Advances in diagnostic and therapeutic endoscopy

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Abstract

The burden to healthcare and the impact of disease to humans from luminal disorders of the gastrointestinal tract have driven the requirement for more efficient endoscopic visualization and instrumentation over the past decade. The push for greater diagnostic yield has driven advances in optical physics and bioengineering which are revolutionizing diagnostic and therapeutic endoscopy. This article will highlight emerging technologies since our last review, focusing on advances in imaging, endoscope design and how this is shaping the therapeutic approach to diseases of the human gastrointestinal tract. Their application to improve diagnostic ability, patient care and their limitations are discussed.

Keywords Ablation; colonoscopy; endoscopic resection; endoscopy; optical biopsy; therapeutic endoscopy

What's new?

- Ever-improving resolution and the widespread use of high-definition endoscopes continues to improve visualization. Alongside this, the introduction of image enhancement technology such as i-Scan and FICE allows for improved lesion recognition. Endoscopists are now capable of detecting subtle but significant pathology, greatly enhancing patient care
- Technologies for accurate in vivo endoscopic diagnosis (optical biopsies) are developing rapidly with promising trial outcomes. Focus, at present, is on confocal endomicroscopy, spectroscopy (elastic scattering and Raman), autofluorescence, molecular imaging and optical coherence tomography
- Progressively smaller, more flexible endoscopes and transnasal endoscopes have improved patient comfort whilst novel endoscope designs such as Third Eye Retroscope and Spyglass cholangioscope are allowing visualization of previously inaccessible areas of the GI tract
- Capsule technology has advanced to allow more accurate visualization of the oesophagus and large bowel in addition to the small bowel. This approach allows for non-invasive visualization of the GI tract but its use remains limited due to, amongst other factors, the inability to gain a histological diagnosis
- Alongside improved lesion recognition comes improved endoscopic therapy. Resection and ablative techniques are transforming patient care and successfully treating patients with conditions for which surgery was once the only option. Developing techniques, such as POEM, continues to expand the endoscopic therapeutic horizons

Introduction

High-definition digital technology has moved endoscopic imaging to a new dimension. Endoscopic innovations have arisen from the explosion of technical achievements through the interaction between physicians and engineers and the incorporation of technology from other fields such as computing, artificial intelligence and physics.

Hand in hand with these advancements in imaging there is continuing evolution of the ergonometric design of the endoscopes, with dedicated accessories that allow increasing applications of therapeutic endoscopy. Advances in the treatment of early cancers of the GI tract continue and are being constantly driven by improved imaging. Endoscopic resective and ablative interventions now shape the future for early neoplasms of the gastrointestinal (GI) tract. From submucosal dissection of established cancer to radiofrequency ablation and cryoablation of precancerous dysplasia, the therapeutic armoury at the disposal of the interventional endoscopist continues to accumulate.

Advances in imaging

Improved digital imaging and virtual chromoendoscopy

Video endoscopes use white light from a xenon or halogen source for illumination and rely on a charge-coupled device (CCD) chip to enhance image resolution and magnification, in order to reconstruct the images. Standard definition (SD) white light endoscopy (WLE) has been rapidly been replaced by the introduction of high definition (HD) endoscopes. Whereas CCD chips produce an image signal of 100,000 to 400,000 pixels that is displayed in SD format, the chips currently in use in HD endoscopes produce resolutions that range from 850,000 to 1.3 million pixels. These latest innovations have exponentially

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increased our ability to inspect and visualize subtle mucosal details.

Manipulation of the image using additional post-processing optical technologies, such as i-Scan, narrow-band imaging (NBI) or Fuji intelligent chromoendoscopy (FICE), can further enhance detection of previously invisible small lesions and is often referred to as virtual chromoendoscopy[1,2] (Table 1).

