LEADING ARTICLE

Gastrointestinal endoscopy: past and future

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The former editor of *Gastrointestinal Endoscopy* reflects on the history of endoscopy, which reveals much about the mechanisms whereby innovation occurred, and attempts to forecast the future. Endoscopic technological development in most industrialised countries will be determined largely by various combinations of many external factors together with the further development of virtual imaging

Near the end of my term as editor (1997–2004), *Gastrointestinal Endoscopy* published an editorial by Robert Granz on the future of endoscopy.[1] Dr Granz began with this observation:

"We now take it for granted that new technology is our birthright, that endoscopic practice will continue to evolve without interference. Is our current complacency warranted, or are there unseen obstacles that may actually interfere with continued endoscopic progress and derail our heretofore rapidly evolving and productive field?"

Because endoscopy is a keystone in the structure of modern gastroenterology, this question has substantial merit. Is it possible that endoscopy has reached a technological plateau? Is the pace of development slowing? Could endoscopy even be rendered partially or wholly obsolete? Or, will ever more technological innovations continuously expand our diagnostic and therapeutic capabilities?

Obsolescence is a normal consequence of innovation. Examples are abundant: the Polaroid Land camera, slide rule, the typewriter are but a few. Examples of outmoded endoscopic technology are also numerous: the plastic oesophageal stent, laser photoablation of oesophageal tumours, sclerotherapy, perhaps even the fibreoptic endoscope.

I believe four factors will shape our endoscopic future:

(1) intrinsic factors (the laws of physics, optics, electronics, computers);
(2) external factors (non-technical, non-scientific, non-endoscopic), cost, and societal issues foremost;
(3) the ever changing nature of digestive diseases (for example, Barrett's oesophagus, which evolved from relative obscurity); and
(4) developments in other medical fields, notably radiology, but also non-medical fields (for example, telecommunications).

To predict the future, it is helpful, even advisable, to understand the past, and the history of endoscopy reveals much about the mechanisms whereby innovation occurred and perhaps continues to occur.

The early pioneers faced two obvious albeit formidable problems: the gut is not straight and its dark in there. Kussmaul is generally credited with the first gastroscopy in 1868.[2] Although unrecognised at the time, the illumination problem was solved around 1878 by Thomas Edison, but 25 years elapsed before the incandescent lamp was incorporated into endoscopes. The first approach to the tortuosity of the gut was an instrument with articulated lenses and prisms, as proposed by Hoffmann in 1911.[3] Approximately two decades elapsed before this concept was perfected in the semi-flexible gastroscope, the work of Wolf, a fabricator of medical instruments, and Schindler, a physician.[4]

> "Image transmission using flexible quartz fibres was conceptualised in the late 1920s but it was not until 1954 that Hopkins built a model of a flexible fibre imaging device"

Image transmission using flexible quartz fibres was conceptualised in the late 1920s but it was not until 1954 that Hopkins built a model of a flexible fibre imaging device.[5] The most significant development in the history of endoscopy then occurred in 1958: the flexible fibreoptic endoscope of Larry Curtiss, then a graduate student in physics, and Basil Hirschowitz, a trainee in gastroenterology.[6] What made this instrument possible was the availability of highly transparent optical quality glass. Over the next 30 years, the fibrescope evolved to a level of technical sophistication that seemed insurmountable. But obsolescence was assured with the invention of the charge coupled device (CCD) in 1969. Ten years later, this technology was incorporated into an endoscope.[7] Because the CCD produced an electronic image, endoscopy suddenly had a wider audience, a television audience. Moreover, the image was digital, and instantaneously an interface between endoscope and computer was established. From 1968 to 1990 there was an explosion of technical achievements that transformed the practice of gastroenterology (table 1). This remarkable 22 year period was so formative that I believe it will come to be considered historically as the golden era of gastrointestinal endoscopy.

