ROLE OF VIDEO ENDOSCOPY IN MANAGING SMALL BOWEL DISEASE

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The small intestine has been relatively inaccessible to flexible endoscopy until recently.[1] Its length is a challenge to endoscopy. The small intestine accounts for 75% of the total length and 90% of the surface area of the gastrointestinal tract. In adults it measures about 570 cm at post mortem,[2] which is substantially longer than conventional video gastroscopes. Colonoscopes and gastroscopes measure 100–180 cm. There are features about its position and anatomy which limit the endoscopist's chance of passing longer endoscopes much further than a few centimetres into it, either through the mouth and duodenum or through the ileocaecal valve. The tight curve from the bulb around the head of the pancreas and its relatively fixed retroperitoneal posterior position as it crosses the spine to the ligament of Treitz where it passes downwards as a loosely supported much looped structure on a mesentery is a challenge. If a colonoscope is passed through the mouth into the jejunum and a surgeon pleats the small intestine over the endoscope by hand at laparotomy, the stiffness of the endoscope tends to stretch the mesentery, which is attached posteriorly as the endoscope follows the loops of small intestine and increases the friction exerted by the intestine on the endoscope. Colonoscopists can usually but not always enter the terminal ileum for a few centimetres. Either way, the distance and curved path that a conventional endoscope has to pass to reach the small intestine means that the force for effective forwards propulsion, which can be exerted on the tip of an endoscope, is small. Loops tend to form and enlarge in the stomach or in the colon, which can make deep small intestinal intubation difficult.

Recent technical developments in the design of longer flexible instruments specifically for push enteroscopy have made this examination much more successful.

The advent of wireless video capsule endoscopy[3] has released the endoscopist from the requirement to exert force on a long floppy cable-type endoscope to examine relatively short segments of small intestine. This device exploits peristalsis to propel the video endoscope through the small intestine and can usually but not always acquire images from the whole of the small intestine from the pylorus to the caecum.

TECHNICAL ADVANCES

There has been a substantial increase in small intestinal endoscopy in the last 10 years which has followed two technical advances (table 1). The first was the development of specific endoscopes for push enteroscopy (fig 1).[1 4–6] Careful attention to the design allowed better transmission of force to the tip and shaft stiffness for use at flexible endoscopy. These instruments were longer than colonoscopes, measuring 200–240 cm, and slimmer, usually measuring 11 mm in diameter but with a 2.8 mm accessory channel. They were initially designed for use with an overtube to aid deep intubation which usually needed *x* ray control for safe insertion. The overtube appeared to cause some of the complications associated with push enteroscopy—for example, sometimes causing oesophageal trauma.[7] The addition of video imaging[4–6] to these instruments allowed very high quality images to be obtained from the oesophagus to the jejunum (fig 2). Despite some evidence that 240 cm enteroscopes do not reach further or find more pathology than those of 200 cm,[8] some of the newer instruments are longer than the earlier enteroscopes (240–280 cm). Variable stiffness enteroscopes have recently become available.[9]

Most[9–16] but not all endoscopists[8] found that these instruments could be used almost as well without an overtube and thus dispensed with the need to perform this procedure under *x* ray control. There was evidence from two studies that the use of an overtube was associated with a significant increase in depth of insertion into the small intestine by 10–15 cm[17 18] but in neither of these studies was more pathology found. The whole of the duodenum and some of the jejunum can be examined by video colonoscopes,[19 20] especially with paediatric colonoscopes, which are more widely available than push enteroscopes. They are of the same diameter but substantially shorter (135 *v* 200–240 cm).[21]

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Table 1 New and available video methods of small intestinal imaging

What is new?
▶ Wireless capsule endoscope
▶ Double balloon push enteroscopy

What is available?
▶ Push enteroscopy
▶ Paediatric/adult colonoscopes to be used for push enteroscopy
▶ Intraoperative enteroscopy with a colonoscope
▶ Laparoscopic assisted enteroscopy
▶ Ileoscopy at colonoscopy

What is no longer used?
▶ Sonde enteroscopy

New non-video methods for small intestinal imaging
▶ CT enteroclysis and virtual enteroscopy
▶ Ultrasound
▶ MR enterography

CT, computed tomography; MR, magnetic resonance.

Figure 1 Types of enteroscopes: push enteroscope with bending section at the tip (above) and Sonde enteroscope with a smaller diameter and balloon at the tip.

It is difficult to be sure how far push enteroscopes are usually advanced into the small intestine because there are no landmarks and it is easy to overestimate the distance examined. A few groups have attempted to measure the distance with or without *x* rays, which seems rather short (45–70–100 cm).[11 17 18]

Wireless capsule video endoscopy was first used in humans in 1999.[3] It was able to provide video images from the whole of the small intestine and received FDA approval in 2002 following the demonstration of safety and efficacy as an adjunct to the investigation of patients with suspected small intestinal disease, especially obscure gastrointestinal bleeding. Although this technology has been available for a relatively short period, it has been widely adopted and used in more than 50 000 patients. Table 2 compares the differences between this technology and push enteroscopy.

