Comparison of capsule endoscopy with enteroclysis in the investigation of small bowel disease

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Abstract

Purpose: To compare results of capsule endoscopy with those of barium enteroclysis or CT enteroclysis.

Methods: Retrospective review of hospital records revealed 65 patients who had an enteroclysis and small bowel capsule endoscopy. The diagnostic yield of capsule endoscopy was compared with the enteroclysis using Fisher's exact test.

Results: The main indications were obscure gastrointestinal bleeding ($n = 37$) and suspected Crohn disease ($n = 17$). Radiologic studies included CT enteroclysis ($n = 30$), and fluoroscopic barium enteroclysis with carbon dioxide ($n = 18$) or with methylcellulose ($n = 17$). Capsule endoscopy had a higher diagnostic yield (8/17) compared to barium–methylcellulose cellulose enteroclysis (1/17) ($P = 0.02$). The diagnostic yield of capsule endoscopy was not significantly different compared with barium–carbon dioxide (12/18 vs. 10/18) enteroclysis or with CT enteroclysis (9/30 vs. 8/30). Vascular lesions were better assessed with capsule endoscopy. However, the CT enteroclysis found more lesions in patients with chronic abdominal pain.

Conclusion: Barium–carbon dioxide enteroclysis and CT enteroclysis have similar diagnostic yields for small bowel disease compared to capsule endoscopy. Barium methylcellulose has an inferior diagnostic yield.

Key words: Capsule endoscopy—Small intestine—Diagnosis—Enteroclysis—CT enteroclysis

Indirect imaging of the small intestine by radiologic investigations has remained dominant in clinical practice due to its wide availability, acceptable tolerance, and the ability to cover the entire gastrointestinal system, all of which are recognized as potential limitations of conventional endoscopy. The status quo changed with the introduction of video capsule endoscopy (PillCam, formerly M₂A Capsule, Given Imaging, Yoqneam, Israel) in August 2000 [1]. Segments of the small bowel that could not be reached by standard endoscopy or push enteroscopy could now be visualized with the capsule endoscope. While capsule endoscopy has been compared with small bowel follow through, there is limited data comparing capsule endoscopy and more advanced radiological techniques [2–5]. We are aware of only two European studies from the same institution comparing capsule endoscopy and CT enteroclysis [6, 7]. No study has compared capsule endoscopy with double contrast barium–air enteroclysis. We wished to retrospectively compare the yield of the newer radiologic techniques with capsule endoscopy in a heterogeneous group of patients being investigated for small bowel disease.

Materials and methods

Patients

The study was approved by our institutional review board, with waiver of informed consent. From the elec-

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tronic records of the gastroenterology and radiology departments we retrospectively identified all patients who had undergone both capsule endoscopy and an enteroclysis examination between January 2002 and December 2003. We excluded patients who had surgery ($n = 4$) or anti-inflammatory treatment ($n = 3$) in between the two studies. We identified 65 patients that met these criteria. The enteroclysis techniques were either fluoroscopic ($n = 35$) or CT enteroclysis ($n = 30$). The fluoroscopic double contrast enteroclysis as performed with combination of barium with methylcellulose ($n = 17$) or with carbon dioxide ($n = 18$). Unlike many prior studies, we included patients in whom the capsule endoscopy was equivocal or nondiagnostic ($n = 6$). We compared the diagnostic yield of the capsule study and each of the radiologic tests per indication and the type of lesion found.

Technique

Capsule endoscopy. Capsule endoscopy was performed using a swallowable capsule (PillCam SB, Given Imaging, Yoqneam, Israel). The capsule contains a metal dioxide silicon chip camera, a focusing lens, four white light emitting diodes, two silver oxide batteries, and a UHF band radio transmitter. Patients fasted for 12 h prior to the study. The capsule was swallowed with water. Two images were acquired per second with resolution of 256×256 , magnification of 1:8, 1–30 mm depth of view, and 140 degrees field of view. Images were transmitted over the life of the battery, typically up to 8 h. Before swallowing the capsule, an array of sensors was taped to the patient's abdominal wall in a predetermined pattern. The sensors were connected to a belt pack that contains a power cell, receiver, processor, and a hard drive that stores the images. After ingestion of capsule, patients were asked to refrain from taking medication for 2 h and to fast for 4 h. At the end of 8 h after capsule ingestion, the data received on the hard drive were downloaded to a work station (RAPID workstation, Given Imaging). Interpretation took between 30 and 90 min [8] and speed of image review varied between 1 and 50 per second.

