2 Small Intestinal Radiography

Fumihito Hirai

2.1 Practical Importance of Radiographic Diagnosis

The advent of capsule endoscopy (CE) and balloon-assisted endoscopy (BAE) is revolutionizing the diagnosis of small intestinal disease, which has hitherto relied on radiographic methods. Endoscopic examination offers a range of advantages, and its future development and widespread adoption are expected. Conversely, the use of radiography can be anticipated to decline still further. However, it is unlikely that it will ever be possible to diagnose small intestinal disease using endoscopy alone, without any need for radiography. The small intestine is bordered on the proximal end by the esophagus, stomach, and duodenum, and on the distal end by the large intestine, and is the longest organ in the human body. These anatomical characteristics mean that it is no easy task to observe the small intestine in its entirety, even with the help of capsule and balloon endoscopy. Endoscopy may also encounter problems due to stenosis, adhesions, or unusual dispositions following surgery. From the disease perspective, although malignant conditions are less frequent compared with other parts of the gastrointestinal tract, chronic inflammatory disorders such as Crohn's disease and lesions associated with systemic disorders are common. In such disorders, grasping the entire picture and describing responses to treatment and the natural course objectively is more important than observing localized areas in detail. Radiography is clearly superior to endoscopy in terms of grasping the entire picture and objectively describing areas or lesions. If imaging is performed properly and interpreted by a competent practitioner, radiography will still have an important role to play in the diagnosis of small intestinal disease. Mechanical advances have also improved visualization by CT and MRI, and these modalities have recently been used for procedures such as enterography and enteroclysis. Unlike regular radiography, these methods also provide information external to the lumen, and have the advantages of being performable even if intestinal tract obstruction is present as well as minimal invasiveness, meaning they will continue to hold important places in diagnostic imaging of the small intestine.

2.2 Radiography of the Small Intestine [1–3]

Small intestinal radiography may be broadly divided into the per-oral method, in which contrast agent is administered by mouth, and the per-tube method, in which it is administered via a probe placed deep into the duodenum (in the neighborhood of the ligament of Treitz) or otherwise injected. Another special method is selective contrast administration following endoscopy of the large or small intestine. In actual clinical practice, the condition of the patient, suspected disease, and pathology of existing disorders are taken into account, and a method is selected in accordance with the objectives of radiography. Table 2.1 shows the contrast agents used in different methods, and the associated advantages and disadvantages [1–3]. Radiography is indicated in most types of small intestinal disease, but the use of barium in radiography is contraindicated in patients with obvious intestinal obstruction or generalized peritonitis.

2.2.1 Per-Oral Method

This can be performed simply to look for small intestinal lesions following gastric fluoroscopy, or with the small intestine as the sole target. In the former case, the objective of radiography is to identify gastric lesions and undertake detailed investigation, with the small intestine as the subject

F. Hirai (✉)
Department of Gastroenterology, Fukuoka University Chikushi Hospital, 1-1-1 Zokumyoin, Chikushino, Fukuoka 818-8502, Japan
e-mail: fuhirai@cis.fukuoka-u.ac.jp

T. Matsui et al. (eds.), *Endoscopy in the Diagnosis of Small Intestine Diseases*,
DOI 10.1007/978-4-431-54352-7_2, © Springer Japan 2014

Table 2.1 Comparison of methods of small intestinal radiography

	Contrast agent, etc.	Advantages	Disadvantages
1. Per-oral method	50–100 w/v %	Simple, minimally invasive	Poor visualization of small lesions
	200–300 mL	Can be used for screening	Easily affected by conditions
2. Per-tube method (a) Double-contrast method (b) Herlinger's method	50–100 w/v % 250–400 mL + 600–800 mL air	Capable of visualizing extensive lesions	Invasive (probe insertion)
		Good visualization of small lesions	Accuracy depends on operator
	70–90 w/v % 250–300 mL + 1.5-2.0 L 0.5 % methyl cellulose	Short radiography time	Poor visualization of small lesions
		Easy separation of loops of small intestine	Inferior visualization of lower ileum
3. Retrograde ileography	50–100 w/v % 100–250 mL + 200–500 mL air	Capable of visualizing intrapelvic lesions	Pain (due to insertion of endoscope into small intestine or large intestine), invasiveness
		Enables evaluation of proximal side of stenoses through which an endoscope is unable to pass	Complex procedure

Modified from Nakamura et al. [1], Yao [2]

of secondary observation. This discussion focuses on the latter case.