Over this period another technology—sonde-type enteroscopy—has atrophied and been largely abandoned. This method was usually carried out with a thin (5–7 mm) very long flexible transnasal endoscope with a balloon and a guide thread attached to its tip (fig 1). Once in the stomach, a conventional transoral gastroscope was used to catch the guide thread and push the sonde enteroscope through the pylorus. The balloon was inflated and the endoscope was propelled by peristalsis through the small intestine. After about six hours, an *x* ray was taken to see how far it had passed and the sonde enteroscope was withdrawn, sometimes recording the image on video.[21 22]

There has been a recent advance in the ability to image the small intestine. Yamamoto *et al*, in conjunction with Fujinon,[23] have developed a double balloon enteroscope system which can be advanced much further into the small intestine than other push enteroscopes. The balloons are used to pleat the small intestine on the overtube, which is cautiously advanced over the enteroscope. This technique takes much longer to perform than a conventional push enteroscopy and needs *x* ray screening but it can sometimes examine even the whole of the small intestine. The system that has only been used in a few cases[24 25] may well be an important advance in enteroscopy because it may allow endoscopic directed therapy such as biopsy, snare polypectomy, and thermal treatment of any area in the small intestine.
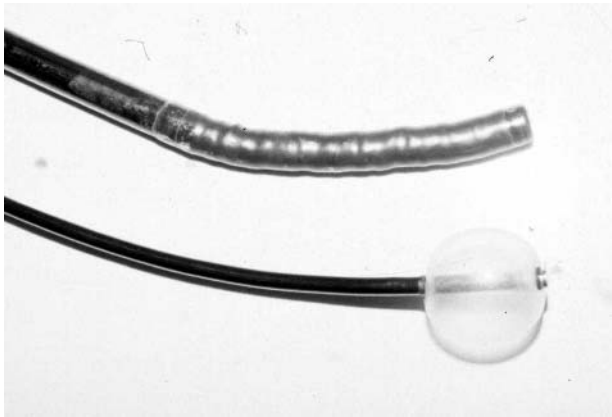
Figure 2 Push enteroscope video image of an adenomatous polyp in the jejunum.

A side viewing duodenoscope is occasionally helpful in viewing periampullary or duodenal abnormalities,[26] which are not well seen with a forward viewing endoscope, or for assessing whether bleeding is from the biliary or pancreatic duct.[27]

Table 2 Comparison of push and capsule enteroscopy

	Push enteroscopy	Capsule endoscopy
Image lesions*	XXX	XX
Biopsy	Yes	No
Therapy	Yes	No
Image quality	XXX	X
Real time viewing	Yes	No
Entire small bowel visibility	No	yes
Sedation	Yes	No
Patient acceptance	X	XXX
Image acquisition time	30 min	8 h
Image assessment time	30 min (as above)	1 h
Value in GI bleeding	XX	XXX
Manual skills needed	Yes	No
Clinical experience needed	Yes	For interpretation only

*In area examined.
XXX, very good; XX, good; X, acceptable.

Diagnostic laparoscopy can be especially valuable in children with suspected small intestinal bleeding[28] and probably should be used early in young males with recurrent bleeding as Meckel's diverticulum is the cause in two thirds of male patients under 25 years.[29] It is also of some value in middle aged patients when a small intestinal tumour is suspected.[30] There has been some interest in using laparoscopy to pleat the small intestine over a push enteroscope in order to advance the enteroscope to the ileocaecal valve.[31 32]

Open surgical exploration with an endoscope passed through the mouth or through an enterotomy—for example, in the caecum—continues to be an important last resort investigation in some patients with difficult gastrointestinal bleeding.[33]

PUSH ENTEROSCOPY
Technique
Push enteroscopes are heavier and longer than standard gastroscopes. They are slightly more difficult to handle during oesophageal intubation and passage across the pylorus but the push characteristics and increased flexibility allow for better handling in the jejunum. The bending section of push enteroscopes are longer, to allow increased angulation in all directions (fig 1).

A complete examination of the oesophagus and stomach should be performed with the instrument before entering the duodenum. Once the scope has been advanced into the second part of the duodenum, as with endoscopic retrograde cholangiopancreatography (ERCP), pulling back will produce ''paradoxical'' advancement. The ligament of Treitz is usually encountered 85–110 cm from the incisors and usually requires full tip deflection to find the lumen. Once around the ligament, the first jejunal loop can be identified by a straight configuration, which points in a caudal direction if seen on *x* ray (fig 3).

Overtube
A variety of methods have been used to try to reduce the tendency of the enteroscope to loop in the stomach. These include the use of abdominal pressure, internal stiffening devices,[11] and overtubes.[11 17 18] Some have two ring shaped

Figure 3 Fluoroscopic image of a 240 cm long push enteroscope which is introduced to its maximum length into the jejunum.

metal tip markers to facilitate placement under screening and to prevent the overtube tip from being compressed. Others have a more pliable Gortex tip of 10 cm in length, which may limit mucosal trauma when advancing the overtube over the endoscope. The overtube is initially back loaded onto the shaft of the endoscope and advanced down the endoscope through the oesophagus until its distal tip rests within the second portion of the duodenum or beyond the ligament of Treitz. Fluoroscopy is helpful for overtube use as prepyloric placement does little to aid deep intubation. The softer Gortex tipped overtube may buckle in the stomach and fail to provide sufficient rigidity.

