Plain abdominal radiography and computed tomographic (CT) enteroclysis are 2 essential radiological investigations in the study of the gastrointestinal tract. Errors in patient preparation, execution, and interpretation may lead to severe consequences in the diagnosis and thus in patient outcome. Abdominal radiography is one of the most frequently requested radiographic examinations, and has an established role in the assessment of the acute abdomen. CT enteroclysis has revolutionized the assessment of small-bowel pathology, especially in patients with inflammatory bowel. The purpose of this article is to describe the pitfalls in the execution and interpretation of plain abdominal film and CT enteroclysis.
Based on the clinical condition of the patient and the availability of the radiological rooms, at times the study of the abdomen can be integrated with 2 other radiographs: a posteroanterior (PA) projection in the left lateral decubitus position and a PA projection in the prone position. By contrast, in cooperative patients who are able to walk, the PA and LL projections performed in the upright position allow the abdomen to be just as effectively assessed.

In all cases, the direct study of the abdomen should be complete with a chest radiograph in the PA and LL projections in the upright position, and when this is not possible, at least an anteroposterior projection in the supine position, with the aim of identifying possible unrecognized chest conditions at times responsible for, or associated with, complications of the acute abdomen. Errors in interpretation can arise from difficult observing patterns that somewhere are small and not well recognizable.

The radiological image is based on the 2-dimensional (2D) representation of anatomical formations that can be assessed by way of their borders, which in essence are lines, angles, margins, convexities, and concavities. These borders can be distinct and separate, but at times they can be overlapping, creating interdependencies within the visual information that determine phenomena of addition, subtraction, and deletion.

In addition, radiographic anatomy is not static and constant, but rather is personalized for each patient, given that it presents variations in constitution, gender, and age, and is conditioned by a great number of factors such as nutrition and previous surgery, as well as varying according to the radiographic projections performed and the position assumed by the patient.

The interpretation of radiographs of the abdomen is based on the careful and orderly observation of the findings that verify or exclude the following features: alterations of the skeleton, calcifications, foreign bodies (Fig. 3), intra- and extraperitoneal collections of gas (Fig. 4), pneumobilia, obliteration of the normal radiotransparency lines, mass effect, pathologies of the base of the lungs, and, above all, morphofunctional aspects of the bowel loops. The latter is highly useful and can be assessed with greater precision by analyzing the radiographs of later examinations. Although defining the patient’s phase based on a single series of radiographs may prove insidious, it becomes simple and highly useful when time series studies are performed at brief intervals, which enables the various findings to be compared. When the first plain film is negative, it is more useful to repeat it.
after a few hours. Knowing their interdependence and succession, the clinical progression, or regression, of the acute insult can be assessed, which allows the radiologist the possibility of suggesting to the physician or surgeon the treatment to be adopted.

An example of the above explanation could be found in the diagnosis of acute ischemic bowel disease (AIBD). The lack of pathognomonic symptoms and findings makes AIBD difficult to detect clinically and radiographically, especially in the early stages. Abdominal plain film is a valuable tool in the evaluation of acute abdomen. In contrast with previous reports, a recent study reported a high prevalence of pathologic findings on initial plain films in AIBD. However, no reliable specific finding in any other examination or clinical sign has been described in AIBD. Hence, to establish the diagnosis, several parameters, indirect signs, and patterns have to be considered, and it is important to monitor the evolution over time with repeated examinations (Fig. 5). Radiologists with a greater degree of experience are likely to be more accurate in the evaluation of abdominal radiographs.

Figure 4 Plain supine abdominal film, in LL and AP projections, of a woman with acute abdominal pain. Missed diagnosis of a little amount of pneumoperitoneum located in the subphrenic space (arrow).