Fluoroscopic enteroclysis. The details of the fluoroscopic enteroclysis techniques have been reported previously [9]. For fluoroscopic enteroclysis examinations we used biphasic contrast with barium, followed by either methylcellulose or carbon dioxide. For carbon dioxide enteroclysis we used 550 mL of barium and between 1 to 2 L of carbon dioxide until distal small bowel showed double contrast appearance on fluoroscopy.

All patients in this study had conscious sedation prior to enteroclysis studies. The patients were monitored throughout the procedure by a registered nurse. Fentanyl (Fentanyl citrate, Abbott Laboratories) was given intravenously at a dose of 25–50 μ g. A titrated dose of

midazolam (Versed, Roche Laboratories) was given in small aliquots to a total of 15 mg. In addition, metoclopramide (Reglan, A.H. Robbins Co., Richmond, VA) 10 mg was given intravenously as a pro-peristaltic agent. A higher dose of metoclopramide (up to 20 mg) was given in those already on narcotic analgesia or anti-cholinergic mediation.

CT enteroclysis. All examinations were performed on a multidetector row CT with four or 16 channels of detectors (Mx8000 or IDT, Philips Medical Systems, Cleveland OH). Section (slice) widths of 2 and 3.2 mm with reconstruction interval of 1 and 1.3 mm were used for the 16- and 4-slice scanners, respectively. CT enteroclysis images were reviewed on a workstation in both the axial and reformatted coronal and sagittal planes. Neutral enteral contrast CT enteroclysis ($n = 10$) was performed using water. Intravenous contrast was given with this technique. Positive enteral contrast CT ($n = 20$) was performed using 12% diatrizoate meglumine (Gastrografin, Bracco, Princeton, NJ). No intravenous contrast was given with positive enteral contrast CT enteroclysis. Site of tube placement, volumes, and rate of enteral and intravenous contrast infusion were as per previous report [9].

Data analysis

Patient demographic information and the original interpretation of the enteroclysis examination were retrieved from hospital and/or radiology information systems. Pertinent surgical and pathological reports were also documented. For each patient, the enteroclysis examinations were interpreted by one of two gastrointestinal radiologists with over 25 years post-fellowship experience. Capsule endoscopy data was interpreted by one of six board certified and fellowship trained gastroenterologists with a minimum of 2 years experience in capsule endoscopy interpretation. Both groups of clinicians interpreted the studies in light of available clinical and imaging information. Findings were considered doubtful if the only findings were focal erythema, luminal blood without focal lesion, or up to three superficial ulcers. These findings were not included in determining diagnostic yield.

Findings that were documented were categorized into vascular lesions such as angiodystasia, inflammatory lesions such as Crohn disease, tumor, strictures (such as from adhesions), and a miscellaneous group that included celiac disease. Differences in yield of the capsule and radiological study were analyzed using Fisher's exact test (2-tailed). Statistical analysis was performed using Matlab Statistics 5.2 (MathWorks Inc., Natick, MA).

Results

The main indications for the tests were obscure gastrointestinal bleeding ($n = 37$), suspected Crohn disease

($n = 17$), chronic unexplained abdominal pain ($n = 8$), suspected small bowel tumor ($n = 2$), and suspicion for celiac disease ($n = 1$). The mean age was 54.2 years (range 9–88 years); 45 patients were female. Double contrast fluoroscopic enteroclysis studies were performed in 35 patients using methylcellulose ($n = 17$) or carbon dioxide ($n = 18$). CT enteroclysis techniques were performed in 30 patients with either positive ($n = 20$) or neutral ($n = 10$) enteral contrast. CT enteroclysis examinations were grouped together. Enteroclysis occurred before capsule endoscopy in 55 of 65 patients (85%). The time interval between the capsule and enteroclysis studies was less than 3 months in 54 patients and between 3 and 6 months in 11 patients. All surgical and pathological gold standard data was available within 3 months of the studies.

The capsule did not reach the cecum in six patients (9%) prior to the end of battery life (typically 8 h). In one patient, the capsule was retained permanently and was removed surgically. In four patients, the capsule views were suboptimal due to excess luminal fluid.

