OPINION

The future developments in gastrointestinal radiology

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Received 22 January 2012
Accepted 13 March 2012

Abstract

The last decade has witnessed great advances in abdominal imaging with technological developments and diagnostic improvements in CT, MRI and positron emission tomography-CT. Over the next decade, gastrointestinal imaging is set to rapidly evolve. Fluoroscopic techniques will be left behind and we will develop beyond simply anatomical imaging, embracing increasingly functional and quantitative techniques. Dose reduction and radiation-free modalities will take centre stage as imaging goes mobile, allowing clinicians at the bedside and remote subspecialty radiologists to review radiology from electronic devices. The authors discuss some of the key trends set to define the next decade in gastrointestinal radiology.

Introduction

Over the last decade we have witnessed great advances in our capability to image the abdomen and gastrointestinal (GI) tract; multi-slice CT is now routine and with developments in MRI and ultrasound scan (USS), rapid acquisition of high quality images is now standard without imparting ionising radiation. The availability of positron emission tomography-CT (PET-CT) has increased, allowing us to link morphology with metabolic function. Picture archiving and communication system (PACS) and voice recognition reporting technology is now the norm in most hospitals.

The next decade will see us build on these achievements, with increased dissemination of new techniques and technologies by healthcare providers. There will be a revolution in how we acquire, store, interpret and disseminate imaging information.

The next five years

General trends

The next five years will see technologies currently new to the market and practised in a handful of teaching and research institutions expand into wider practice. This will include CT and MRI enterography, CT colonography and MRI proctography. Technological advances will continue with reduced dose and improved image quality. The ability to view diagnostic quality imaging on tablet and handheld devices will become routine.

Imaging techniques

CT use will continue to grow, driven in part by increasing demands for rapid, cheap and ubiquitously available imaging of the abdomen and GI tract, both in oncological and non-oncological practice. However, patients and healthcare professionals alike will be increasingly aware of the potential risks of repeated diagnostic ionising radiation exposure. Dose reduction techniques will become the norm. In particular CT data reconstruction using iterative techniques will allow good quality images to be required at around half the dose of standard CT.[1 2] Low dose CT will continue to replace standard abdominal x-ray in the assessment of acute patients.

The inevitable increase in CT detector row number will speed image acquisition, reducing movement artefact and improving image resolution. New flat panel detection technology will provide even faster imaging, allowing large volumes to be acquired in less than 1 s and facilitating analysis of real time physiological functions such as blood flow and perfusion. The increased technical capabilities of CT combined with changes in clinical paradigms will see its role expand. For example, detailed CT staging of colon cancer with identification of adverse prognostic factors such as extramural extension and venous invasion will likely become routine as use of neoadjuvant therapies increases.[3] This will also drive the need

for accurate preoperative whole body staging of colorectal cancer; use of PET-CT and whole body MRI will increase (currently under investigation in a National Institute of Health Research Health Technology Assessment (NIHR HTA) funded multi-centre trial). Use of PET-CT in other GI cancers will also increase and new tracers will be developed, although for the near future fluoro-deoxy-glucose (FDG) will remain the most widely used agent.

CT colonography (CTC) will replace barium enema as the first line whole colon radiological investigation of choice; initial data from the SIGGAR 1 trial (a UK randomised controlled trial of colonoscopy, CT colonography and barium enema) shows diagnostic superiority of CTC over barium enema.[4] (figure 1). Such a change will require significant investment in radiological infrastructure at many institutions. Computer assisted detection (CAD, automated software detection of colonic neoplasia) will also become more widely used during CTC interpretation. At least two multi-case, multi-reader trials have shown the benefit of CAD to radiologists, increasing their sensitivity in CTC interpretation.[5 6] National committees to oversee the implementation of CTC have been formed (for example under the auspices of the British Society of Gastrointestinal and Abdominal Radiology (BSGAR) in the UK) and guidelines for more formal integration of CTC in national Bowel Cancer Screening Programmes (BCSPs) have been developed. Standards in training and quality will be introduced, akin to those in optical colonoscopy.