Figure 5 Plain abdominal film. AP projection. (A) First radiological findings suggested diagnosis of intestinal infarction. (B) Same patient, the subsequent XR monitoring revealed the evolution of the pathology to the resolution and not to necrosis.
Errors in Multidetector-Row Helical CT Enteroclysis

Despite the widespread diffusion and technological evolution of endoscopy, the small bowel is still the only portion of the gastrointestinal tract that cannot be completely explored with endoscopic techniques. As a consequence, the diagnosis of small-bowel disease is still mostly established by radiology, which enables the study of both the bowel lumen and wall, as well as of extraparietal structures. The most commonly used methods for studying most gastrointestinal diseases are conventional radiology, ultrasonography (US), and CT. Magnetic resonance imaging still has only a marginal role. Single- or double-contrast enteroclysis has high levels of sensitivity and specificity in the diagnosis of small-bowel disease, as has been widely documented over the past decades. Forced bowel loop distension through nasointestinal intubation allows a more accurate study compared with that obtained with oral opacification of the small bowel. Spiral technology, initially single slice and then multislice, represents the most recent development of CT. Volumetric acquisition can rapidly explore, in a single inspiratory breath-hold, the entire abdominopelvic region, almost completely eliminating artifacts caused by respiration and intestinal peristalsis.

In the study of small-bowel disease, volumetric CT—single slice first and multislice later—has eliminated the presence of movement artifacts caused by peristalsis and allowed the adequate assessment of intestinal-wall enhancement with the possibility of obtaining excellent-quality multiplanar reconstructions (MPR).

Multislice CT enteroclysis (MSCT-E) is a recent technique in small-bowel imaging, which combines the advantages of bowel distension with nasointestinal intubation with those of spiral CT.

CT enteroclysis is an imaging technique that is dedicated to studying the small bowel and combines enteroclysis and helical CT, thereby giving a better depiction of mucosal and wall abnormalities and fistulas, among other problem situations. MSCT enteroclysis (invasive CT enterography, multidetector-row helical CT enteroclysis) is an imaging method that involves distension of the small bowel with intraluminal contrast material administered via a nasointestinal tube, bowel hypotonia, and the infusion of intravenous (IV) iodinated contrast material.

The aim of MSCT enteroclysis is to combine all the advantages of conventional enteroclysis and abdominal spiral CT into a single modality.

Bowel Preparation

In our experience, bowel preparation is indispensable in that a clean colon facilitates the intraluminal flow of contrast material through the small bowel, avoids the reflux of fecal matter into the terminal ileum, and reduces patient discomfort caused by loop distension. The earliest reports did not stress the need for bowel preparation. There are 2 possible methods for bowel preparation.

**Method 1**

The afternoon before the examination

a. No solid foods.
b. Three to 4 L of fluid during the day.

The morning of the examination

a. Complete fast.
b. Cleansing enema at the radiology unit.

**Method 2**

The afternoon before the examination

a. No solid foods.
b. Four sachets of iso-osmolar laxative dissolved in 2 L of water.

The morning of the examination

a. Complete fast.

Intubation

Nasointestinal intubation is done under fluoroscopy guidance with the patient having an empty stomach. After the tube has passed the hypopharynx, one can let the patient continue the intubation himself or herself under guidance until the tube is near the duodenojejunal flexure. Selection of the tube depends on the individual operator's experience. Unlike the French and North American schools, none of the Italian groups believe patient sedation is necessary. A local anesthetic may be useful. Use of the nasal route is mandatory.

Transfer to the CT Room, Performance of Scout View, and Planning of the Scan

Once intubated, the patient is transferred to the CT room. The scout view is then performed; the correct position of the tube is checked; and the volumetric scan is planned. The speed and power of current multislice spiral CT scanners enable a complete abdominal CT examination to be planned. Technical parameters of the volumetric acquisition depend on the equipment used.