Diagnostic yield per indication

The diagnostic yields of capsule endoscopy, methylcellulose enteroclysis, carbon dioxide enteroclysis, and CT enteroclysis are given in Table 1. There was no statistical difference in the diagnostic yields of CT enteroclysis (9/30) and capsule endoscopy (8/30) ($P = 0.78$). Capsule endoscopy had a significantly higher diagnostic yield (8/17) compared to methylcellulose barium enteroclysis (1/17) ($P = 0.02$). There was no significant difference in yield of positive finding with carbon dioxide barium enteroclysis (12/18) compared to capsule endoscopy (10/18) ($P = 0.73$). Carbon dioxide enteroclysis had a high yield in showing small ulcers in patients with obscure gastrointestinal yield (Fig. 1).

CT enteroclysis showed numerous adhesions in three patients with chronic abdominal pain following prior surgery. Capsule endoscopy was negative in these patients. For other indications, both CT enteroclysis and barium carbon dioxide enteroclysis were equivalent to capsule endoscopy. However, methylcellulose had poor diagnostic yields for both obscure gastrointestinal bleeding and suspected Crohn disease.

Diagnostic yield per etiology of lesions

The diagnostic yields per etiology are given in Table 2. The numbers in each subgroup were too small to make satisfactory statistical comparisons. Nevertheless, it appears that methylcellulose enteroclysis was suboptimal compared to capsule endoscopy in assessing both vascular and inflammatory lesions.

CT enteroclysis and carbon dioxide enteroclysis were not as good as capsule endoscopy in diagnosing vascular lesions, particularly angioectasia. However, these radiologic tests were as good as or better than capsule endoscopy in assessing small inflammatory ulcers from Crohn disease or nonsteroidal anti-inflammatory drug (NSAID) use. This finding was in part due to equivocal capsule studies, or the capsule not reaching the cecum before the end of battery life. In addition, although the capsule endoscopy had a high sensitivity, its specificity was low (Fig. 2).

In detecting tumors, capsule endoscopy showed small multifocal carcinoid tumors in one patient which was missed by CT enteroclysis (Fig. 3). On the other hand, CT enteroclysis showed serosal metastases which were missed by the capsule study.

Discussion

There is considerable data comparing capsule endoscopy with small bowel follow through. Two studies (total $n = 60$) assessing patients with obscure gastrointestinal bleeding found significantly lower yield of small bowel follow through (3–20%) compared to that of capsule endoscopy (45–55%) [10, 11]. Two other studies (total $n = 53$) investigating obscure gastrointestinal bleeding found diagnostic yields of 55–66% with capsule endoscopy [12, 13]. In these studies, all patients had prior normal small bowel follow through. Seven studies that looked at patients with suspected or established Crohn disease found the yield of small bowel follow through (0–33%) significantly lower than that of capsule endoscopy (43–71%) [14–20]. Small bowel follow through was also not particularly helpful in excluding strictures that may potentially trap the capsule. Capsule retention occurred in a total of 20 patients in four studies, all of whom had prior normal small bowel series [21]. Thus, the role of small bowel follow through in the era of capsule endoscopy is questionable.

Table 1. Diagnostic yields of enteroclysis studies and capsule endoscopy per indication

	CTE	Capsule	CO ₂ CE	Capsule	Methyl CE	Capsule
Chronic abdominal pain	3/8 ^a	0/8				
Obscure GI bleeding	3/16	5/16	8/12	8/12	1/11	6/11
Suspected Crohn disease	2/5	2/5	4/6	2/6	0/6	2/6
Suspected celiac disease	1/1	1/1				
Overall	9/30	8/30	12/18	10/18	1/17	8/17

CTE, CT enteroclysis; Capsule, capsule endoscopy; CO₂ CE, barium–carbon dioxide enteroclysis; Methyl CE, barium–methylcellulose enteroclysis

^aThe numerator is the number of patients with positive diagnosis and the denominator is the number of patients examined with particular indication

Fig. 1. A 68-year-old female with obscure gastrointestinal bleeding, with history of nonsteroidal anti-inflammatory drug NSAID use. **(A)** Enteroclysis with barium and carbon dioxide showed linear mucosal abnormalities (*arrowheads*) interpreted as ulcers. **(B)** Capsule endoscopy performed 2 days later demonstrated linear ulcers (*arrow*) with raised margins. NSAID enteropathy was diagnosed and bleeding resolved when NSAID usage ceased.

