Warm CO2 CT enteroclysis or virtual enteroscopy (VE): preliminary experience of a new technique for small bowel imaging on Crohn’s patients with subocclusive or complicated disease

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Purpose

• Aims and objectives:

The course of Crohn's disease is unpredictable, with periods of remission, but also frequent relapses. Chronic inflammation may lead to severe complications such as bowel stenosis due to fibrosis or scarring reaction.

Each phase of the disease may have its most specific imaging and its most specific therapy: steroids (luminal or general), immunosuppressive drugs, biologics, antibiotics and eventually surgery to cure severe fibrotic strictures [1].

Cross-sectional imaging is mainly performed for diagnosing submucosal and transmural inflammation.

It will also show the inflammation’s extent into the mesentery, which is causing fistulae, eliciting lymph node reaction, and sometime causing abscesses.

Scarring will then inevitably occur causing various degrees of fibrotic reaction inside the bowel wall or outside with mesenteric fibro-fatty proliferation. Diagnostic imaging should reliably image these lesions to allow timely elective surgery for the best possible outcome.

First-line examinations in developed countries rely increasingly on MR-Enterography (MR-E), which requires fluid filling agents ingested orally for distending the loops of the small bowel [2]. However, this actual imaging strategy may be biased by local preferences and habits, the available infrastructure, a radiologist's experience or expertise, the perceived costs and many additional factors. Significantly, large randomised studies are still lacking in this difficult and controversial area of medical imaging.

Another imaging technique, Capsule Endoscopy and its on-going refinements, has been advocated as one of the most powerful diagnostic tool for screening the small bowel in suspected Crohn's patients, however it is limited by stenotic complications [3].

Therefore the optimal imaging approach for Crohn's disease remains uncertain, especially for complicated cases showing stenotic disease, and when therapeutic strategies may eventually include surgical planning.
The technique we propose, CT-Enteroclysis (CT-E) or Virtual Enteroscopy (VE), has been anticipated since the late 1990s when post-processing techniques were first applied to cross-sectional imaging [4]. A number of publications have assessed the feasibility of using a similar technique but as of yet, none have been applied to Crohn's disease [5-8].

Our study aims:

1. assess feasibility and evaluate the clinical value of a new technique, CT Enteroclysis or Virtual Enteroscopy (VE), using warm CO2 as a negative intraluminal contrast agent for small and large bowel imaging in complicated Crohn's disease;
2. describe this alternative technique which can be utilised when first-line MR-Enterography is contra-indicated, or when MR-E is inconclusive in spite of specific clinical and/or biological findings;
3. highlight how this technique should be reserved for complex Crohn's disease cases, when surgical planning might be contemplated and when MR-E is considered suboptimal in terms of technical quality.
Methods and materials

Patients:

This prospective study was approved by the Clinical Governance Committee of our institution and was regarded as a mere variation to previously performed conventional enteroclysis. All patients gave written informed consent to CT-Enteroclysis and agreed to the subsequent analysis and exploitation of their imaging and personal data for evaluation and research purposes.

In our pilot study, we consecutively assessed 5 patients known to have Crohn's disease affecting the small bowel or both the small and large bowel and who were suspected to have sub-occlusive symptoms.

All these patients were referred after multidisciplinary team discussions when first-line exam, MR-Enterography, was considered inconclusive or conflicting to symptomatology and/or biological data.

The five selected patients were 3 women and 2 men, age range: 36-69 years old.

CT-E technique:

Patients underwent minimal bowel "cleansing" preparation consisting of a low residue diet for 48 hours and a minimal cathartic cleansing with 40 mL of gastrogafin diluted in 500 mL of water taken orally.

A nasojejunal (NJ) tube (14 French two-way enteroclysis catheter with an inflatable balloon at its tip, Vimap Technologies) was inserted in the duodenum or just after the Treitz angle under fluoroscopy guidance. The balloon was then inflated with 20 mL of air to maintain the catheter tip in place and prevent any significant retrograde leakage of CO2.

A dedicated piece of equipment is used for insufflation of CO₂ which provides warm gas under real-time controlled volumes and pressures. The pressure is set to between 20 to 25 mm of Hg (VMX-1020A, Vimap Technologies). To date, this is the only insufflation device licensed for this purpose.
Single top-end, via the NJ tube, or simultaneous top-end and lower-end insufflation was then performed, using a rectal cannula and Y-connector to distribute the CO\textsubscript{2} to both the small and the large bowel with the same insufflator device. The process of insufflation for both the small and large bowel took 5 to 10 minutes to complete.

This technique of insufflating from both ends was tolerated and our preliminary experience shows that no anti-peristaltic was necessary to obtain a desirable distension of both the large and the small bowel. If it was indicated, IV antiperistaltic agent was used to relieve patient abdominal bloating and discomfort.

CT was acquired in the supine position using a 128 slice-CT with iodine contrast injection at one minute delay. A second acquisition could be performed at the request of the radiologist if the initial inflation was not deemed to be optimal.

