individual-level data should not be extracted unless expressly required, with appropriate consent.
Secure storage and access control	Robust safeguards, including encryption, password protection, firewalls, and access logs, should be implemented. Access should be restricted on a need-to-know basis. Clear roles and responsibilities for data management should be defined.
Data retention and eradication	Clear data retention policies aligned with the intended purpose and regulatory requirements should be established. The data should be promptly deleted when they are no longer needed.
Transparency	Easily understandable information about video data practices is provided to patients and staff; policies are accessible and communicated. A point of contact for data-related queries is designated.
Compliance with regulations	Applicable privacy laws like HIPAA and GDPR are legal counsel when necessary to ensure compliance.
Accountability	Regular audits and reviews of data handling practices are instituted. Incident response plans are implemented in case of breaches. Mechanisms for patient complaints and redress are established.
Data quality and integrity	Measures to ensure that the accuracy, completeness, and reliability of the video data are implemented.
Continuous evaluation and improvement	Ethical data practices are regularly reviewed, considering ongoing advances in technology, societal expectations, and legal regulations.

GDPR, General Data Protection Regulation; *HIPAA*, Health Insurance Portability and Accountability Act.

clinical settings, some general principles apply. Herein, we focus primarily on privacy and confidentiality issues and their associated professional risk/medical liability implications, and we outline critical considerations for healthcare providers, institutions, and researchers who implement EMR in their practice (Table 2).

Privacy, confidentiality, and informed consent

To successfully incorporate video recording into routine endoscopic practice, consideration must be given to protecting both patient privacy and the privacy of the endoscopy team.[69,70] Although endoscopic videos primarily depict the GI lumen, ostensibly maintaining anonymity, there is the potential for indirect identification of participating patients, providers, and staff (eg, through video time stamps cross-referenced with endoscopy schedules or unique pathological findings), compelling adherence to privacy principles.[70]

Privacy considerations in this space include laws relating to personal data, medical records, and professional confidentiality.[5] It should be noted that principles governing patient privacy are clearer than those governing the confidentiality of the endoscopy team, which remain obscure. In the United States, the federal HIPAA is explicitly designed to protect the privacy of patients' health information. This key federal legislation is supplemented by state law and institutional regulations.[70] Although our primary focus here is on U.S. law, similar principles apply internationally, including those outlined in the European Union (EU) General Data Protection Regulation (GDPR), which took effect in 2018 and was designed to harmonize data privacy laws across the EU.[5,71] In addition, health data are regulated by the Common Rule (45 CFR 46 subpart A) when used in human subject research.

In safeguarding patient privacy, it is vital to use a "privacy-by-design" approach (also known as "data-protection-by-design").[5,72] This methodology aims to achieve the highest level of privacy by integrating privacy measures proactively into the design and architecture of information technology systems and protocols, rather than adding them retroactively. This approach obligates prioritizing patient and healthcare provider privacy throughout every stage of system design, ensuring that privacy serves as an integral component without compromising functionality. Proactive measures are taken to formulate an algorithm delineating the specifics of data collection and management. This ensures the maximization of EVR benefits while mitigating known risks. Moreover, organizations should monitor the implementation and management of EVR programs to address any unforeseen issues that may arise effectively.[73] The development of related policies is then pursued through consultation with local legal counsel due to variations in institutional regulations and the existence of unresolved legal questions in this domain.

The informed consent form for the clinical procedure should include a statement specifically addressing the patient's consent to the acquisition of endoscopic photo documentation and/or video recording. This statement should clearly indicate the potential uses of video, such as diagnosis and treatment, QI, and research. The form should also indicate that the patient retains the right to access any and all endoscopic photo/video documentation, and processes should exist to facilitate such requests. This documented consent should be incorporated into the medical record, not only as a legal requirement but also to enhance patient trust and foster a culture of transparency. Adhering to privacy-by-design principles, the anonymization of patient and healthcare provider data should occur at the earliest possible stage. This may involve the use of image blurring and voice alteration technology to facilitate the early deidentification of participants involved in the procedure, encompassing both the patient and endoscopy providers/staff.[5] The use of aggregated, anonymized data offers enhanced privacy protection, as does the deletion of data once their intended purpose is fulfilled. For example, if video recordings are intended for the assessment and analysis of an endoscopy team's performance or educational purposes, only the performance report, augmented with pertinent video clips, should be presented to the team. Any recorded data not included in the report should be promptly deleted.[5]

After collection, video recording data should be diligently safeguarded to uphold confidentiality. This involves secure storage, such as encryption and password protection, restricting access to essential staff, and adhering to short data retention periods. Ensuring transparency regarding data security policies/protocols, deidentification of patient data captured on video, the right to retroactively decline participation, and the process for addressing questions and requests are an essential part of ethical use of these data. These safeguards are not only essential for compliance with privacy laws but also for fostering public confidence in healthcare institutions that leverage individual patient information for advancing global patient care through QI, training, or research. Transparency achieved through notice and informed consent, along with stringent safeguards to mitigate the risk of privacy breaches, is imperative.