We wished to see if the more sensitive radiologic techniques of fluoroscopic and CT enteroclysis would have a higher yield in patients who may also have capsule endoscopy. There is limited published data on such comparisons. In common with virtually all publications

Table 2. Diagnostic yields of enteroclysis studies and capsule endoscopy per etiology

	CTE	Capsule	CO ₂ CE	Capsule	Methyl CE	Capsule
	30		18		17	
Number of patients						
Vascular ^a	1	3	0	4	0	4
Inflammatory ^b	5	4	12	6	1 ^c	3
Tumor ^d	1	1			0	1
Adhesive stricture	2	0				

Note that inflammatory lesions such as Crohn disease and nonsteroidal anti-inflammatory drug ulcers may have presented as obscure GI bleeding

CTE, CT enteroclysis; Capsule, capsule endoscopy; CO₂ CE, barium-carbon dioxide enteroclysis; Methyl CE, barium-methylcellulose enteroclysis

^aIncludes angioectasia and arterio-venous malformations

^bInflammatory lesions include Crohn disease, NSAID ulcers, and radiation enteritis

^cMethylcellulose detected ulcerations in a surgical blind pouch. Capsule studies also showed ulcers but suspected Crohn disease

^dInclude a case each of ileal carcinoid and serosal metastases

on capsule endoscopy [4, 6, 10, 12–17, 22–48] we assessed the diagnostic yield. To measure the true sensitivity and specificity a gold standard is required. In most patients with suspected Crohn disease or unexplained gastrointestinal bleeding, surgical pathology or intraoperative enteroscopy, which could be used as gold standard, are inappropriate.

CT enteroclysis vs. capsule endoscopy

In our study, capsule endoscopy showed vascular lesions in three patients vs. only one with CT enteroclysis. Capsule endoscopy also showed a 7 mm primary carcinoid tumor that was missed on CT enteroclysis. These findings suggest that capsule endoscopy is superior to CT enteroclysis for detecting flat mucosal lesions. On the other hand, CT enteroclysis was superior for assessing bowel wall lesions, such as adhesions, enteric fistula, and serosal metastases. Capsule endoscopy did not detect any lesions of these types, while they were seen in four patients with CT enteroclysis.

Our study findings are mirrored by another study comparing capsule endoscopy and CT enteroclysis. In this study of 56 patients with known Crohn disease [49], 15 patients (27%) did not have capsule endoscopy because preceding CT enteroclysis showed intestinal strictures. In the remaining 41 patients, capsule endoscopy was found to be superior to CT enteroclysis in detecting proximal small bowel lesions (yields of 61% and 29%, respectively) but the two tests were equivalent in detecting distal ileal disease (yields of 58% and 49%, respectively). Many of the patients in this study had early Crohn disease as manifested by the mean symptom duration of 12 months. Looking at the study more closely, the major component of the high yield of capsule

Fig. 2. A 21-year-old male with abdominal pain and anemia. **(A)** Enteroclysis with barium and carbon dioxide showed large Meckel's diverticulum (arrow) with wide neck and small pools of barium (arrowheads) suggesting presence of ulcers. **(B)** Capsule endoscopy performed 3 weeks earlier demonstrated ulcers (arrows), but the wide neck of Meckel's diverticulum (arrowhead) was misinterpreted as normal ileocecal valve and patient was considered to have active Crohn disease. Surgical pathology confirmed Meckel's diverticulum with ulceration of Brunner's glands.

endoscopy was due to detection of minor lesions, such as aphthous ulcers and erythema. In the assessment of major lesions, such as fissures, fistula, and stenosis, CT enteroclysis had a higher yield than capsule endoscopy (distal ileal lesions in 13 patients and 10 patients, respectively). Capsule endoscopy has been shown to have a poor yield in patients with chronic abdominal pain [50, 51] and our

Fig. 3. A 55-year-old female with overt gastrointestinal bleeding. Multiple subcentimeter nodules in proximal jejunum (arrowheads) were confirmed to be carcinoid at surgery. CT enteroclysis with neutral enteral and intravenous contrast (not shown) was normal.

results confirm this, with the capsule study being negative in all eight patients with this indication.

Methylcellulose enteroclysis vs. capsule endoscopy

Two studies assessing known or suspected Crohn disease patients showed diagnostic yields of 71–93% for capsule endoscopy compared to 26–33% for enteroclysis [17, 52]. Our results confirm the lower diagnostic yield of methylcellulose enteroclysis. In our heterogeneous group, this method of enteroclysis had the lowest yield (8%) and was significantly lower than capsule endoscopy (47%) ($P < 0.05$). One of the lesions missed by this technique of enteroclysis included a 2 cm carcinoid tumor that was detected on capsule study.