Diagnostic applications
The main indication and pressure for improvements in enteroscopy has been obscure gastrointestinal bleeding in patients with a negative gastroscopy and colonoscopy. Push enteroscopy has been performed with published diagnostic yields of 30–50%.[1 11] One surprise has been that in a proportion of such patients having a push enteroscopy—approximately 25%—the cause has been found in the oesophagus, stomach, or duodenum, within reach of a gastroscope, and was missed on a previous gastroscopy. A list of common missed causes of obscure bleeding is found in table 3.

Push enteroscopy has helped in the diagnosis, biopsy, and management of small intestinal tumours (table 4). Other indications include malabsorption (including coeliac disease), assessment of Cohn's disease, non-steroidal anti-inflammatory drug induced strictures and erosions, abnormalities on barium or computed tomography, and worm infestation.

Therapeutic applications
Push enteroscopes include a standard 2.8 mm biopsy channel that has been used for several therapeutic functions within the proximal small intestine as well as for directed biopsy.[11] The more the instrument becomes looped as it advances into the small bowel, the greater the difficulty in getting instruments to emerge from the biopsy channel. This particularly applies to instruments with a long rigid tip such as heater or bipolar probes and balloons, rather than snares and laser fibres.

Biopsy
Endoscopic forceps-type biopsy has now largely replaced the use of a suction fired biopsy capsule as a means of obtaining small bowel biopsies.[34] The advantages of the endoscopic method are speed, ease, patient comfort, and reliability. Enteroscopic biopsies can reduce the chances of proximal duodenal inflammation and shorter villi in the bulb causing confusion when examining for coeliac disease. They may offer advantages in the workup of patients with diarrhoea or
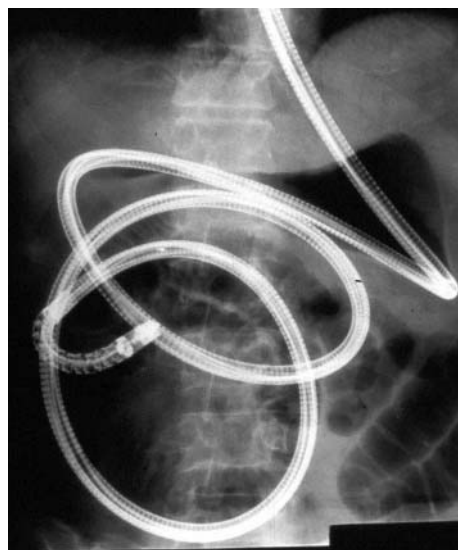
Table 3 Common missed causes of bleeding in the upper gastrointestinal tract which may be found during enteroscopy

- ▶ Large hiatus hernia with Cameron erosions
- ▶ Watermelon stomach
- ▶ Dieulafoy exulceratio simplex
- ▶ Varices
- ▶ Ulcers
- ▶ Angiodysplasia

Table 4 Small bowel tumours that may be detected during enteroscopy

- ▶ Lymphangiectatic cysts
- ▶ Gastrointestinal stromal cell tumours (GIST)
- ▶ Neuroendocrine tumours (eg, carcinoid, Zollinger Ellison)
- ▶ Polyps
  - – Adenomas
  - – Hamartomatous polyps
- ▶ Lipoma/angiolipoma
- ▶ Neurofibromas
- ▶ Duplication cysts
- ▶ Adenocarcinomas
- ▶ Lymphomas
- ▶ Sarcomas
- ▶ Metastases (eg, melanoma, renal cell carcinoma)

Figure 4 Snare polypectomy during push enteroscopy. (A) The snare is placed around the polyp and removed (B).

malabsorption, particularly if focal specific mucosal abnormalities have been seen in the proximal jejunum on small bowel *x* ray contrast series.[14] In countries such as the UK where coeliac disease is the commonest cause of malabsorption, enteroscopic biopsy does not add much information that is not acquired by duodenal biopsies taken with a gastroscope as coeliac disease mainly affects the proximal jejunum. It is more useful in assessing coeliac-like syndrome patients with unresponsive sprue or coeliac patients with weight loss when a lymphoma is suspected.[35–37] Biopsies from the jejunum were more likely to find a cause of diarrhoea in patients with chronic human immunodeficiency viral related diarrhoea than were duodenal biopsies.[38]

Jejunal feeding tube placement

Push enteroscopy has also been used in a variety of ways to place jejunal feeding tubes. It has been used to carry a transgastric jejunal tube through a previous gastrostomy into the jejunum.[39–41] Nasojejunal feeding tubes have been placed using the Seldinger over the wire technique.[42] The push enteroscope is placed into the jejunum initially and then a guidewire is advanced. The endoscope is removed, leaving the guidewire in place. A feeding tube is advanced over the wire and then re-routed from the mouth through the nose. This method has been combined with a sewing method for attaching the jejunal feeding tube to the stomach to prevent displacement.[11]