Both HIPAA and GDPR permit the use of limited, deidentified datasets for research and QI initiatives. Although the legal framework dictating what information must be stored in the patient's EHR remains unclear in the United States, it appears to suggest that video recording data may not need to be stored in the patient record if it is being used solely for these purposes, and this is explicitly incorporated and agreed to by the patient as part of the informed consent process. However, it is important to note that this does not preclude reporting of medical errors or "near-miss" situations that may be captured on a video recording. In this case, patients should be informed as early as possible, and the incident filed in the medical record (Table 2).[5]

Professional risk/liability implications

As described earlier, video recording of medical encounters entails both benefits and potential risks. One significant concern among clinicians, particularly in the context of procedural encounters, is the possibility of these recordings being used as evidence of substandard care in medicolegal proceedings during the discovery process or trial. Although the threat of medical liability is a valid consideration, intraprocedural video recording akin to detailed written documentation in the EHR more frequently acts as a protective measure for clinicians. It offers detailed video documentation of events, serving to bolster the clinician's position in the event of a medical negligence claim. In addition, such recordings have the potential to enhance the doctor-patient relationship by fostering transparency, thereby reducing the likelihood of claims being filed.[74] As is imperative even in the absence of recording, maintaining professionalism should be of utmost importance in the procedural unit. This is crucial to prevent casual remarks that might be misconstrued or taken out of context when recorded, potentially impacting the therapeutic alliance with the patient.

The intended use of the video recordings also plays a role in whether this information would be discoverable in a medical professional liability claim as part of the patient's medical record. It is noteworthy that certain states, such as Wisconsin, have endeavored to pass legislation granting patients access to video recordings of their medical procedures. Although these legislative attempts have been unsuccessful to date, it is essential for healthcare organizations to be proactive in establishing policies for the optimal use of EVR. This proactive stance is essential to preclude vulnerability to external regulations as EVR is more widely disseminated in the future.

FUTURE DIRECTIONS

Looking ahead, the clinical implementation of routine EVR in everyday practice is likely inevitable. We anticipate a trajectory mirroring that of other medical imaging technologies, for which the archival preservation of examinations in perpetuity has gained universal acceptance and has become standard practice. Recent technological strides foreshadow the impending realization of this new paradigm in endoscopy. As we highlight in this white paper, the implementation of EVR is likely to have a beneficial impact not only on clinical care delivery but also on quality assurance, education and postgraduate training, and research and development in endoscopy. In particular, the implementation of AI-driven tools for real-time diagnostics and procedural guidance could significantly enhance the efficiency and quality of endoscopy, and the advancement of such technology intimately relies on big data generated by EVR. While acknowledging potential logistical, technological, fiscal, and medicolegal concerns, gastroenterology societies, including ASGE, should proactively address these issues, championing endeavors to maximize the great potential of EVR in clinical practice, education, and research.

DISCLOSURE

Dr Greenberg holds an uncompensated leadership role at the Academy for Surgical Coaching. Dr Visrodia is a speaker for Boston Scientific and Pentax. Dr Shahidi is a speaker for Boston Scientific and Pharmascience. The other authors disclosed no financial relationships.

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Abbreviations: ADR, adenoma detection rate; AI, artificial intelligence; AI-CDSS, AI clinical decision support solutions; ASGE, American Society for Gastrointestinal Endoscopy; BESAT, Bethesda Endoscopic

Retrograde Cholangiopancreatography Skill Assessment Tool; CRC, colorectal cancer; CSPAT, cold snare polypectomy assessment tool; DAVE, Digital Atlas of Video Endoscopy; DCD, data capture device; DICOM, Digital Imaging and Communications in Medicine; DVI, Digital Visual Interface; EHR, electronic health record; EMR, electronic medical record; ERCP, endoscopic retrograde cholangiopancreatography; EU, European Union; EVR, endoscopic video recording; GDPR, General Data Protection Regulation; HD, high definition; HDMI, High-Definition Multimedia Interface; HIPAA, Health Insurance Portability and Accountability Act; NEJM, New England Journal of Medicine; OR, operating room; PACS, picture archiving and communication systems; PC, personal computer; POEMAT, Peroral Endoscopic Myotomy Assessment Tool; QI, quality improvement; VNA, vendor-neutral archive.

2468-4481
https://doi.org/10.1016/j.vgie.2024.09.013

CentraCare, Interventional Endoscopy Program, St Cloud Hospital, St Cloud, Minnesota, USA (1), Division of Gastroenterology, Hepatology and Nutrition, University of Minnesota, Minneapolis, Minnesota, USA (2), Illinois Masonic Medical Center, Center for Advanced Care, Chicago, Illinois, USA (3), Division of Digestive and Liver Diseases, University of Texas Southwestern Medical Center, Dallas, Texas, USA (4), Division of Gastroenterology, University of Michigan Medical School, Institute for Healthcare Policy and Innovation, Ann Arbor, Michigan, USA (5), Division of Gastroenterology, University of British Columbia, Vancouver, British Columbia, Canada (6), Columbia University Irving Medical Center, New York Presbyterian Hospital, New York, New York, USA (7), American Society for GI Endoscopy, Downers Grove, Illinois, USA (8), Division of Internal Medicine, Department of Gastroenterology Hepatology and Nutrition, MD Anderson Cancer Center, Houston, Texas, USA (9), Department of Surgery, University of North Carolina, Chapel Hill, North Carolina, USA (10), Division of Gastroenterology, Department of Medicine, University of California San Francisco, San Francisco, California, USA (11), Division of Gastroenterology and Hepatology, Medical University of South Carolina, Charleston, South Carolina, USA (12).