Pharmacologic Hypotonia

Before infusing the intraluminal contrast material, small-bowel hypotonia is induced with 20 mg of IV hyoscine N-butylbromide (Buscopan). This serves to lessen patient discomfort and reduce intestinal peristalsis and the resulting segmentation of the loops so the entire small bowel is adequately and uniformly distended during the volumetric scan. Induction of hypotonia, together with loop distension, helps to highlight the difference in diameter between the normal loops and pathologic segments. The timing of hypotonia induction is controversial: some investigators induce hypoto-
Intraluminal Infusion of Contrast Material

Water or 0.5% methylcellulose (MC) in water can be used as a negative contrast medium. Water is inexpensive, easy to use, readily available, and well tolerated by the patient. MC is a well-known contrast agent that is safe, well tolerated, and not absorbed. Because this solution has a CT density similar to water, it is capable of creating a significant difference in contrast between the lumen and the wall enhanced by the iodinated contrast medium. About 1800 mL of intraluminal contrast medium at a temperature of 37°C is administered without interruption. It is useful to have a peristaltic pump or a sophisticated remote-controlled compressor called a “microcontrolled double contrast insufflator,” as it is difficult to achieve uniform distension of the loops by manual infusion. According to some investigators, intraluminal infusion should be done at a steady flow rate of 100 mL/min for the entire duration of the examination. Others have proposed a more complex infusion pattern whereby the first 500 mL is introduced at a rate of 120 mL/min, followed by 1000 mL at a rate of 240 mL/min, and a further 300 mL at 120 mL/s. The slower infusion rate aims to avoid patient distress caused by sudden distension, reduce the sensation of nausea, and prevent vomiting. The faster infusion rate serves to force distension of the loops and increase the vis a tergo to advance the previously infused contrast as far as the right colon. Some investigators have proposed hypodense and hyperdense agents as an alternative to neutral contrast agents. The use of oil-based substances as a negative intraluminal contrast agent allows a faster manual injection but does not provide any substantial benefit in terms of image. In Italy, these substances are not authorized as contrast agents, and they are particularly expensive. Positive intraluminal contrast agents hinder the assessment of wall lesions, as their hyperdensity is confused with the hyperdensity of the intestinal wall enhanced by the IV iodinated contrast medium.

Administration of IV Iodinated Contrast Medium

Once about 1500 mL of intraluminal contrast material has been infused, the iodinated contrast medium, heated to 37°C, is injected intravenously with a common CT mechanical injector. According to most authors, the IV injection of iodinated contrast material is given as a single bolus at a rate of 3-4 mL/s with different scan delay times. Some perform the “classic” arterial and portal venous phase scans, obtaining similar images in the 2 acquisitions. Others have suggested performing a single acquisition but using different delays: 25, 35, 40, 45, 50 seconds. Until now, the study of the parenchyma has influenced the way iodinated contrast agents have been administered, with various phases being required to identify and characterize parenchymal lesions. In our view, the study of bowel loops requires a different approach to the use of contrast media. The intestinal wall enhances with an adequate bolus of IV iodinated contrast material. Several authors have found that mucosal enhancement is optimal in the late arterial and early portal venous phases. Starting from these assumptions, some investigators have standardized a new “biphasic” method of contrast infusion. In this method, 130 mL of IV iodinated contrast medium at a concentration of 400 mg of iodine/mL (iomeprol, Iomeron 400, Bracco, Italy) is injected with a scan delay of 80 seconds. During the first 40 seconds, the contrast medium is injected at a rate of 1 mL/s, whereas during the next 30 seconds, it is administered at a rate of 3 mL/s. Ten seconds after the infusion of IV iodinated contrast medium has been completed, the CT scan is started. This infusion protocol allows opacification of the arteries and enhancement of the mucosa (provided by the bolus at 3 mL/s), as well as slight opacification of the veins and intestinal wall (provided by the bolus at 1 mL/s). This way, the abdomen “lights up” as a result of the simultaneous enhancement of the loop walls, vascular network, and parenchyma, allowing analysis of the various components of the abdomen and intestine. Thus, the “biphasic” injection technique represents a good compromise.

Volumetric Acquisition

The examination is performed with a single breath-hold volumetric acquisition, with the patient in supine position.