Narrow-band imaging: conventional WLE uses the entire spectrum of visible light (400–700 mm) to examine tissue. NBI developed by Olympus Medical Systems (Olympus, Japan) uses optic filters to isolate two specific bands of light: 415 nm blue and 540 nm green. By isolating these two bands of light and taking into account their absorptive and reflective properties on the mucosal surface, an image that enhances visualization of superficial mucosal and vascular structures is created. The quality of the surface pit pattern morphology is also clearly enhanced by this technology[3] (Figure 1).

i-Scan: a new endoscopic image enhancement technology, i-Scan, has been developed by PENTAX (HOYA Corporation, Japan). i-Scan uses the EPKi processor technology, which enables resolution above standard HDTV, with distinct digital filters for special post-processing online imaging, which can provide detailed analysis. The computer controlled digital processing provides resolution of about 1.25 mega pixels per image. The operator enhances different elements of the mucosa by pressing a button on the hand piece of the HD endoscope. i-Scan can be used for surface analysis to recognize lesions using three modes of image enhancement:

(i) Surface enhancement (SE)/i-scan 1 – enhancement of the structure through recognition of the edges.
(ii) Contrast enhancement (CE)/i-scan 2 – enhancement of depressed areas and differences in structure through coloured presentation of low-density areas.
(iii) Surface and tone enhancement (TE)/i-scan 3 – enhancement tailored to individual organs through modification of the combination of red, green and blue (RGB) components for each pixel (Figure 2).

FICE: FICE (Fujinon, Japan) is a post-processor technology that captures spectral reflectance via a colour CCD video endoscope. This is sent to a spectral estimation matrix processing circuit contained in the video processor. The reflectance spectra of corresponding pixels that make up the conventional image are estimated mathematically. From these spectra, it is feasible to reconstruct a virtual image of a single wavelength. Three such single-wavelength images can be selected and assigned to the RGB monitor inputs, respectively, to display a composite colour-enhanced multi band image in real time. In practice this can be used like narrow band imaging to remove data from the red part of the waveband and narrow the green and blue spectra.

Real-time in vivo diagnosis

Even with advancements in endoscopic imaging, current practice still relies widely on endoscopic sampling of suspicious areas for histological confirmation of neoplasia. New technologies now exist that allow *in vivo* diagnosis of cellular atypia and guide therapy.

Confocal laser endomicroscopy (CLE): Confocal laser endomicroscopy (CLE) is a developing technology that enables the high-resolution in vivo imaging of tissue microstructures at or near the level of histopathology without requiring tissue excision. CLE uses depth-specific tissue illumination and pinhole-limited detection to create an image from the fluorescent light reflected back from a very thin focal plane. Tissue fluorescence is achieved using intravenously or topically applied contrast agents, usually intravenous fluorescein. There are currently two commercially available devices: an endoscope-based system (eCLE) that is fully integrated into the tip of a conventional endoscope (Optiscan Pty., Ltd., Notting Hill, Australia; Pentax); and a probe-based system (pCLE) that can be passed down the working channels of a range of standard endoscopes (Cellvizio; Mauna Kea Technologies, Paris, France).

Spectroscopy and 'optical biopsies': spectroscopy is based on light interaction with tissue. The incident light directed on the tissue may be reflected in different patterns, called 'scattering

Digital imaging techniques

Modality	Mechanism	Advantages	Limitations
Narrow-band imaging	Taking into account absorptive and reflective properties of mucosa surface, optic filters isolate two specific bands of light (415 nm blue and 540 nm green) to enhance visualization.	These techniques allow for significantly improved mucosal visualization by highlighting subtle architectural or vascular differences on the mucosal surface. This improves detection of subtle irregularities and improves therapeutic outcomes.	The principal drawback for all these techniques lies in the need for careful observation of the mucosa followed by detailed inspection using image manipulation. This is time consuming and requires considerable expertise.
i-Scan	Digital image enhancement settings such as tonal, contrast and surface filters that improve visualization of vascularity and topography.		
FICE	Post-processing technique that reconstructs a virtual image of a single wavelength (red, green and blue) in real time enhancing visualization.		

Table 1