The use of MRI in primary cancer staging will increase, driven in part by the need to reduce diagnostic ionising radiation exposure, and in part due to its superior tissue characterisation. Already established in rectal cancer staging, MRI will be more widely employed at other organ sites, for example in the oesophagus. Its role in rectal cancer will also expand. Current trials of 'watch and wait' following chemo-radiation rely on the ability of imaging to accurately identify viable tumour while cure is still possible. MRI protocols will develop, and inclusion of new sequences, notably diffusion weighted imaging, will become the norm.[7 8] The role of 'functional' imaging techniques which provide information such as tissue cellularity and vascularity will increase. Currently such techniques are limited to a relatively small selection of centres; dissemination will occur, but it will take several years before their full potential can be reached. However, diffusion weighted imaging will become mainstream in detection and characterisation of solid organ lesions.

The forecast epidemic in chronic liver disease will require greater use of non-invasive imaging techniques to characterise liver fibrosis—use of ultrasound elastography will increase and MRI elastography (figure 2) will continue to develop. The need for accurate detection and staging of primary hepatic malignancy in high risk patients will increase the use of MRI.

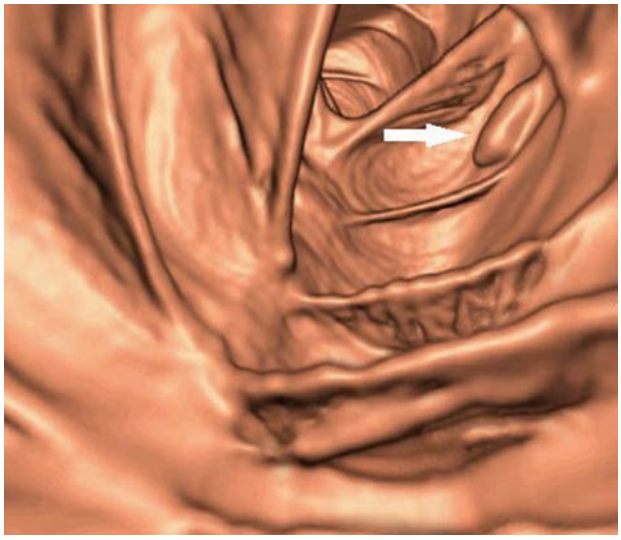

Figure 1 Endoluminal 3D reconstruction of a CT colonography dataset shows a 12 mm polyp (arrow) in the descending colon.

The trend away from conventional barium fluoroscopy to cross-sectional techniques in the diagnosis and staging of small bowel inflammatory bowel disease (IBD) will intensify. This will be driven by the superior mural and extra-luminal information afforded by cross-sectional imaging, the need to reduce radiation exposure, assess disease activity and general 'disinterest' in conventional barium techniques by the new generation of radiologists. The recently proposed Lemann score for example[9] relies on assessment of the bowel wall using cross-sectional imaging. MRI enterography is already routinely used by just under 40% of UK hospitals[10] and in the next 5 years most centres will offer this service (figure 3). MR fluoroscopy (cine motility imaging of the gut) will largely obviate the need for conventional fluoroscopy when assessing the mechanical function of the gut (for example, upstream of a stricture). The use of USS in IBD has remained relatively static over recent years. Planned new multicentre comparative trials between USS and MRI may increase its role.

CT enterography will be a viable alternative to MRI and USS, particularly as dose reduction techniques are implemented; although it will never be radiation-free, which will curtail use in those requiring repeated imaging. In the short term, CT will remain quicker, cheaper and technically less demanding than MRI, although the gap is closing. Its role in the diagnosis of acute GI bleeding will expand and largely replace diagnostic angiography and red cell scanning.

Fluoroscopic techniques will increasingly be reserved for problem solving and in instances where fine mucosal detail is critical and cannot be acquired endoscopically.