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Abbreviations: CCD, charge coupled device; EUS, endoscopic ultrasonography; NIH, National Institutes of Health

Table 1 Highlights from the ''golden era'' (1968–1990) of gastrointestinal endoscopy

1968	Endoscopic retrograde pancreatography
1969	Colonoscopic polypectomy
1970	Endoscopic retrograde cholangiography
1974	Endoscopic sphincterotomy (w/bile duct stone extraction)
1979	Percutaneous endoscopic gastrostomy
1980	Endoscopic injection sclerotherapy (reinvented)
1980	Endoscopic ultrasonography
1983	Electronic (charge coupled device) endoscope
1985	Endoscopic control of upper gastrointestinal bleeding
1990	Endoscopic variceal ligation

Two things are evident from the history of endoscopy. Firstly, innovation arose from close collaborations between physicians struggling to solve clinical problems and artisan-engineers: witness (among many) Schindler and Wolf, Hirschowitz and Curtiss. Secondly, progress occurred largely through incorporation of technology from other fields. Most of our technology was not, in fact, invented specifically for endoscopy. In retrospect, the fundamental elements for every major technological advance existed for some time, in most cases many years. Because endoscopy borrows heavily from other fields, it is possible to know its future potential by reference to existing technology, although this requires particular insight.

Before attempting to forecast the future, it will be instructive to consider one of the great technical developments from the golden era, namely endoscopic ultrasonography (EUS). Prior to the advent of EUS at around 1980,[8] endoscopic diagnosis had not changed fundamentally since 1868. Even the most modern endoscope merely improved upon the original goal of visual inspection of the gut. By combining ultrasonography and endoscopy, EUS opened an entirely new dimension in imaging.

> ''Because EUS is unique, moreover a true advance, it serves as a model for future innovation''

Because EUS is unique, moreover a true advance, it serves as a model for future innovation. As such, the history of EUS suggests several things: endoscopy will continue to borrow from other fields, innovation will require longer time periods, new technology will be costly, each advance will have a narrower focus, sometimes a single disease, and because new technology is likely to be complex, proficiency in its application will require longer training.

EUS is still not universally accepted by non-gastroenterologists. This is because it emerged as the ''rules'' for introduction of new technology were changing, specifically the growing demand for evidence that technology, especially if costly, improves outcomes. ''Perhaps the greatest lesson that EUS offers is the absolute need for more and better data, compelling data with statistical power, at the outset of development. Whether endoscopists possess the discipline and resolve to act according to the lessons offered by EUS will be a major determinant of the future course of endoscopy.''[9]

At the end of my term as editor I reflected on what the prior decade had provided in terms of endoscopic innovation. By reviewing publications in *Gastrointestinal Endoscopy*, I listed these major achievements from 1994 to 2004:

(1) most procedures are now performed on an outpatient basis,
(2) band ligation largely replaced sclerotherapy,
(3) high level disinfection of endoscopes (assuredly among the most important),
(4) disposable accessories,
(5) the electronic endoscope fully supplanted the fibrescope,
(6) endoscopy with limited prior consultation (so-called ''open access''),
(7) for many indications, endoscopic retrograde cholangiopancreatography has been replaced by EUS,
(8) new methods and drugs for conscious sedation,
(9) outpatient management of gastrointestinal bleeding (a reality in many parts of the world), and
(10) endoscopic images routinely linked to computer generated reports.

Unfortunately, few of these achievements are advances in technological capability (that is, new methods of diagnosis and therapy). So, using the journal again as the data source, I attempted to quantitate the development of new instruments and methods, admittedly a subjective exercise. Nevertheless, I think the main conclusion is valid.

> ''Technological development in terms of diagnostic and therapeutic capability slowed substantially during the last decade by comparison to the earlier ''golden era'' (1968–1990)''

I divided new technology into endoscopes, devices/accessories, and procedures, and further categorised these into proposed and actualised (that is, those that can be considered established in clinical practice). There were many remarkable developments that altered clinical practice: the capsule endoscope, self expanding metallic stent, and the linear array echoendoscope. The lists are too long for this article, but of 36 proposed endoscopes, 11 could be considered actualised; of 41 proposed devices/accessories, 17 were actualised; and of 48 new procedures, seven could be regarded as implemented in practice. Based on this analysis, it can be concluded that technological development in terms of diagnostic and therapeutic capability slowed substantially during the last decade by comparison to the earlier ''golden era'' (1968–1990).

The explanation for this change in pace and direction lies in the second major group of external non-endoscopic factors that influence the evolution of endoscopy. These will undoubtedly impact development for the foreseeable future. What are they?

In his editorial, Dr Granz[1] proposed four factors: demography, reimbursement, the ongoing consolidation of manufacturing, and deficits. I would add: risk aversion, a steady loss of the necessary infrastructure and tradition of innovation, a growing emphasis of outcomes research, essentially the evaluation of existing technology, and lastly the evolution of radiological imaging, specifically virtual imaging.