Direct percutaneous endoscopic jejunostomy placement

By using push enteroscopy, the "pull" technique for placement of percutaneous gastrostomies has been extended to permit direct percutaneous jejunostomies.[11 41 42] This technique has also been used to place jejunal tubes for small bowel enemas[43] as well as to obtain cholangiograms in patients after Roux-en-Y hepaticojejunostomy.[11 44]

Polypectomy

Polypectomy can be performed in the small intestine via the push enteroscope using snares (fig 4A, B).[11 45] Surveillance of patients with a polyposis syndrome can be performed with push enteroscopy, allowing biopsy and polypectomy of larger lesions. Removal of large jejunal hamartomatous polyps in Peutz-Jeghers syndrome has become part of the screening of this autosomal dominant condition with malignant potential (fig 2). The more proximal lesions are relatively easy to
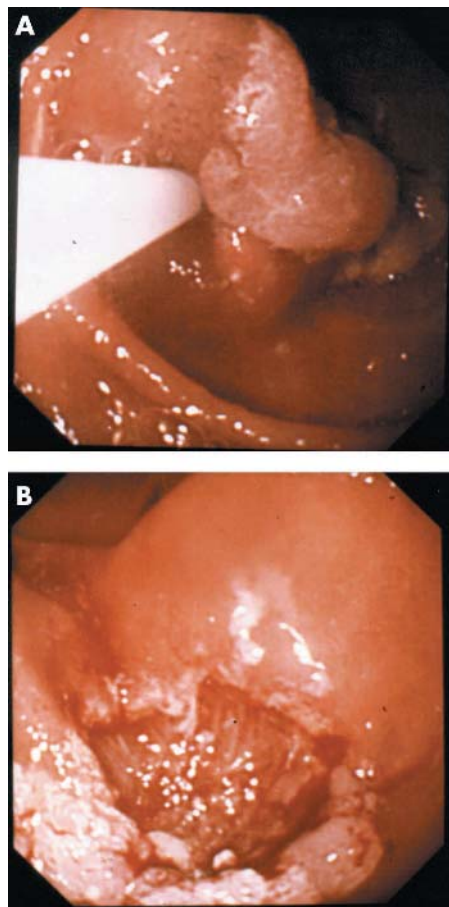
remove but endoscopic removal may require an enteroscope and snare used at open surgery: this technique can find and deal with polyps which cannot be identified by surgical palpation and translumination.[46]

Treatment of gastrointestinal bleeding

In addition to diagnosis, push enteroscopy allows cauterisation of bleeding sites. Using bipolar cautery, Foutch *et al* was able to fulgurate angiodysplasias in 11 of 12 patients.[19] Control of bleeding was obtained in 8 of the 11 treated patients. Askin and Lewis[47] assessed the long term effectiveness of push enteroscopic cauterisation of bleeding arteriovenous malformations in 89 patients. Of these patients, 61 were cauterised and 28 were not. The group that was cauterised required significantly fewer blood transfusions than the non-cauterised group. In another series of 50 patients undergoing therapeutic push enteroscopy, bleeding was terminated in all patients with isolated angiomas and reduced in more than half of the patients with multiple jejunal angioma as well as in some malignant tumours.[48] In addition, in 9/50 patients the bleeding source was found within the reach of a gastroscope[48] and successfully treated. This group had a significantly reduced transfusion requirement when compared with their pre-cauterisation status.

Injection of small intestinal varices

Small intestinal varices, especially in the duodenum and ileum, around anastomoses or adhesions in patients with

mesenteric thrombosis are an uncommon cause of bleeding but can be misdiagnosed and biopsied and may cause torrential bleeding. Successful treatment of bleeding jejunal varices using push enteroscopy to inject a sclerosant has been described.[49]

Complications

Complications are uncommon with push enteroscopy, which is probably nearly as safe as gastroscopy, and most series report that no complications occurred. Some of the complications appear to be associated with the use of a metal tipped overtube. These include a Mallory-Weiss tear, pancreatitis most likely secondary to papillary trauma, a pharyngeal tear, and three cases in which long strips of gastric mucosa were torn off during advancement of the overtube.[7 12 21] These complications with overtubes occurred prior to the addition of a Gortex tip. Duodenal perforation has been described[50] but appears less common than with ERCP or endoscopic ultrasound. Some series describe severe patient discomfort, which is usually due to stretching the stomach as a loop is formed along the greater curve while trying to transmit forward pressure to advance the tip in the small bowel.

INTRAOPERATIVE VIDEO ENTEROSCOPY
Technique

The endoscope is advanced into the proximal jejunum through the mouth prior to laparotomy as once the abdomen is open it may be difficult to advance the instrument around the ligament of Treitz. With oral intubation using an adult colonoscope, the endotracheal tube cuff may need to be deflated to permit passage of the wide calibre endoscope.