On average, the total time for this procedure from the moment of inserting the NJ tube to completing the imaging was less than one hour for all cases studied.

Insufflation of both small and large bowel was achieved in between 5 to 10 minutes.

Full bowel wall musculature relaxation was obtained by insufflation of warm gas starting from a set value of 43 degrees Celsius, now optimised to 45 degrees Celsius.

**Image analysis:**

CT-E images were evaluated by a single consultant radiologist specialised in gastrointestinal radiology. The following features were evaluated: overall image quality, sufficiency of bowel distension, presence of stenosis, location of stenosis, pre-stenotic dilation, bowel wall thickness and enhancement, any other findings.

The CT acquisitions were analysed with 2D/3D post-processing, mainly using curved MPR reformats and fly-through or “virtual endoscopy” imaging to study both the small and large bowel during the same session if insufflated simultaneously. Precise assessment with relevant measurements could then be performed as with other virtual imaging applications such as Virtual Colonoscopy.

The stenosed lesions could be individually measured and precisely localised along the bowel from standard reference points such as at the Treitz angle or the ileocecal valve (ICV).
Results

Demographics and results are reported in Table 1.

The short following vignettes describe the reasons for allowing further imaging at the multidisciplinary meetings.

**Case 1 (Figs. 1-3)**

Long standing Crohn’s disease patient having recurrent occlusive symptoms. MR-Enterography performed 6 months previously was considered normal. Further upper GI endoscopy and optical colonoscopy were normal. On-going and unremitting epigastric pain.

**Case 2 (Figs. 4-5)**

Known Crohn's patient: previous stricturoplasty (two years ago), previous proctectomy with left colostomy. Recurrent symptoms. Optical colonoscopy was normal and biopsy at ICV was negative.

**Case 3 (Figs. 6-11)**

Large and small bowel Crohn's patient. Planning before surgery. Optical colonoscope unable to pass distal sigmoid stenosis. Left iliac fossa pain was predominant.

**Case 4 (Figs. 12,13)**

Known terminal Crohn's ileitis with on-going recurrent symptoms with a fecal calprotectin markedly raised at 860.

The stenosis discovered on VE was interpreted as fibrotic rather than truly active disease. Optical colonoscopy confirmed a chronic-active disease of pre-terminal ileum with a normal ICV.

**Case 5 (Figs. 14,15)**

Known Crohn's disease with TI disease, and also both left colonic and pelvis disease. Severe abdominal pain despite being under AZT and steroids for months. MR-E could not show any disease within the small bowel. VE was requested because of clinical discrepancy, which confirmed a multi-stenotic ileum without any active signs.
Unfortunately, VE findings are not yet confirmed by histopathology as patient is currently undergoing medical therapy, which may be followed by surgery if unsuccessful.

Based on the image findings, we believe that the higher spatial resolution of CT-E vs. MR-E increases the diagnostic confidence in the radiological findings of our CT-Enteroclysis technique (Figs. 1,4,7,13-15).

Additionally, by using a both ends insufflation technique, this technique allows one to visualise Crohn’s disease lesions in both the small and the large bowel in the same session (Figs. 6,9).

Using CO2 as a negative contrast agent to distend the bowel lumen, measurements according to identifiable anatomical landmarks were performed in all cases when relevant (Fig. 14).

Our technique helped to differentiate true small bowel strictures which did not have significant underlying wall thickening from previous images on MR-E that had false positive results due to peristalsis and collapsed segments (Figs. 4,5).

Other false positive cases noted on MR-E were due to stool high signal in T1 sequences, preventing a fine analysis of the enhancement of the bowel wall (Fig. 12).

When assessing a stenosed segment, an issue could arise from the lack of marked distention with gas insufflation whereas a liquid-filling technique (such as used in MR-E) would markedly dilate the upstream segment of bowel and thus potentially better highlight a stenosis of even moderate tightness. However, it was felt that, since we were using a dual-end insufflation technique, CO2 would dilate equally well both sides of a stenotic segment, thus allowing an altogether clearer depiction of any segment resisting bowel wall relaxation, despite the absence of an index prestenotic dilatation, as shown in a multistenotic case (Fig. 15).

Retained fecal material or fluids due to significant stenosis may however hinder the full relaxation effect of warm CO2 in some cases (Fig. 9).

Comparing MR-E exams and VE in our population study, although there was huge variation of distention according to topography by patient and between patients for MR-E, distention was far more homogeneous globally for all patients in VE exams in non diseased segments.
Issues were related to segments with retained stools and fluid and in areas where the bowel was sharply looping.

VE identified strictures in all patients where MR-E was reported negative or indeterminate.

There were no other significant findings other than stenosis in this small series of patients.
### Table 1: Patients data and imaging findings

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Fig. 1: VE detected a long segmental stenosis of first jejunum loop confirmed to be poorly differentiated mucinous adenocarcinoma (arrow)

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**Fig. 2:** Virtual Endoscopic views (upstream and downstream, respectively left and right).