Multiplanar Reconstructions

The use of MPR has proved to be very useful for the analysis of such a convoluted and complex structure as the small bowel. Instead, the use of MPR facilitates the anatomotopographic location of the lesions and allows greater potential for assessing extension. The resulting images may at times afford a panoramic view equal to that provided by conventional barium studies. This makes the reconstructions, above corona, particularly well-accepted by the clinicians, given their familiarity with the frontal images of the barium study. The overall level of diagnostic confidence is significantly higher when the analysis of the axial scans is carried out with the aid of MPR.

However, each step in the process of a CT enteroclysis examination carries the potential for misdiagnosis.

The absence of a correct indication, suboptimal patient preparation, CT scanning protocol deficiencies, and perception and interpretation errors can lead to false-positive and false-negative findings, adversely affecting the diagnostic performance of CT enteroclysis. These problems and pitfalls can be overcome with a variety of useful techniques and observations (Figs. 6 and 7).

Enrollment Errors

Malabsorption

In malabsorption syndrome, CT enteroclysis has no place in typical situations of celiac disease, as duodenal biopsy remains the key examination showing villous atrophy.
Although the radiological pattern of adult celiac disease (ACD) has been well codified, it should be noted that radiology has no practical role in the clinical suspicion of ACD or for an initial diagnosis of ACD, with the exception of the rare cases of atypical presentation, which makes the disease a “diagnostic surprise.” Conventional enteroclysis (with barium) and MSCT-E may, instead, be indicated when intestinal complications of ACD are suspected: ulcerative enteritis and lymphoma.

Small-Bowel Occlusion
Mechanical small-bowel occlusion (SBO), a very common clinical condition, may be complete or partial. In complete SBO, MSCT-E has no indication. “Conventional” CT has high levels of sensitivity in both the diagnosis of SBO and in demonstrating the cause of the obstruction and the possible presence of signs of parietal damage.

In addition, there is no need to administer endoluminal contrast material, as the bowel distension induced by the occlusion is sufficient for an optimal study of the loops, thanks to the natural contrast between the hypodense lumen (due to the fluid content of the stasis) and the wall that is made hyperdense by the IV iodinated contrast medium. MPR may at times facilitate the diagnosis of SBO, above all in the case of complex adherence syndromes.

In partial SBO, the diagnosis may prove challenging. In these cases, MSCT-E with neutral or positive endoluminal contrast agent provides good results. In low-grade SBO, conventional CT is less accurate (sensibility 50%, specificity 94%), whereas performance of CT enteroclysis with positive enteral contrast material is better (sensibility 89%, specificity 100%). There also may be an indication for magnetic resonance enteroclysis or conventional enteroclysis, which allow progression of the endoluminal contrast material to be followed through the bowel loops.

Crohn’s Disease
When complications are suspected based on the clinical and ultrasonographic findings, MSCT-E is gradually replacing barium studies because it can detect both parietal and extraparietal lesions and complications. It easily detects phlegmon, abscesses, and inflammatory conglomerates. Whether neutral or positive endoluminal contrast material provides the best depiction of fistulas is still controversial. The choice generally depends on the operator’s preferences and the patient’s clinical situation.

CT enteroclysis often fails to show fine mucosal changes, such as linear ulcers and the cobblestone appearance of CD. Thus, CT enteroclysis remains ineffective in superficial exploration of the intestinal mucosal lining, without demonstration of early aphthous ulcers of CD.

Intestinal Bleeding
CT enteroclysis is not the primary modality for diagnosing a gastrointestinal bleeding, although, in a few cases, it may reveal the cause of the bleed. In chronic bleeds of unknown origin with negative gastrocolonoscopy, definition of the site and cause of the bleed is often difficult. It is in this clinical situation that MSCT-E has one of its main indications. Meanwhile, CT enteroclysis has no role in the diagnosis of acute intestinal bleeding, even resulting in an worsening of clinical state. Indeed, in acute bleeds, endoscopy, nuclear medicine, and angiography preserve their fundamental role in both diagnostic and therapeutic terms.