Barium-carbon dioxide enteroclysis vs. capsule endoscopy

Double contrast barium-carbon dioxide is not commonly used in the USA but is popular in Japan. It has been considered to be a good technique for detecting superficial mucosal pathology, such as ulcers (Fig. 1) [53–55]. Carbon dioxide may be preferred to air as the negative enteral contrast because of a lower incidence of abdominal cramping.

There are no previous studies comparing carbon dioxide enteroclysis and capsule endoscopy. In our sub-

Fig. 4. A 38-year-old male with obscure gastrointestinal bleeding. **(A)** Early spot view from enteroclysis with barium and methylcellulose showed subtle filling defect in distal ileum (*arrow*). **(B)** Later image after further infusion of methylcellulose did not show the filling defect which was considered

artefactual. Enteroclysis was read as normal. **(C)** Capsule endoscopy performed one month later demonstrated sub-mucosal mass (*arrow*), confirmed to be carcinoid. It is possible that methylcellulose “washed off” the barium from the lesion.

group of patients with both tests, the yield of barium–carbon dioxide enteroclysis was equivalent to capsule endoscopy in both obscure gastrointestinal bleeding and in suspected Crohn disease. Ulcers from Crohn disease and NSAIDs were seen in 10 of 18 patients evaluated with this technique. In fact, this technique had a higher, but not significantly better, overall yield than capsule

endoscopy (67% vs. 56%, $P = 0.73$). However, barium–carbon dioxide enteroclysis is more difficult to perform than methylcellulose enteroclysis, as insertion of the optimal amount of the gas is difficult to determine. It is also an uncomfortable procedure and ideally would require patient sedation. As a result, it is unlikely to be considered as a first line test. In sites with experience in

this technique, we recommend it as a second line test in those with suspected obscure gastrointestinal bleeding or Crohn disease, if capsule endoscopy is equivocal or is contraindicated. We postulate two possible reasons for the difference in sensitivity of the two fluoroscopic enteroclysis techniques. The higher density of methylcellulose may reduce the visibility of a small pool of barium in a superficial ulcer. During its infusion, the more viscous methylcellulose may wash out barium from a mucosal lesion (Fig. 4) [56].

Limitations of capsule endoscopy include the inability to perform biopsies or therapeutic procedures, capsule retention, assessment of trivial lesions, poor localization of lesions, and cessation of battery power prior to reaching the cecum. Capsule retention has been seen from 1% of patients investigated for obscure gastrointestinal bleeding to 8% of patients with Crohn disease [21]. Thus, capsule endoscopy generally is contraindicated in patients with symptoms of small bowel obstruction, long-term nonsteroidal anti-inflammatory drug use, and small bowel surgery, though anecdotal reports have challenged some of these guidelines [57, 58]. In previous studies of capsule endoscopy, small bowel ulcers have been thought to represent Crohn disease. However, 14% of asymptomatic volunteers and another 7% of those on placebo medication show at least one such ulcer [59]. Thus, earlier studies may have overinflated the diagnostic yield of capsule endoscopy [15, 60, 61]. In addition, as noted earlier capsule endoscopy does not reliably assess the small bowel wall. On the other hand, enteroclysis is a difficult technique to implement. The required logistics include a dedicated hydraulic pump, nursing support, and, in the case of CT enteroclysis, the immediate availability of the CT scanner following enteral infusion. Nasoduodenal intubation is an otherwise unpleasant procedure which is best performed under conscious sedation.

We are aware of several limitations of the study, including its small numbers and retrospective nature. The capsule and enteroclysis studies were interpreted without blinding to other tests or clinical information. A limitation of our study is verification bias favoring capsule endoscopy, as there is no pathologic proof for most cases of angioectasia. Intraoperative enteroscopy, which may be considered the gold standard examination, is not the standard of care for most common small-bowel capsule endoscopy findings.

Our study has shown that more advanced radiologic techniques such as CT enteroclysis could complement capsule endoscopy in investigating small bowel lesions. Further studies are required to determine which indications are best investigated by enteroclysis and when. The roles of other newer radiologic tests such as CT enterography or MR enteroclysis (which does not have the risk of radiation) also need to be clarified by future studies. In particular, CT enterography deserves further

research as it is easier to perform than enteroclysis, and does not require nasojejunal incubation or conscious sedation.