For barium, 200–250 mL of a 50–100 w/v % suspension is used. In our department, we normally administer 250 mL of 100 w/v % barium by mouth. Because of individual differences in transit time through the small intestine and the area to be investigated, however, this must be adjusted for each patient. A basic principle common to all small intestinal radiography is to separate the loops of small intestine as far as possible and eliminate overlap, to improve radiographic accuracy. In particular, as barium-filled and compression images are the main types of image with this technique, it is important for the small intestine to be completely filled with barium and for the loops of small intestine to be carefully compressed when searching. Different procedures are required for different areas to avoid overlapping of the small intestine. For the upper small intestine, a shallow left anterior oblique position is adopted, and observation and imaging are performed while the patient takes a deep breath. For the central small intestine, frontal imaging and a right anterior oblique position are adopted, and imaging is normally performed while the patient breathes in. In both cases, a small quilt may be used as necessary to apply an appropriate level of compression. The ileum within the small pelvic cavity and the terminal ileum are frequent sites of lesions, but are often difficult to separate. The use of sedatives and compression with a quilt are both effective, and clear separation can be achieved in many cases by putting the patient in the prone position and placing the quilt over the lower abdomen (Fig. 2.1a–c). Transanal air insufflation may also prove effective.

During fluoroscopy, or when interpreting images, it is important to focus on whether abnormal disposition edema, deformity, or stenosis is present. In particular, deformity is an important key to the identification of small intestinal disease. If a deformity is observed under fluoroscopy, applying pressure may permit some type of cause to be recognized in the surrounding area (Fig. 2.2a, b). It is vital to be well acquainted with the characteristic images seen in each different disorder in order to interpret radiographic images. For example, the presence of the widespread spoke-like lesions seen in systemic lupus erythematosus (SLE) (Fig. 2.3), or the longitudinal aphthae evident in Crohn's disease (Fig. 2.4) in themselves comes close to a confirmed diagnosis. Detailed descriptions of the various disorders are given in Part II, "Specific Findings of Small Intestinal Lesions," and are therefore omitted here, but it is important to carry out any additional tests required for diagnosis in an efficient manner based on the results obtained by this method.

2.2.2 Per-Tube Method

Two different methods are used: the double-contrast method [1, 2] utilizing air; and Herlinger's method [3] in which barium transit is enhanced by the use of methyl cellulose. In both cases, a 12- to 16-Fr probe is used, which is normally inserted per-nasally as far as the neighborhood of the ligament of Treitz under fluoroscopy. This technique is unaffected by gastric juices or transit time through stomach, unlike the per-oral method, and has the advantage that the