Intestinal Ischemia
Mesenteric ischemia is a complex disease. In the acute phase, there is no indication for MSCT-E, and the method...
should be regarded as contraindicated until the intestinal
distress and consequent risk of infarction and/or perforation
are overcome. In the subacute and chronic phase, MSCT-E is
currently the method of choice, as it simultaneously demon-
strates both vascular and parietal alterations and tests the
ability of the ischemic bowel loops to distend. To study mes-
enteric circulation, forced distension of bowel loops is not,
however, necessary.54-56

**Technical Errors**

**Patient Preparation**

Bowel preparation is indispensable in that a clean colon fa-
cilitates the intraluminal flow of contrast material through
the small bowel, avoids the reflux of fecal matter into the
terminal ileum, and reduces patient discomfort caused by
loop distension17 (Fig. 8).

**Intubation**

There are a few common procedural problems that may be
encountered while placing the tube. There may be difficulty
in the region of the gastric fundus and when navigating the
pylorus. The catheter is placed with fluoroscopic guidance.21
Patients tolerate nasal passage in a seated position better than
oral passage because the gag reflex is avoided, although pull-
ing it out through the nose is sometimes more delicate be-
cause of the risk of blocking the distal olive tip at the poste-
rior aperture of the nose.31 Passing the pylorus is easier in the
decubitus position. The guide wire should not be advanced
to the end of the catheter to leave enough flexibility at the
distal end and to prevent perforations. The catheter should
be placed downstream of Treitz’s angle, and it is preferable to
have it follow the direction of the superior part of the duo-
denum and not the ascending part to avoid gastric reflux.
One must always verify that the catheter is not bent or
kinked. To study the duodenum conjointly with the jejunum
and the ileum, the distal olive tip must be more proximal.31

In some cases, the procedure cannot be performed because
of inability to place the enterocolysis tube in an adequate po-
sition57 (Figs. 9 and 10).

**Transfer to the CT Room, Performance of Scout View, and Planning of the Scan**

Before transferring a patient to the CT room, it is necessary to
fix the catheter to the nostril to avoid dislocation of the tube.

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**Figure 8** Incorrect preparation. The presence of fecal material in the
colon determines failure progression of water in the small-bowel loops with insufficient distension.

**Figure 9** (A) Error in the positioning of the tube: the apex of the tube
is located in the duodenum in a patient who previously underwent
Billroth II gastrectomy (even selection error). (B) The incorrect po-
sitioning of the tube determines incomplete relaxation of the small-
bowel loops with interpretation problems at the level of not ex-
tended loops.
The missing nostril fixation and the consequently change of position of the catheter lead to scant loop distension and sickness.

Slice thickness should be 3 mm at the most, and the reconstruction interval should be 1.5 mm. Image analysis and documentation are carried out with a soft-tissue window (center 30 HU; width 400 HU).

The development of multidetector-row CT changed the type and frequency of occurrence of some artifacts that were well known at helical CT. Helical CT artifacts, such as respiratory and stair-step artifacts, have become rare with multidetector-row CT. With improvement in spatial resolution, lesion depiction and differentiation also improved. Other artifacts, such as image noise, become more important owing to the use of thinner sections and of imaging protocols with dose reduction.

**Pharmacologic Hypotonia**

Distension leads to luminal narrowing or intestinal segment collapse, which results in perception and interpretation errors.

Pharmacologic hypotonia is necessary to avoid diagnostic errors caused by collapsed and contracted loops; failure to achieve adequate loop distension may result in both false-positive results—mimicking abscesses, masses, enlarged lymph nodes—and false-negative results due to nondistended loops masking lesions.

**Intraluminal Infusion of Contrast Material**

Water is the ideal opacifying agent because it is a neutral liquid, contrary to positive agent, but water is usually substantially reabsorbed before reaching the last ileal loop and can therefore limit intestinal distension.