Diagnosis and assessment of colitis will remain mainly in the domain of the endoscopist, but MRI colonography (with colonic contrast filling via the rectum or after prolonged oral load) is a validated, less invasive alternative for disease follow up[11] and

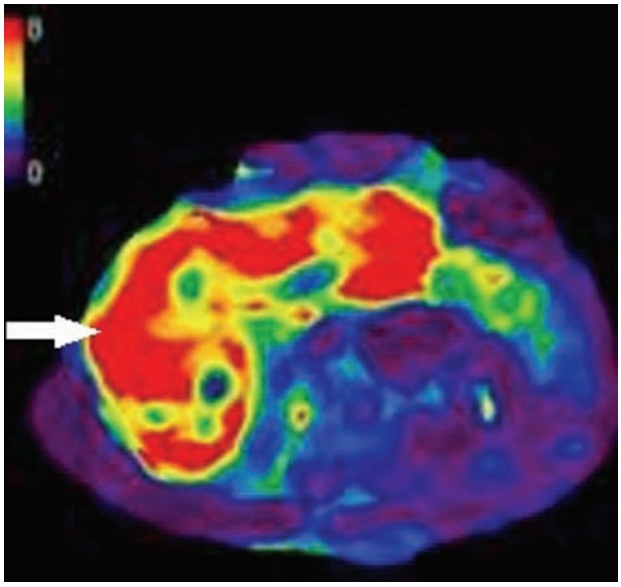

Figure 2 Axial magnetic resonance elastography of the liver (arrow). The technique uses mechanical waves to measure the mechanical properties of tissue based on its stiffness and expresses the data using a colour scale. It is increasingly used to assess liver fibrosis.

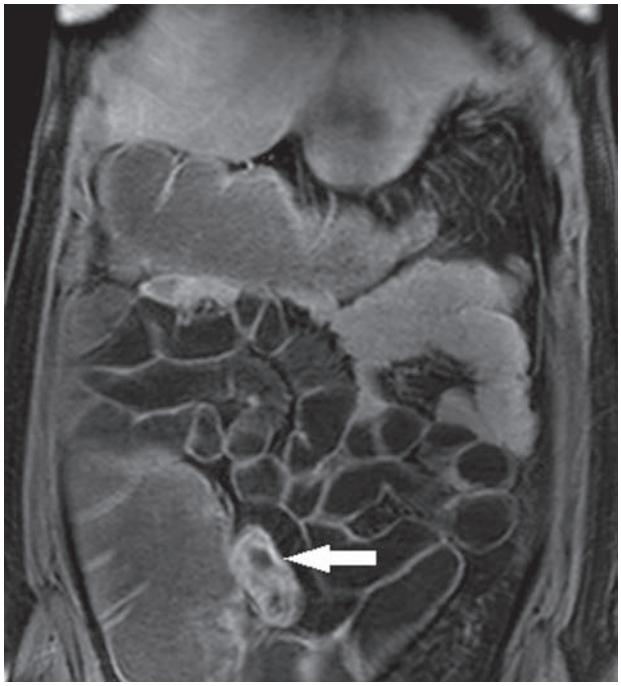

Figure 3 Coronal T1 weighted contrast enhanced image from an MR enterography examination in a patient with Crohn's disease. The thickened enhancing terminal ileum (arrow) is easily seen.

will be increasingly employed. The radiological monitoring of acute colitis will also increasingly use cross-sectional imaging instead of multiple abdominal radiographs. For example, rapid (<10 min) MRI protocols can provide a safe and validated marker of colitis severity.[12]

The general trend of replacement of fluoroscopic techniques will continue in the pelvis — MRI proctography will increasingly replace fluoroscopic proctography, with radiation-free visualisation of the whole pelvic floor and its associated organs.

Imaging technology

Increasing demand for rapid turnaround of requests for radiological imaging, together with the need for timely dissemination of reports, will continue to drive improvements in the speed and efficiency of imaging departments. Improved communication networks will help, with doctors remote from the radiology department being able to wirelessly review and report studies as they are performed. The food and drug administration approval has already been granted for the use of a diagnostic imaging interpretation application for tablet computers and handheld devices, and others will follow. Technologies such as these will increasingly enable clinicians, however remote, to access timely expert interpretation of imaging. For clinicians, this also gives the opportunity to review imaging on tablet computers at the bedside, with the potential to revolutionise teaching and patient communication. The use of teleradiology will almost certainly increase, driven by internal market forces within healthcare systems. How the quality of such services can be ensured and how they will align with current hospital-based provision of healthcare (for example, multi-disciplinary team meetings, etc) remains hotly debated.