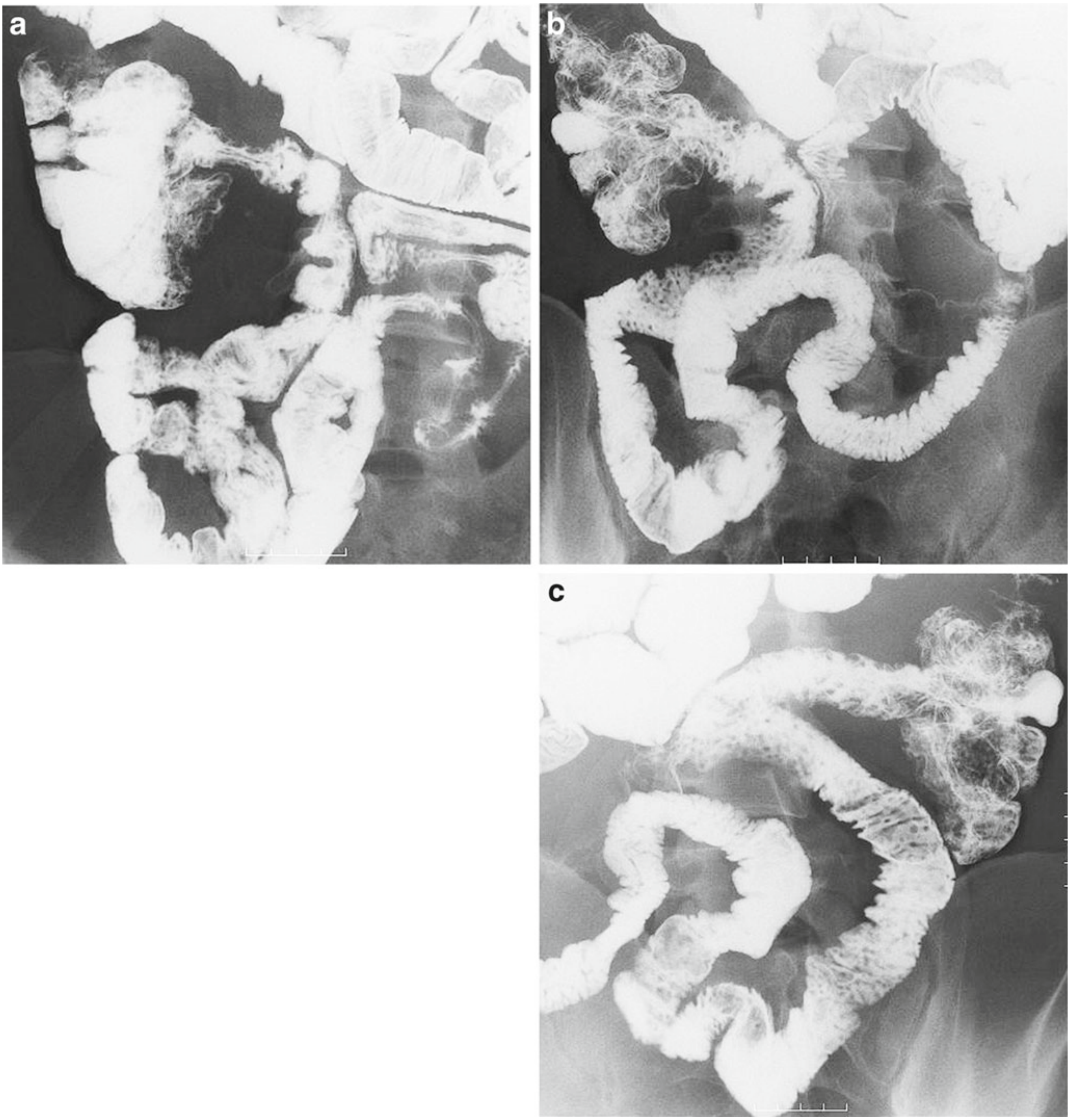

Fig. 2.1 Performance of per-oral small intestine contrast imaging. (**a**) X-ray image focusing on the lower ileum once the contrast agent has reached the terminal ileum. The intrapelvic small intestine is not separated. Peristalsis is present, making evaluation of the mucosal surface difficult. (**b**) Image obtained after intramuscular sedative injection and application of pressure with a quilt. The small intestine within the pelvis is almost completely separated, and lymph follicles are visualized in the terminal ileum. (**c**) When imaging is performed with the patient in the prone position and a quilt placed on the abdomen, the small intestine within the pelvis is completely separated. This image can be interpreted as showing the presence of multiple lymph follicles, restricted to the terminal ileum