In the USA, and probably many countries, endoscopists as a group are aging. In 1983, 55% of members of the American Society for Gastrointestinal Endoscopy were less than 45 years of age; in 2001, 35% were less than 45 years.[1] As Dr Granz suggested, older physicians are less likely to learn new skills, adopt new technologies, and to perform endoscopic research.

The balanced budget act of 1997 in the United States shifted federal funding for medical education to primary care and away from specialist training. For this and other reasons, the number of fellows completing gastroenterology training in the USA declined from around 500 in 1991 to less than 250 in 1999.

The populations of industrialised nations are aging. Consequently, utilisation of endoscopy has increased dramatically. However, this is dominated by certain procedures, notably screening colonoscopy. Thus we are inundated by low level established procedures, and have less time to incorporate new technology.

A relative value system for Medicare reimbursement was adopted in the USA in 1992. This established a payment system for health services resembling that of many industrialised countries (at least for patients over 65 years of age). Dr Granz termed such a system a monopsony (that is, one with essentially a single buyer of services). The lone buyer naturally forces reimbursement as low as possible. Inevitably, such a system favours simple high volume procedures and penalises labour intensive difficult procedures, especially those that are costly. Eventually, this control over reimbursement impacts the profits of instrument and device manufactures.

Over the last 10 years the manufacturing of instruments and devices has undergone substantial consolidation. Companies became larger but decreased in number. In effect, the present systems for reimbursement favours well capitalised companies, and because companies are fewer they are under less pressure to compete through innovation.

> ''Spending cuts decrease reimbursement for services and profit for manufacturers, and ultimately translate to disincentives for innovation and adoption of new technology''

As a taxpayer in the USA, my personal share of the federal budget deficit amounts to about $100 000. This is not unique; the competitive demands on the public purse are problematic for most industrialised nations. This invariably causes the payer or payers for health services, essentially the government, to resist implementation of new technology. Spending cuts decrease reimbursement for services and profit for manufacturers, and ultimately translate to disincentives for innovation and adoption of new technology.

A further aspect of deficits is limited funding for endoscopic research. As with EUS, the environment for implementation of new technology has changed. If you wish to innovate, you must demonstrate benefit; that your innovation favourably influences outcomes. High quality data that demonstrate benefit are acquired only through prospective well designed clinical trials with statistical power, a type of research generally lacking in endoscopy. Such trials cost money.

Wallace and Hurlstone[10] studied federal funding for endoscopic research in the USA using a National Institutes of Health (NIH) database. They found that funding for endoscopic grants increased by 2325% from 1972 to 2002. However, the actual number of funded grants increased from one (1972–1982) to only 93 (1993–2002). To put this into perspective, they compared funded grants for endoscopic research with grants for other research. The numbers speak for themselves: endoscopy, 93; *Helicobacter pylori*, 866 grants; cardiac catheterisation, 1547; and liver disease, 61 804 funded research grants. In my opinion, the blame for this dismal state of affairs lies more with endoscopists than the NIH, specifically our relative inability to design, organise, and conduct research that irrefutably demonstrates the clinical benefit of endoscopic innovation.[11]

When all of the above factors are taken into account, an attempt can be made to address the question: Is our present endoscopic technology as good as it is going to get, or is there more to come?

Endoscopic technological development in most industrialised countries will be determined largely by various combinations of the many external factors outlined above together with the further development of virtual imaging. Diagnostic endoscopy will be replaced by capsule endoscopy and virtual imaging. However, if the capsule is to supplant the electronic endoscopic for general diagnostic purposes, substantial improvements in capsule technology are required. In the interim, routine endoscopic procedures will be performed increasingly by non-physicians. There is evidence that nurses perform routine procedures as well, and in some respects better, than physicians.[12] Cost and availability of physician endoscopists will drive this transition. Simultaneously, endoscopy will become increasingly therapeutic. Traditional divisions between medicine and surgery will become progressively blurred. Endoscopes will be radically redesigned to allow hands free operation. One result will be a range of combined laparoscopic-endoscopic procedures. Endoscopy procedure rooms will resemble operating rooms. Also, as the complexity of endoscopic procedures increases, the distinction between specialist and generalist endoscopist will become more definite. Emphasis will be given to development of less invasive endoscopic methods for treating obesity. High resolution endoscopes, a virtual certainty, will reveal new findings that will lead to new problems with interpretation.