Into 2020 and beyond

General trends

Changing computer interfaces, increasing globalisation of imaging services and the rise of functional imaging will likely drive change into 2020 and beyond. The concept of personalised medicine will become integral and imaging will play an increasing role in patient treatment triage and prognostication—the concept of 'radiogenomics' will be established (table 1).

Imaging techniques

Dose reduction techniques will continue to advance and eventually diminish abdominopelvic CT dose to 10% of its present level. Abdominal scanning will take less than 2–3 s and demand will continue to increase, with expansion particularly in surveillance and screening; for example using CT colonography, where non-laxative protocols will be routine. MRI technology will also advance and image acquisition times will drop considerably, probably to a quarter of current levels. Whole body MRI cancer staging will be routine in many cancers, replacing CT.

The whole thrust of medical imaging will move away from simple anatomical assessments to more detailed functional analysis in order to produce an imaging phenotype of the disease, specific to that particular patient. Akin to genetic typing of tumours, 'radiogenomics' will provide personalised imaging based on specific characteristics of the pathological process to

Table 1 Priority areas for imaging

Priorities for imaging	Implementation strategies/solutions
Reducing radiation exposure	▶ Increasing use of MRI especially in acute disease and for cancer staging
	▶ Dose reduction techniques such as iterative image reconstruction technology for CT
Improved diagnostic accuracy and disease prevention	▶ Cross-sectional imaging replacing fluoroscopy
	▶ Increasing use of computer aided detection software
	▶ Automated analysis of functional imaging techniques
	▶ Robust and defined standards in training and quality
	▶ Development of imaging platforms; dissemination of 3 T MRI and introduction of 7 T MRI and PET-MRI into clinical practice
	▶ Increased implementation of validated image-based screening such as for liver fibrosis
Implementation of functional information to complement basic anatomical imaging	▶ International standardisation of functional imaging technique acquisition and analysis
	▶ Routine assessment of lesion cellularity and vascularity in diagnostic reporting
	▶ Personalised imaging, incorporating the specific characteristics of an individual's pathology to enable prediction of therapeutic response
	▶ Validation of new PET-CT and PET-MRI biomarkers with increased labelling of drugs and antibodies.
Rapid and robust dissemination, storage and recall of imaging data	▶ Remote imaging reviews on mobile devices
	▶ Cloud technology with national imaging databases
	▶ 3D viewing with automated segmentation and intuitive navigation tools

PET, positron emission tomography.

guide patient therapy at diagnosis. Early prediction of patient response will allow a change in therapeutic approach well before conventional clinical or anatomical measurements are able to detect treatment failures.

This revolution in imaging biomarkers will be based on the development of existing techniques such as diffusion and perfusion imaging, which assess cell density and vascularity (a 5 year HTA funded multicentre trial of perfusion CT to predict future metastasis in colon cancer is already underway), and the development of new sequences specially designed to tease out the histological features of interest. For example, new MRI sequences are being developed to analyse the axonal structure in the brain based on the known histological footprint of the tissue.[13] Such techniques could be expanded to look at malignant cell patterns in cancer or precursor lesions, neutrophil/granuloma density in Crohn's disease or fibrosis grade in liver disease. Such 'intelligent' sequence design will become an important part of imaging development.

International bodies will agree on guidelines for the acquisition, quality assurance and analysis of functional imaging data across imaging platforms and countries, so large scale population data will become comparable—a vital step in the 'coming of age' of functional imaging. Multicentre trials will report using hard endpoints, such as progression-free survival and mortality to validate new imaging biomarkers; Response Evaluation Criteria in Solid Tumours (RECIST) criteria will be updated with imaging biomarkers other than simply tumour size.

Analysis of functional imaging data will be automated, eliminating the need for time-consuming and subjective region of interest drawing by interpreting radiologists. Indeed, development of automated software quantification of Crohn's disease activity using MRI enterography is already underway in an European Commission - Seventh Framework Programme (EU FP7) framework funded study, a first step in producing a personalised GI tract model using imaging.[14]

Optimisation and proper validation of MRI sequences used today will have occurred and it will be possible to accurately assess liver fibrosis and fat content using improved elastography and chemical shift MRI techniques. New techniques to measure extracellular volume such as equilibrium imaging[15] will be refined.