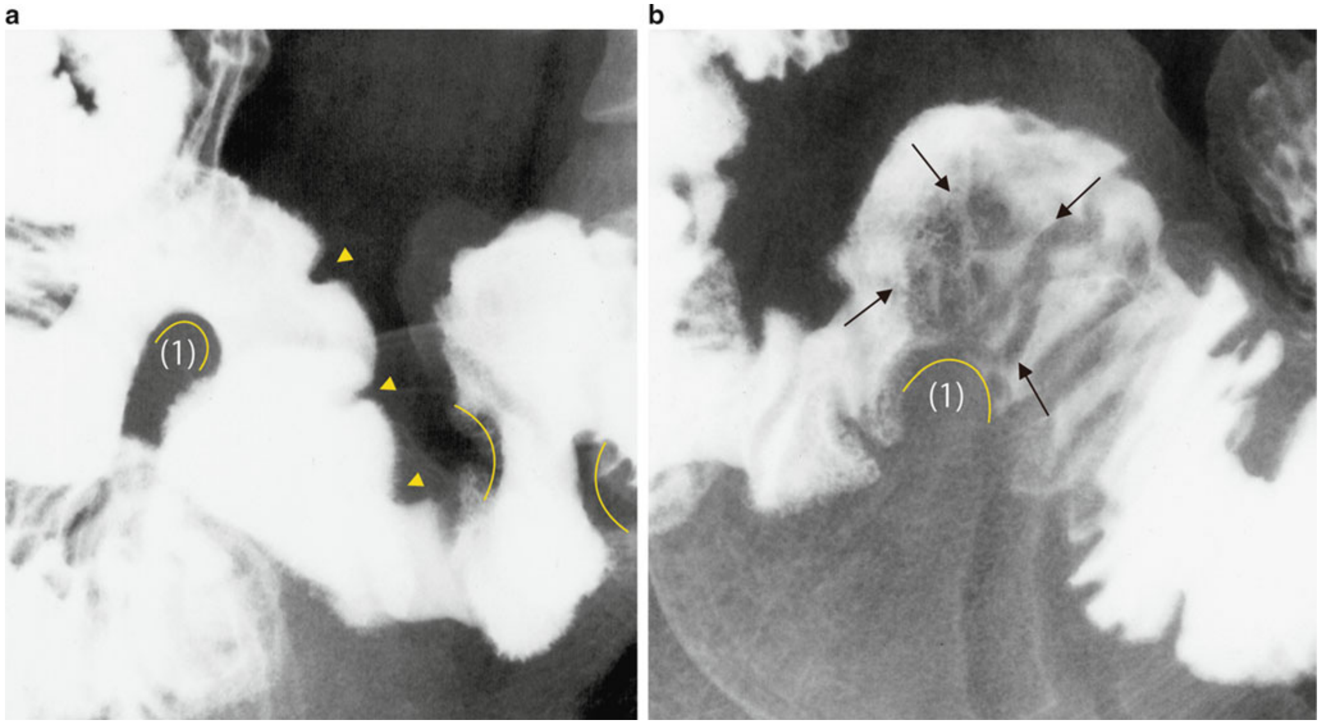

Fig. 2.2 Use of compression to visualize findings of deformity. (**a**) Multiple deformities of the ileum seen in chronic non-specific multiple ulcers of the small intestine (CNSU). The barium-filled image shows indentations of different sizes within a small area of the ileum (the area marked (*1*) is a comparatively severe indentation). (**b**) When the severe indentation marked (*1*) on the barium-filled image was carefully compressed, ulcerative lesions with mild activity and slight protrusion were visualized in the surrounding area (*arrows*)

Fig. 2.3 Small intestinal lesions in SLE. Diffuse, spoke-shaped lesions are evident across a wide area from the jejunum to the ileum. This finding is characteristic of the enteritis seen in SLE

Fig. 2.4 Visualization of small aphthae by compression. Multiple aphthae of the ileum seen in Crohn's disease. Aphthae with a prominent pattern of protrusions are visualized in this compression image

Fig. 2.5 Double-contrast image of longitudinal ulceration. Longitudinal ulceration of the ileum seen in Crohn's disease. Double-contrast images have been obtained over a wide area from the lower ileum to the terminus of the ileum, and the lesions are clearly visualized

volume of barium can be adjusted while its passage through the small intestine is observed.