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Fig. 3: MR-E exam 6 months before VE. The lesion was not initially identified and, even retrospectively, is still difficult to see, although maybe smaller in size at that time (arrow).

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Fig. 4: Recurrent stenosis at 42 cm upstream from ICV with a tiny recess formation on a previous site of stricturoplasty (arrow). VE exam axial and sagittal views on left and middle images respectively and Virtual Endoscopic view on right image. With a fecal calprotectin not extremely high (150), this ileal lesion is more likely to be a fibrostenotic lesion than anything else.

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**Fig. 5:** MR exam (4 months before VE) was indeterminate (arrow a: suspected stenosis on ileum confirmed on VE, arrow b: spasm on distal jejunum since not observed on VE and arrow c: left colostomy).

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![Image of MR exam](image_url)

**Fig. 6:** Large bowel Crohn's lesions on MPR curved reformat on VE exam (a: ascending colon, b: transverse colon, c: descending colon, proximal sigmoid colon)

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Fig. 7: Crohn's distal sigmoid stenosis on MPR curved reformat on VE. Lumen measures 13 mm largest diameter, proximal sigmoid measures 37 mm largest diameter.

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Fig. 8: Sigmoid stenosis on Virtual Endoscopic view.

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Fig. 9: VE exam showing a: collapsed distal ileum lumen due to retained stools and fluids. 
b: normal ICV but fibrotic cecum and ascending colon.

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Fig. 10: Consecutive fluid-filled CT Enterography showing underlying fibrotic stenosis (arrow a), which was missed on VE and well expanded terminal ileum (arrow b) that was collapsed before.

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Fig. 11: MR-Enterography mentioned fecal sign in terminal ileum due to right-sided colitis with stenotic lumen (arrow a), but missed out cecum retraction as the pre-terminal ileum loop sticture (arrow b).

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**Fig. 12:** MR-E (T1 Fat Sat post Gadolinium injection) is negative. In addition, the high signal stool contents may mask any disease related hyper-enhancement in the bowel wall.

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Fig. 13: VE showed irregular thickenings over a long segment of the pre-terminal ileum (arrow a) with some retained fluid as well (arrow b), while ICV was normal (arrow c).

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**Fig. 14:** VE confirmed a multi-stenotic ileum without any active signs. A first stenosis (arrow) was depicted 15 cm above normal ICV (left and middle images). Virtual Endoscopic view is showing the degree of stenosis (right image).

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**Fig. 15:** VE identified two more short stenotic segments (arrow a and b).

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Conclusion

In spite of the prevalence of MR-E in many centres across the world for the small bowel imaging in Crohn's disease, in spite of the advent of ever new developments with this technique (DWI, Cine view study, 3-Tesla MR imaging, angio-dynamic sequences, Magnetisation Transfer sequences), there still remains many pitfalls and difficulties/limitations for MR-E:

- Motion and breathing artefacts during the examination
- Suboptimal bowel distention through fluid filling intraluminal agents
- Time-dependent bowel distention
- Fluid filling intraluminal agents are poorly or not tolerated by patients having sub-occlusive disorders
- False negatives in poorly distended areas such as the jejunum
- False positives due to collapsed segments, stool high signal in T1 sequences, relatively low spatial resolution of MR
- Orthogonal planes imaging constraint

Our technique with warm CO2 insufflation allows a fast and homogeneous distention of the bowel with fully relaxed bowel wall musculature.

The imaging is performed via CT with a higher spatial resolution than MR-E.

The resulting images permit an easier assessment of the lesion topography along the bowel and its precise localisation with related measurements in a much easier and robust way than with MR-E [9].

One single drawback in terms of imaging analysis is that iodine contrast IV injection represents the single modality to assess the inflammatory nature of a lesion, although MR-E has a multiparametric approach in such respect.

Besides, since CT uses ionising radiations, this should be reserved for selected cases after multidisciplinary team discussion and after informed consent from the patient.

Based on this preliminary study that is in progress, VE has shown to be useful in Crohn's patients with sub-occlusive disease, whether in the natural course of the disease or in the setting of post-operative recurrence.
The potential advantages of CT-based VE over MR-E drawn from this preliminary experience are:

- "One-stop shop" screening of both the small and large bowel for Crohn's disease.
- An increase in spatial resolution of the images, therefore improving diagnostic confidence of the reporting radiologist.
- Optimal distention of small bowel loops, crucial to evaluating bowel wall pathologies with higher accuracy.
- A decrease in number of collapsed loops, which can hide pathology or mimic disease.
- Evaluation of both intraluminal and extra-luminal findings.
- Improving the evaluation of the ileocecal area and the jejunum.
- Improving the detection of strictures (especially those without underlying mural thickening), and potentially of sinus tracts or fistulae.
- In terms of patient's comfort, the occurrence of bowel occlusion may render gas-filling techniques better tolerable than fluid-filling techniques, albeit the NJ tube insertion.
References