The examination is carried out by an endoscopist and a surgeon; the endoscopist looks at the endoscopic image using minimal air insufflation while the surgeon holds the endoscope tip inside the small bowel so as to inspect a short segment ahead of the endoscope. Once examined both internally and externally, the small bowel is pleated onto the shaft of the endoscope and the next section of bowel is examined. Care has to be taken not to overstretch the mesentery on colonoscopes, which are rather stiff for this use. Active bleeding within the small bowel may diminish the effectiveness of this examination. Visual examination and interpretation has to be performed during intubation and not on pull-back as mucosal trauma occurs with the pleating causing an artefact that may be confused with the appearance of angiodysplasia.[51] A technique of ''reverse transillumination'' to help differentiate trauma from vascular ectasias in this setting has been described[52] to allow visualisation of feeding vessel. At the end of the examination, the endoscope is withdrawn and the surgeon can resect the abnormalities identified by the sutures.

An alternative technique is to perform an enterotomy through which a ''sterilised'' endoscope or an endoscope covered by a sterile plastic sheath is placed. The enterotomy is generally performed in the mid small bowel, allowing both proximal and distal intestinal intubation, but it can be performed in the caecum if vascular ectasias are suspected in this area or distal small bowel. Retrograde intubation of the small bowel can be performed after the caecum has been inspected. The colonoscope is advanced through the ileocaecal valve by the surgeon and up the small intestine.

Diagnostic and therapeutic utility

Intraoperative endoscopy has been used for a variety of indications[46 47 52–58] but until recently was probably the endoscopic method most widely used in identifying small intestinal sites of bleeding beyond the proximal jejunum. It can be successful in identifying the site of blood loss in selected patients, with reported yields of 83–100%.[53–58] Vascular ectasias are the most common non-palpable cause of bleeding, but radiation enteritis, ulceration, malignancies, strictures, and polyps (for example, multiple polyps in Peutz-Jeghers syndrome) may require endoscopic identification. Haemostasis can be achieved at intraoperative enteroscopy either by resection of the bleeding lesion or by transendoscopic ablation of the bleeding lesion, usually with a thermal endoscopic method.

Complications

Prolonged ileus, sepsis, and perforations (the surgeon should listen for a hissing sound that indicates that perforation has occurred) are common sequelae of operative enteroscopy.

Outcome studies of the value of video enteroscopy with flexible instruments

Several studies have examined the number of diagnoses, influence on management, and subsequent clinical path of patients who have enteroscopy for suspected small intestinal outcome. Recent prospective studies suggested that management was altered in more than 50% who had push enteroscopy.[57 58] One study has shown that the costs of investigating and managing patients who bleed from the small intestine are different and substantially more expensive than the costs of patients who bleed from other gastrointestinal sites.[59] Outcomes studies of the value of push enteroscopy in non-bleeding conditions suggest that it can be of value in malabsorption,[14 60] Crohn's disease,[61] non-steroidal anti-inflammatory drug toxicity,[62] and worm infestation.[63] It can be usefully performed in non-specialist district general hospitals.[64]

It may be helpful to have some knowledge of the clinical patterns and appearances of the many less common or rare diseases which can affect the small intestine.[65] Access to an atlas[66] and book length reviews on enteroscopy in *Gastrointestinal Endoscopy Clinics of North American*[67] may help.

WIRELESS CAPSULE VIDEO ENDOSCOPY

The development of wireless capsule endoscopy[3 68–72] has changed video endoscopy of the small intestine into a much less invasive and more complete examination.[3 71 73–83] It has been particularly successful in finding the cause of obscure gastrointestinal bleeding of suspected small intestinal origin (fig 5).[73–83]

The capsule endoscope (M2A; GivenImaging, Yoqneam, Israel) contains a video imager, transmitter, light source, and batteries in a rounded cylindrical plastic container measuring 11×26 cm.[3] There is a clear optical dome shaped window which allows the intestine to be illuminated by an array of six (formerly four) light emitting diodes. The image is captured through a short focal length lens with a wide angle as the optical window of the capsule sweeps past the gut wall, without requiring air inflation of the gut lumen. Video images are transmitted using radiotelemetry to an array of eight aerials attached to the body. They allow image capture and calculation and an indication of the position of the capsule in the body. The capsule transmits images at a rate of two frames per second.

These images are subsequently downloaded from the portable recorder for analysis off line. Currently, the time

needed to evaluate the video sequence takes between 45 minutes and two hours and varies with the experience and concentration of the examiner as well as the number of pathological abnormalities present.

Wireless capsule endoscopy can provide approximately 7–8 hours of continuous video imaging of the gastrointestinal tract. This usually allows image acquisition from the oesophagus, stomach, small intestine, and right colon. The capsule is propelled by peristalsis and is passed through the anus into the toilet usually one or two days after ingestion. Because the gut is a hollow tube it is unimportant whether the capsule points forwards or backwards as it passes through. This form of endoscopy is painless, does not require sedation, and as a consequence the patient is ambulant and does not need to be confined to hospital during the examination.[3] [73–83]

Procedure and technique

Consent should specifically include an explanation that the capsule may become stuck in the small intestine requiring surgical removal, that capsule endoscopy does not always image the whole of the small intestine, that a plain abdominal x-ray may be performed if colonic images are not seen and the capsule is not seen in the toilet by the patient, and that magnetic resonance imaging scans should not be done if the capsule is not known to have emerged.