2.2.2.1 Double-Contrast Method

The double-contrast method is capable of visualizing tiny lesions in the small intestinal mucosa over a wide area, and is therefore suited to detailed investigations (Fig. 2.5). The barium concentration is varied as appropriate, but in general is around 50–100 wv %, with 250–300 mL often used. In our department, we place the patient in the left lateral decubitus position or a steep right anterior oblique position, and normally start with an initial introduction of 100–150 mL of 80 wv % barium. We then move the patient to a position from supine to left anterior oblique and observe the passage of the barium, adding a further 100–200 mL. As increasing the amount of barium makes it more difficult to obtain double-contrast images over a wide area, it is preferable that the terminus of ileum be reached with a volume of around 300 mL if possible. We perform the procedure while massaging the barium manually toward the distal end, but as barium degrades if this takes too long, we also administer water or inject metoclopramide (Primperan®) if necessary to speed the process along. Air insufflation is initiated after barium has reached the terminal ileum. To start with, 200–300 mL is injected, and movement of the air toward the distal end is monitored. A further 100–200 mL is then injected while the position of the patient is repeatedly varied, until the air reaches the terminal ileum. Under favorable conditions, double-contrast images can be obtained across a wide area of the small intestine, but there are always at least a few points at which the barium pools and continues to fill the intestine, or where it has been preceded by air and barium adhesion is insufficient. It is therefore necessary to adjust the procedure to enable clear visualization by double-contrast imaging of the location where visualization is most desired (Fig. 2.6a, b). Once the air has reached the terminal ileum and the target location contains sufficient air, a sedative is administered (normally an intravenous injection of 1-2A hyoscine butylbromide (Buscopan®) and imaging is performed. It is no exaggeration to state that the quality of radiographic films is determined by the timing of sedation, and this therefore requires care.

Interpretation of double-contrast images is basically the same as for the per-oral method, but there is a greater possibility of obtaining information on matters such as tiny bumps and patterns on the mucosal surface (Fig. 2.7), abnormal disposition of Kerckring's folds (Fig. 2.8), and the degree of deformity (when extended). Because lesions that go unnoticed during screening may be picked up during image interpretation, imaging should be performed for areas in which lesions frequently occur for the suspected disease while varying body positions and angles.

2.2.2.2 Herlinger's Method [3]

The greatest advantage of this method is that radiography can be completed during a short space of time. Methyl cellulose is used to speed up passage of the barium, which is effective in reducing the time required and preventing loops of small intestine from overlapping. Around 250–300 mL of barium of around 50–100 wv % concentration is used. When 1.5–2.0 L of 0.5 % methyl cellulose is introduced immediately after barium introduction, sequential double-contrast images can be obtained from the proximal end of the small intestine. Visualization of lesions, however, is poor compared with both good compression images obtained by the per-oral method and double-contrast images obtained by utilization of air (Fig. 2.9). The barium also degrades the closer it approaches the distal end of the ileum, and this method is therefore not generally used.