References

1. Iddan GJ, Swain CP (2004) History and development of capsule endoscopy. *Gastrointest Endosc Clin N Am* 14:1–9
2. Albert JG, Martiny F, Krummenerl A, et al. (2005) Diagnosis of small bowel Crohn's disease: a prospective comparison of capsule endoscopy with magnetic resonance imaging and fluoroscopic enteroclysis. *Gut* 54:1721–1727
3. Hara AK, Leighton JA, Heigh RI, et al. (2006) Crohn disease of the small bowel: preliminary comparison among CT enterography, capsule endoscopy, small-bowel follow-through, and ileoscopy. *Radiology* 238:128–134
4. Golder SK, Schreyer AG, Endlicher E, et al. (2006) Comparison of capsule endoscopy and magnetic resonance (MR) enteroclysis in suspected small bowel disease. *Int J Colorectal Dis* 21:97–104
5. Voderholzer WA, Beinhoelzl J, Rogalla P, et al. (2005) Small bowel involvement in Crohn's disease: a prospective comparison of wireless capsule endoscopy and computed tomography enteroclysis. *Gut* 54:369–373
6. Voderholzer WA, Ortner M, Rogalla P, et al. (2003) Diagnostic yield of wireless capsule endoscopy in comparison with computed tomography enteroclysis. *Endoscopy* 35:1009–1014
7. Voderholzer WA, Beinhoelzl J, Rogalla P, et al. (2005) Small bowel involvement in Crohn's disease: a prospective comparison of wireless capsule endoscopy and computed tomography enteroclysis. *Gut* 54:369–373
8. Keroack M (2004) Video capsule endoscopy. *Curr Opin Gastroenterol* 20:474–481
9. Maglinte DD, Lappas JC, Heitkamp DE, et al. (2003) Technical refinements in enteroclysis. *Radiol Clin North Am* 41:213–229
10. Costamagna G, Shah SK, Riccioni ME, et al. (2002) A prospective trial comparing small bowel radiographs and video capsule endoscopy for suspected small bowel disease. *Gastroenterology* 123:999–1005
11. Hara AK, Leighton JA, Sharma VK, et al. (2004) Small bowel: preliminary comparison of capsule endoscopy with barium study and CT. *Radiology* 230:260–265
12. Ell C, Remke S, May A, et al. (2002) The first prospective controlled trial comparing wireless capsule endoscopy with push enteroscopy in chronic gastrointestinal bleeding. *Endoscopy* 34: 685–689
13. Lewis BS, Swain P (2002) Capsule endoscopy in the evaluation of patients with suspected small intestinal bleeding: results of a pilot study. *Gastrointest Endosc* 56:349–353
14. Eliakim R, Suissa A, Yassin K, et al. (2004) Wireless capsule video endoscopy compared to barium follow-through and computerized tomography in patients with suspected Crohn's disease – final report. *Dig Liver Dis* 36:519–522
15. Fireman Z, Mahajna E, Broide E, et al. (2003) Diagnosing small bowel Crohn's disease with wireless capsule endoscopy. *Gut* 52: 390–392
16. Herreras JM, Caunedo A, Rodriguez-Tellez M, et al. (2003) Capsule endoscopy in patients with suspected Crohn's disease and negative endoscopy. *Endoscopy* 35:564–568
17. Marmo R, Rotondano G, Piscopo R, et al. (2005) Capsule endoscopy versus enteroclysis in the detection of small-bowel involvement in Crohn's disease: a prospective trial. *Clin Gastroenterol Hepatol* 3:772–776
18. Rguelles-Arias F, Caunedo A, Romero J, et al. (2004) The value of capsule endoscopy in pediatric patients with a suspicion of Crohn's disease. *Endoscopy* 36:869–873
19. Dubcenco E, Jeejeebhoy KN, Petroniene R, et al. (2005) Capsule endoscopy findings in patients with established and suspected small-bowel Crohn's disease: correlation with radiologic, endoscopic, and histologic findings. *Gastrointest Endosc* 62:538–544
20. Hara AK, Leighton JA, Heigh RI, et al. (2006) Crohn disease of the small bowel: preliminary comparison among CT enterography, capsule endoscopy, small-bowel follow-through, and ileoscopy. *Radiology* 238:128–134