The patient should have an overnight fast or be nil by mouth for 12 hours prior to ingesting the capsule. Preparation as for colonoscopy may improve the quality of images in the lower small intestine but there are few data to support one regimen against another. It is necessary if images of the right colon are important, as for example in patients with incomplete colonoscopy.

The capsule can then be removed from its packaging which contains a magnet. This action will activate the capsule by releasing an internal magnetic switch and the capsule will start flashing.

The patient can then swallow the capsule, usually with some water. It is helpful to ask the patient to keep an eye on
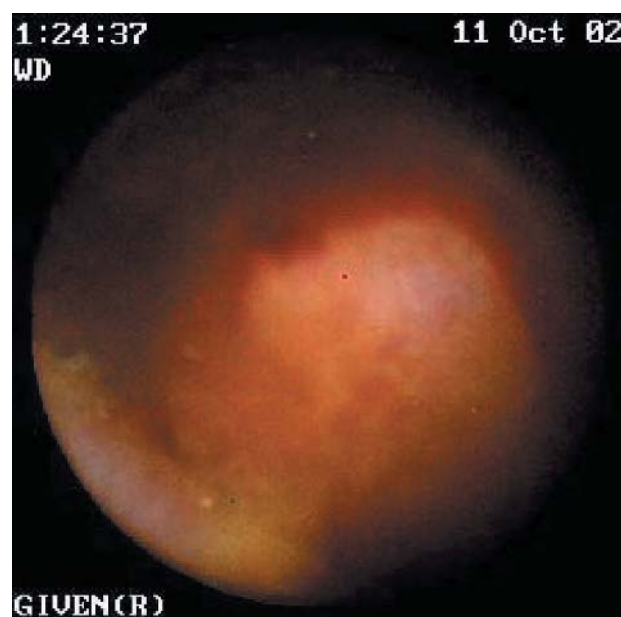
Figure 5 Bleeding from a jejunal adenocarcinoma.

Figure 6 Ulcers in the small bowel. The appearance is non-specific and can be seen in diseases other then Crohn's. (A) Ulcer due to intake of anti-inflammatory drugs. (B) Ulcer due to Crohn's disease.

the flashing light on the recorder and the connection between the aerial and the recorder and to report back if it stops flashing over the next two or three hours.

Patients should be asked not to eat for three hours after swallowing the capsule but told that they can drink clear water. They can have a light meal after this time. The belt and aerial can be removed eight hours after swallowing the capsule or when the recorder has stopped flashing. Patients should return the recorder, aerials, and belt but do not need to find and return the disposable capsule.

The images on the recorder need to be downloaded and processed prior to interpretation. Currently, image analysis of the 50 000 or so images acquired over the eight hour period takes about an hour or more to complete. It is probably unwise to read all the images at the fastest of the three

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Figure 7 Red spot in small bowel representing an angiodysplasia.

available speeds. It is helpful to store any unusual images as well as definite abnormalities as ''thumbnails'' for more careful subsequent review. Points of entry into the stomach, duodenum, and caecum need to be marked to enable the localisation software to image the passage of the capsule inside the abdomen. Abnormalities detected as blood by the blood sensing algorithm need to be checked. Newer software places two adjacent images side by side to allow faster image analysis. The recording, with marked thumbnails, need to be saved to the hard drive and to a CD-ROM. A typed report with interpretation of the findings needs to be generated.

Interpretation of small intestinal images is not always easy and it may help to go backwards and forwards over some image sequences and to ask another endoscopist for an opinion. There is a wide range of pathologies and numerous rarities are found which can affect the small intestine. Visual appearances are not specific, especially for the wide range of tumours found in the small intestine (see table 4, fig 5). Benign conditions, including Crohn's disease, amyloidosis, and lymphangiectasia, have a wide range of appearances (figs 6, 7). It can be difficult to be sure when a red spot is really an angiodysplasia (fig 7). In young males it may be

helpful to review the lower small intestinal images for a double lumen suggestive of a Meckel's diverticulum and to run over some of the images in the light of the clinical history in most patients.

Most patients believe that wireless capsule endoscopy is good and find it preferable to conventional endoscopy or colonoscopy.[74 82] It has been at least as successful as, and sometimes significantly more successful[75 82] than, push enteroscopy in finding the cause of obscure gastrointestinal bleeding (table 5) in published series, with yields of 55–70% (table 6). A blood sensing algorithm may assist in alerting the physician to an area of bleeding pathology.[84] It has been successful in identifying small intestinal tumours (table 4) when multiple other investigations have failed,[74 82 85] but may miss such tumours.[86] It has been significantly more successful than barium studies[87] in finding pathology in the small intestine and has outperformed barium meal as well as state of the art enteroclysis[88 89] and computed tomographic enteroclysis[90] in fully published recent studies.