> ''High resolution endoscopes, a virtual certainty, will reveal new findings that will lead to new problems with interpretation''

There are also many lingering problems for which solutions are highly desirable: effective endoscopy simulators for training, better sedative and analgesic drugs, better methods for colon preparation as well as devices for clearing stool from the colon, a non-clogging plastic stent, and perhaps self guiding enteroscopes and colonoscopes.

Thomas Kuhn,[13] in his great book *The Structure of Scientific Revolutions*, noted that progress occurs in two ways, ''from the normal science, which is the slow, steady accumulation of knowledge, and from unexpected discoveries that entail paradigm shifts''. As potential paradigms the following items could markedly shift the direction of endoscopic development:

(1) technologies based on light-tissue interactions (for example, optical coherence tomography, laser induced/light scattering spectroscopy, light induced fluorescence endoscopy, Raman spectroscopy);
(2) photodynamic diagnosis and therapy;
(3) use of tissue glues in therapeutic procedures;
(4) computer aided diagnosis;
(5) application of Doppler ultrasound, specifically to the problem of recurrent gastrointestinal bleeding;
(6) injection pharmacotherapy, with particular reference to EUS guided injection;
(7) narrow band imaging; and
(8) high intensity ultrasound ablation.

Conspicuously absent is the endoscopic treatment of gastro-oesophageal reflux disease.

For any of this to happen it will be essential to deal effectively with the many external factors that presently govern and perturb endoscopic innovation. Pressure must be applied in the political arena for funding for endoscopic research, and thereby greatly improve our ability to conduct meaningful clinical trials. Manpower needs must be addressed by promoting academic endoscopy and training many more gastroenterologists to do endoscopic research. Under the new rules of evidence based medicine, technical skill alone is now of secondary importance. Such individuals must have a thorough knowledge of biostatistics, study design, and even biomedical engineering. We must enhance and expand the infrastructure needed to train these individuals and provide them with a suitable environment in which to work. Links should be forged with biomedical engineering as a new iteration of the old relationship between craftsman and physician that was so productive throughout the history of endoscopy. Lastly, we must forge new relationships with industry that emphasise innovation.

The great American baseball player and every man's philosopher, Yogi Berra, master of the malapropism, once observed that "the future ain't what is used to be." For the future, the only certainty is that endoscopic innovation is no longer assured.

Conflict of interest: None declared.

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EDITOR'S QUIZ: GI SNAPSHOT

A unusual cause of anaemia

Robin Spiller, *Editor*

Clinical presentation

A 17 year old girl presented with increasing fatigue, paleness, and recurring episodes of abdominal pain. Physical examination was unremarkable except for a moderate pressure pain in the right upper quadrant. Laboratory evaluation revealed microcytic hypochromic anaemia (haemoglobin 10.7 g/dl) due to iron deficiency (serum iron 9 μg/dl, transferrin saturation 1.9%, and plasma ferritin 5 μg/dl). Oesophagogastroduodenoscopy was performed (fig 1).

Question

What abnormality was found in the duodenum? Could we remove it?

See page 1077 for answer

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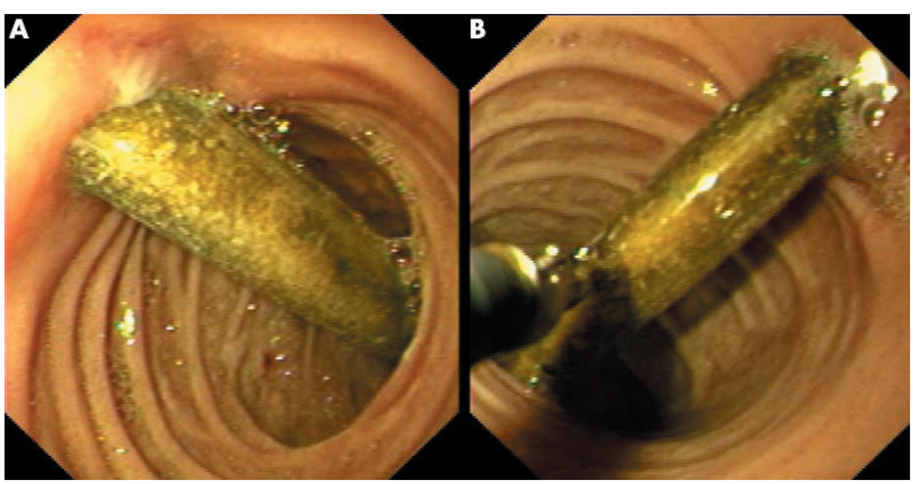

Figure 1 Endoscopic image of the upper duodenum.