21. Cave D, Legnani P, De FR, et al. (2005) ICCE consensus for capsule retention. *Endoscopy* 37:1065–1067
22. Scapa E, Jacob H, Lewkowicz S, et al. (2002) Initial experience of wireless-capsule endoscopy for evaluating occult gastrointestinal bleeding and suspected small bowel pathology. *Am J Gastroenterol* 97:2776–2779
23. Eliakim R, Fischer D, Suissa A, et al. (2003) Wireless capsule video endoscopy is a superior diagnostic tool in comparison to barium follow-through and computerized tomography in patients with suspected Crohn's disease. *Eur J Gastroenterol Hepatol* 15:363–367
24. Hartmann D, Schilling D, Bolz G, et al. (2003) Capsule endoscopy versus push enteroscopy in patients with occult gastrointestinal bleeding. *Z Gastroenterol* 41:377–382
25. Liangpunsakul S, Chadawalada V, Rex DK, et al. (2003) Wireless capsule endoscopy detects small bowel ulcers in patients with normal results from state of the art enteroclysis. *Am J Gastroenterol* 98:1295–1298
26. Mylonaki M, Fritscher-Ravens A, Swain P (2003) Wireless capsule endoscopy: a comparison with push enteroscopy in patients with gastroscopy and colonoscopy negative gastrointestinal bleeding. *Gut* 52:1122–1126
27. Saurin JC, Delvaux M, Gaudin JL, et al. (2003) Diagnostic value of endoscopic capsule in patients with obscure digestive bleeding: blinded comparison with video push-enteroscopy. *Endoscopy* 35:576–584
28. Van GA, Hittelet A, Schmit A, et al. (2003) A prospective comparative study of push and wireless-capsule enteroscopy in patients with obscure digestive bleeding. *Acta Gastroenterol Belg* 66:199–205
29. Adler DG, Knipschild M, Gostout C (2004) A prospective comparison of capsule endoscopy and push enteroscopy in patients with GI bleeding of obscure origin. *Gastrointest Endosc* 59:492–498
30. Ben SE, Antonietti M, Herve S, et al. (2004) Diagnostic yield and therapeutic implications of capsule endoscopy in obscure gastrointestinal bleeding. *Gastroenterol Clin Biol* 28:1068–1073
31. Buchman AL, Miller FH, Wallin A, et al. (2004) Videocapsule endoscopy versus barium contrast studies for the diagnosis of Crohn's disease recurrence involving the small intestine. *Am J Gastroenterol* 99:2171–2177
32. Delvaux M, Fassler I, Gay G (2004) Clinical usefulness of the endoscopic video capsule as the initial intestinal investigation in patients with obscure digestive bleeding: validation of a diagnostic strategy based on the patient outcome after 12 months. *Endoscopy* 36:1067–1073
33. Fireman Z, Friedman S (2004) Diagnostic yield of capsule endoscopy in obscure gastrointestinal bleeding. *Digestion* 70:201–206
34. Fireman Z, Eliakim R, Adler S, et al. (2004) Capsule endoscopy in real life: a four-centre experience of 160 consecutive patients in Israel. *Eur J Gastroenterol Hepatol* 16:927–931
35. Ge ZZ, Hu YB, Xiao SD (2004) Capsule endoscopy in diagnosis of small bowel Crohn's disease. *World J Gastroenterol* 10:1349–1352
36. Hara AK, Leighton JA, Sharma VK, et al. (2004) Small bowel: preliminary comparison of capsule endoscopy with barium study and CT. *Radiology* 230:260–265
37. Mata A, Bordas JM, Feu F, et al. (2004) Wireless capsule endoscopy in patients with obscure gastrointestinal bleeding: a comparative study with push enteroscopy. *Aliment Pharmacol Ther* 20:189–194
38. Rastogi A, Schoen RE, Slivka A (2004) Diagnostic yield and clinical outcomes of capsule endoscopy. *Gastrointest Endosc* 60:959–964
39. Tang SJ, Christodoulou D, Zanati S, et al. (2004) Wireless capsule endoscopy for obscure gastrointestinal bleeding: a single-centre, one-year experience. *Can J Gastroenterol* 18:559–565
40. Albert JG, Martiny F, Krummenerl A, et al. (2005) Diagnosis of small bowel Crohn's disease: a prospective comparison of capsule endoscopy with magnetic resonance imaging and fluoroscopic enteroclysis. *Gut* 54:1721–1727