Considering that MC is hardly absorbed at the intestinal level, it is preferred to water in patients with precarious cardiocirculatory compensation to avoid a dangerous blood volume overload resulting from the rapid absorption of water by the intestinal mucosa. Contrast infusion should be continued throughout the scan to prevent the patient ingesting excessive amounts of air. A high flow rate abolishes peristalsis and produces hypotonia and then atonia, with a reflux toward the stomach. A low flow rate produces hyperperistalsis, and therefore the absence of optimal distension. The infusion should be monitored and adapted to each patient (Fig. 11).

**Administration of IV Iodinated Contrast Medium**

It is advisable not to exceed the dose of 1 mg of iodine per kilo of body weight (Fig. 12).

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![Figure 10](image1.jpg) Incorrect placement of jejunal feeding tube, denounced by severe water distension of the stomach; the apex of tube is in pyloric place as a result of mobilization of the device during patient transfer.

![Figure 11](image2.jpg) Insufficient distension of the small-bowel loops (A), with incorrect timing of contrast medium intravenous administration (B). These errors lead to misinterpretation of semiotics loop ileum in the right iliac fossa with image of “false” hypervascular wall.
Volumetric Acquisition

Performing a single scan, without an unenhanced CT scan, means radiation dose to the patient is markedly reduced.

Helical CT protocols with breath-hold times of 35-50 seconds are prone to breathing artifacts. Acute respiratory motion results in data misregistration and substantially degrades image quality. Respiration results in characteristic linear artifacts on 2D and 3D images that appear as abrupt wall defects or polyloid structures, often on opposite parts of the bowel wall. On coronal or sagittal 2D reformatted images, respiratory artifacts can easily be identified as irregularities of the outer abdominal wall along the z axis. The importance of this artifact decreases with shorter acquisition times, which are feasible with multidetector-row CT scanners. The reduced breath-hold times of about 7-13 seconds virtually eliminate these artifacts in almost all patients.58

Multiplanar Reconstructions

Insufficient image processing may lead to an increased number of artifacts; as a result, perception and interpretation errors occur, increasing the number of false-negative findings and adversely affecting the diagnostic performance of CT enteroclysis. MPR can aid in the correct interpretation of possible equivocal findings in the axial scans. Identifying the precise location and extension of disease may prove difficult. It is often laborious and at times impossible in the axial images. Stair-step artifacts are typical artifacts present on 2D MPR images. These artifacts increase with increasing section thickness and pitch. Stair-step artifacts are minimized by reducing the section thickness to 1.5 mm or less, which is standard procedure with 16-64-section multidetection-row CT. After the examination, the criteria for judging whether it has been correctly carried out are the uniform distension of all the intestinal segments and the identification of the intraluminal contrast medium in the right colon, which attests to its passage through the entire small bowel.58

Pitfalls in Evaluation

Pitfalls in evaluation can be related to the evaluation technique and to reading errors.

In data evaluation, pitfalls include failure to detect a lesion (perception errors) and misinterpretation of a finding (interpretation errors).

Failure to achieve adequate loop distension may result in both false-positive results—mimicking abscesses, masses, and enlarged lymph nodes—and false-negative results due to nondistended loops masking lesions. Poor bowel distension is a problem, and subtle early wall and mucosal changes may be missed. False-positive results generally correspond to partial volume effects of the connivent valves, intestinal spasm, and functional invaginations. The latter can be confused with simple intestinal contraction or an intestinal fold, but not with organic invagination because it does not result in upstream distension. MPR makes it possible to proceed through the intestinal loops and in particular to differentiate the folds, the connivent valves, and the intestinal curves.58

A correct interpretation of morphologic features is necessary to decide whether the finding is true positive or false positive. There is no standardized method for reading a CT enteroclysis image. Nevertheless, the small intestine is long and is often difficult to follow continuously over its entire length. It is better to begin by analyzing axial and frontal views in the dynamic mode. If an anomaly is detected on the axial views, oblique multiplanar reformations should be used to uncoil the length of the abnormal intestinal loop.58

References