Limitations

Images from the oesophagus, stomach, and colon are less good than those acquired during conventional endoscopy but may show pathology in these areas. Images from the small intestine are somewhat less good than enteroscopic views because the capsule cannot wash or be pulled back to re-examine a possible abnormality. At present, wireless capsule endoscopes cannot take biopsies or deliver therapy. With its current acquisition time of 7–8 hours, the capsule fails to provide images from the caecum approximately 15% of the time. As a consequence, an uncertain length of small intestine remains unexamined. A few patients, especially children, have difficulty swallowing it. Occasional patients retain it for prolonged periods in the stomach as there is a very wide range of ''normal'' gastric emptying times. Images may be poor in patients with morbid obesity. It can take a long time to interpret the images. Skill and experience are required. A lot of the findings can be of unknown significance. Pathology may only be seen on a single frame. As it may travel looking forwards or backwards, it may not look at pathology in an expected direction. Images in the lower small intestine are often rather dark. The recurring cost of the capsule as a disposable and the relatively lengthy examination times require specific funding and organisational strategies.

The main complication is that the capsule may become impacted in strictures[91] or diverticulae.[83] Most commonly, capsule impaction is symptomless. Sometimes capsule impaction may be a good outcome, leading to identification of strictures, diverticulae, or ulcers which can be resected. If the capsule can be reached by an endoscope, a snare with a net is the most useful retrieval tool as the capsule is more

Table 5 Possible causes of small bowel bleeding

- ▶ Angiodysplasia and vascular malformations
- ▶ NSAID enteropathy
- ▶ Erosive jejunitis
- ▶ Diverticulae
- ▶ Crohn's disease
- ▶ Jejunal or ileal ulceration: idiopathic, NSAID induced, etc.
- ▶ Intussusception
- ▶ Small intestinal tumours (see table 4)
- ▶ Ischaemic enteropathy
- ▶ Graft versus host disease
- ▶ Cytomegalovirus infection
- ▶ Aortoenteric fistula
- ▶ Blue rubber bleb syndrome

NSAID, non-steroidal anti-inflammatory drug.

Table 6 Comparison of the diagnostic yield of capsule endoscopy and push enteroscopy in the diagnosis of gastrointestinal bleeding

	Capsule	Enteroscopy
Mata[100]	66%	19%
Mylonaki[82]	68%	32%
Saurin[101]	69%	38%
Lewis[74]	55%	30%
Ell[75]	66%	28%

difficult to grasp with a stone basket or simple snare. Inadvertent magnetic resonance imaging may cause complications as the capsule will respond to a magnetic field. If a capsule examination does not provide colonic images and the patient does not see the capsule in the toilet, it might be sensible to take a plain abdominal *x* ray to check for passage. Pacemakers are probably not a contraindication. Capsule endoscopy has been approved by the FDA for use in children over 10 years.

CLINICAL MANAGEMENT OF PATIENTS WITH OBSCURE GASTROINTESTINAL BLEEDING

Investigation of patients with obscure gastrointestinal bleeding and a suspected small intestinal bleeding source is the commonest indication for video enteroscopy. Angiodysplasia is the commonest finding but there are many other potential causes (table 5). Management still remains demanding despite technological improvements in enteroscopy.

It is assumed that these patients have been investigated with a negative gastroscopy (OGD) and colonoscopy. If review of the reports of gastroscopy and colonoscopy findings suggest that this examination was incomplete or of poor quality, it may be appropriate to repeat OGD and colonoscopy prior to any other examinations.

Clinical history and any other investigations should be reviewed for hints about the possible location of the obscure bleeding. Age, location of any discomfort, length of history, colour of blood seen by the patient, presence of skin abnormalities, unexplained abnormal blood tests, weight loss, hiatus hernia symptoms, and previous history of malignancy (for example, melanoma) should be used to focus the search. Investigation pathways can be constructed based on the age and symptoms of the patients (figs 8, 9).

If male, between 10 and 25 years, a Meckel's scan should be performed early. If positive, surgery should be undertaken without further imaging. Because the scans are frequently negative in such patients and bleeding from a Meckel's diverticula accounts for bleeding in two thirds of this group of patients, capsule examination could be the next step to look for this and other causes of bleeding, such as Crohn's disease. If capsule examination is negative, an early laparoscopy should still be considered (fig 9).

If aged between 40 and 65 years, with a short history of recurrent anaemia, continuous bleeding or transfusion requirement, or weight loss and raised inflammatory markers, a more intensive investigational algorithm should be followed with early push enteroscopy or capsule examination (figs 8, 9), perhaps followed by laparoscopy or surgical laparotomy and enteroscopy.

If female, and there is doubt that the bleeding is coming from the gastrointestinal tract, consider gynaecological opinions, including pelvic ultrasound and faecal occult blood testing prior to intensive small intestinal investigation.

If there is a short story, active bleeding, transfusion requirement, blood seen coming from the ileocaecal valve, alarm symptoms, or an anxious patient, then capsule examination should be the next examination if available.

An algorithm of examinations for these groups of patients is given in fig 8.

CONCLUSIONS

Recent improvements in push and capsule video enteroscopy has changed the management of patients with small intestinal disease.