41. Chong AK, Taylor A, Miller A, et al. (2005) Capsule endoscopy vs. push enteroscopy and enteroclysis in suspected small-bowel Crohn's disease. *Gastrointest Endosc* 61:255–261
42. Culliford A, Daly J, Diamond B, et al. (2005) The value of wireless capsule endoscopy in patients with complicated celiac disease. *Gastrointest Endosc* 62:55–61
43. Jones BH, Fleischer DE, Sharma VK, et al. (2005) Yield of repeat wireless video capsule endoscopy in patients with obscure gastrointestinal bleeding. *Am J Gastroenterol* 100:1058–1064
44. Mata A, Llach J, Castells A, et al. (2005) A prospective trial comparing wireless capsule endoscopy and barium contrast series for small-bowel surveillance in hereditary GI polyposis syndromes. *Gastrointest Endosc* 61:721–725
45. Neu B, Ell C, May A, et al. (2005) Capsule endoscopy versus standard tests in influencing management of obscure digestive bleeding: results from a German multicenter trial. *Am J Gastroenterol* 100:1736–1742
46. Pennazio M (2005) Small-intestinal pathology on capsule endoscopy: tumors. *Endoscopy* 37:1008–1017
47. Voderholzer WA, Beinhöelzl J, Rogalla P, et al. (2005) Small bowel involvement in Crohn's disease: a prospective comparison of wireless capsule endoscopy and computed tomography enteroclysis. *Gut* 54:369–373
48. Hara AK, Leighton JA, Heigh RI, et al. (2006) Crohn disease of the small bowel: preliminary comparison among CT enterography, capsule endoscopy, small-bowel follow-through, and ileoscopy. *Radiology* 238:128–134
49. Voderholzer WA, Beinhöelzl J, Rogalla P, et al. (2005) Small bowel involvement in Crohn's disease: a prospective comparison of wireless capsule endoscopy and computed tomography enteroclysis. *Gut* 54:369–373
50. Bardan E, Nadler M, Chowder Y, et al. (2003) Capsule endoscopy for the evaluation of patients with chronic abdominal pain. *Endoscopy* 35:688–689
51. Keuchel M, Hagenmüller F (2004) Video capsule endoscopy in the work-up of abdominal pain. *Gastrointest Endosc Clin N Am* 14:195–205
52. Albert JG, Martiny F, Krummenerl A, et al. (2005) Diagnosis of small bowel Crohn's disease: a prospective comparison of capsule endoscopy with magnetic resonance imaging and fluoroscopic enteroclysis. *Gut* 54:1721–1727
53. Maglinte DD, Lappas JC, Heitkamp DE, et al. (2003) Technical refinements in enteroclysis. *Radiol Clin North Am* 41:213–229
54. Kobayashi S (1974) Double contrast study of the small bowel. *Jpn J Clin Radiol* 19:619–624
55. Tanaka K (1977) Double contrast study of the minute lesions of Crohn's disease of the small intestine. *Stom Intest* 12:1467–1469
56. Liangpunsakul S, Chadawalada V, Rex DK, et al. (2003) Wireless capsule endoscopy detects small bowel ulcers in patients with normal results from state of the art enteroclysis. *Am J Gastroenterol* 98:1295–1298
57. De Palma GD, Rega M, Puzziello A, et al. (2004) Capsule endoscopy is safe and effective after small-bowel resection. *Gastrointest Endosc* 60:135–138
58. Leighton JA, Srivathsan K, Carey EJ, et al. (2005) Safety of wireless capsule endoscopy in patients with implantable cardiac defibrillators. *Am J Gastroenterol* 100:1728–1731
59. Goldstein JL, Eisen GM, Lewis B, et al. (2005) Video capsule endoscopy to prospectively assess small bowel injury with celecoxib, naproxen plus omeprazole, and placebo. *Clin Gastroenterol Hepatol* 3:133–141
60. Chong AK, Taylor A, Miller A, et al. (2005) Capsule endoscopy vs. push enteroscopy and enteroclysis in suspected small-bowel Crohn's disease. *Gastrointest Endosc* 61:255–261
61. Eliakim R, Fischer D, Suissa A, et al. (2003) Wireless capsule video endoscopy is a superior diagnostic tool in comparison to barium follow-through and computerized tomography in patients with suspected Crohn's disease. *Eur J Gastroenterol Hepatol* 15:363–367