MRI assessment and quantification of GI tract motility will facilitate new insights into disorders of gut motility in a safe and non-invasive fashion, allowing more 'intelligent' therapeutic intervention.

New PET tracers will be developed and marketed; (Gallium-68 (Ga-68) DOTA-Phe(1)-Tyr(3)-Octreotide (DOTATOC))will replace conventional indium-based tracers for neuroendocrine tumours and hepatocellular carcinoma will be imaged with choline-based agents. New tracers aimed specifically at an underlying pathological process such as apoptosis, fibrosis or inflammation will become available and better validated. PET labelling of drugs and antibodies will allow better therapeutic planning. Positron-emitting bevacizumab is already available; others will follow. It will be possible to define lesion

uptake of the drug and accurately predict chemosensitivity.

Imaging technology

It is unlikely there will be a 'game changing' new imaging technology sufficiently developed to impact on clinical practice in the next 10 years (at least to the authors' knowledge!). However existing technologies will markedly improve. PET-MR machines are currently being installed around the world and the combined functional and anatomical data from each modality will only further strengthen the 'functional imaging revolution'.

High field strength MRI will expand, with 3 Tesla machines being found in most centres, decreasing scanning times and improving signal-to-noise ratio. Technical challenges to using higher field strengths (such as 7 Tesla units) in the abdomen will be overcome and resolution will be in the order of 100 microns or less, providing 'histology like' images of target organs.

The volume of data generated by imaging will increase exponentially and 'cloud technology' will become mainstream, solving storage problems and allowing instant, safe and ubiquitous availability of patient imaging data across healthcare systems. Such storage systems could open the door to unparalleled national imaging databases for clinical care and research. Detailed quantitative imaging data will be stored on each patient allowing increasingly automated comparison between scans for assessment of treatment response. The new generation of radiologists will be expert in computer image manipulation. Commercially available three-dimensional (3D) television display technology will be integrated into the radiology department, without the need for a dedicated headset or 3D glasses. Image interpretation will evolve, radiologists will 'swipe' through images to see the part they wish, and zoom by 'pinching' on the relevant part of the image, just as we presently use a smartphone or tablet. Looking behind a fold on colonography may simply need a tilt of the head, a motion sensor will track where the radiologist is looking and alter the display accordingly. Automated segmentation processes will extract individual organs from the imaging dataset for detailed separate review, for example by tapping on the gallbladder to allow a rotating view of it and the biliary tree in 360 degrees. Measurement of the length and volume of lesions will be quicker and easier to perform with a single click (or tap). Computer assisted detection will be incorporated into all work stations and will routinely be used in image review.

The upcoming technological revolution will open up opportunities for high volume dataset analysis by a combination of computer-assisted technology and trained technicians. Imaging-based high patient volume screening strategies, for example of the liver (for fat and fibrosis) or colon (by non-laxative CT or MR colonography) will be increasingly viable, shifting some of the focus of healthcare to prevention rather than cure.

Conclusion

The next 10 years and beyond are set to revolutionise GI imaging, with the disappearance of conventional fluoroscopy and a new emphasis on functional quantitative data acquired using low dose or radiation free modalities. The concept of personalised imaging and 'radiogenomics' will become established. Data interfaces will change, incorporating much of the functionality we now see in other sectors, such as the gaming industry. A global marketplace will exist in imaging interpretation, increasing competition. Financing and implementing these changes will be challenging but the imaging community is ever adaptive, quick to embrace technology and the opportunities that lie ahead.

Acknowledgements This work was undertaken at UCLH/UCL who received a proportion of funding from the Department of Health's NIHR Biomedical Research Centre's funding scheme. The views expressed in this publication are those of the authors and not necessarily those of the Department of Health.

Contributors ELH, AAP and ST were all responsible for the literature search and drafting of the manuscript. All authors approved the final version. ST is the guarantor.

Competing interests None.

Provenance and peer review Commissioned; internally peer reviewed.

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Frontline Gastroenterol 2012 3: i36-i41
doi: 10.1136/flgastro-2012-100121