Both push and capsule enteroscopy are of proven value in the diagnosis of patients with obscure gastrointestinal bleeding. Because there is a high incidence in most enteroscopic series of lesions missed or their significance not understood on initial gastroscopy (table 3), a case could be made for a repeat gastroscopy by an experienced endoscopist before performing push enteroscopy or wireless capsule examination. There is also a well documented miss rate[92] at colonoscopy of polyps and cancers, which may be due to failure to reach the caecum in 10–22% in large colonoscopy series or to incomplete examination on rapid withdrawal of the colonoscope. Repeat colonoscopy should also be considered in patients with persistent difficult gastrointestinal bleeding

In patients with documented malabsorption, push video enteroscopy with biopsy is sometimes of value in establishing a diagnosis when duodenal biopsies are unhelpful. It is more valuable in assessing compliant patients with coeliac disease who have weight loss and diarrhoea and a lymphoma is suspected, and in assessing ulcerating jejunitis. Capsule examination may also prove useful in this subgroup.

Push enteroscopy is frequently disappointing in assessing patients with negative barium studies in whom Crohn's
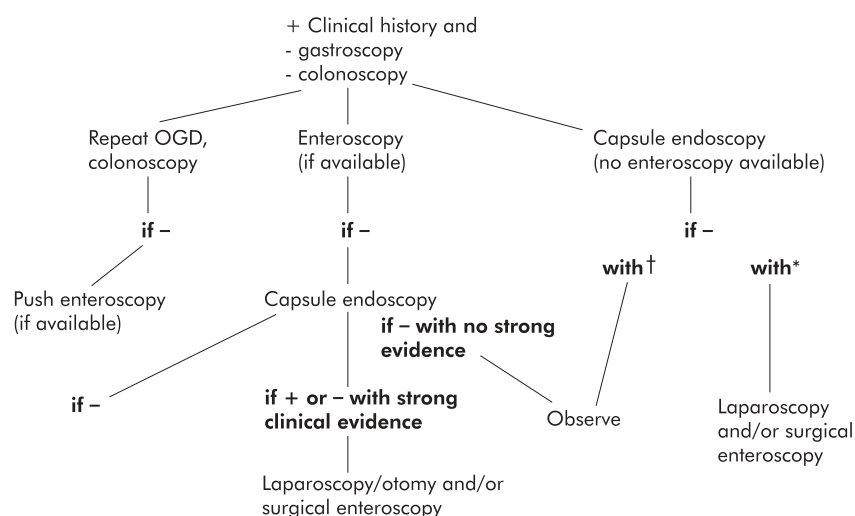
Figure 8 Algorithm for investigation of patients with obscure bleeding. *Short history of bleeding, continued bleeding (transfusion dependent), weight loss, and other abnormal blood tests. †Long history of bleeding, >2 years anaemia corrected with iron, no weight loss, and no other abnormal blood tests.
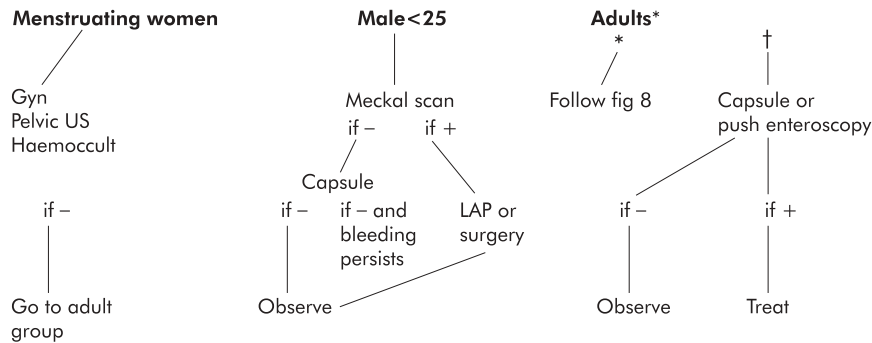
Figure 9 Investigation pathways in different patient groups with obscure bleeding. *Short history of bleeding, continued bleeding (transfusion dependent), weight loss, and other abnormal blood tests. †Long history of bleeding, >2 years anaemia corrected with iron, no weight loss, and no other abnormal blood tests.

disease is suspected,[11] [14] probably because Crohn's disease less commonly affects the proximal jejunum. Wireless capsule endoscopy has been perhaps surprisingly good at finding evidence of early Crohn's disease[93–96] in patients with negative colonoscopy and barium studies, and is probably the most important advance in imaging for this disease. It has shown that negative ileoscopy does not exclude the diagnosis of Crohn's disease. The fairly common finding of one or a few aphthous ulcers in the small intestine at capsule endoscopy requires further assessment as not all of these patients have Crohn's disease or is the ulceration likely to be the cause of chronic abdominal pain in all of them. The yield of wireless capsule endoscopy in patients with chronic abdominal pain is low but not zero.[96] Wireless capsule studies have been able to visualise ileal tuberculosis,[97] worm infestation,[71] and has helped in the management of small bowel transplantation.[98] It has been suggested that abnormal delays in capsule transit can indicate the presence of small intestinal pathology.[99]

Video enteroscopy has opened up a new world of diagnoses and possibilities to the gastroenterologist. It is a privilege to see images of small intestinal abnormalities at video endoscope, such as an ulcerated Meckel's diverticulum or active bleeding from a tumour in the middle of the small intestine, which were not possible until recently. The increasing use of this resource and the comfort and ease with which some of these examinations can be performed make it likely that video imaging will have a substantial impact on the management of small intestinal disease.

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