2.2.3 Retrograde Ileography

One disadvantage of double-contrast imaging is the difficulty of visualizing the intrapelvic small intestine and the terminal ileum. Barium frequently fails to reach these locations even after some time has passed, or becomes denatured, reducing the quality of radiography. Barium may also fail to flow smoothly, making double-contrast images difficult to a b

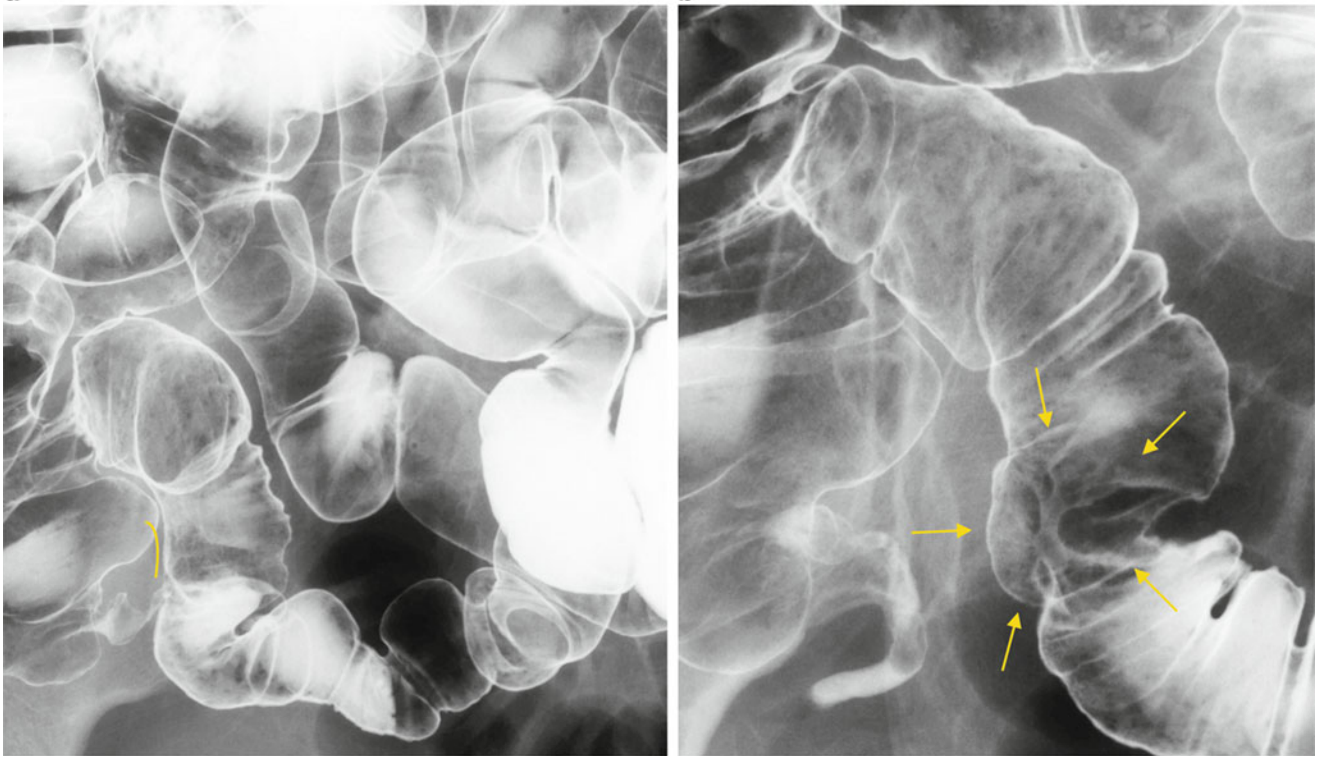

Fig. 2.6 Double-contrast imaging in practice. (**a**) Double-contrast imaging focusing on the lower ileum. Barium is pooled in some areas, and there are overlapping loops of bowel. A lesion of the terminus of the ileum was originally suspected in this case, so radiography focused on that area, and a sclerotic area was noticed during scanning. (**b**) When imaging was performed from a different angle, a somewhat bumpy concave lesion was visualized (*arrows*). Non-steroidal anti-inflammatory drug (NSAID)-induced enteropathy was diagnosed on the basis of the patient's history of NSAID use, biopsy results, and the fact that improvement was observed after medication was discontinued

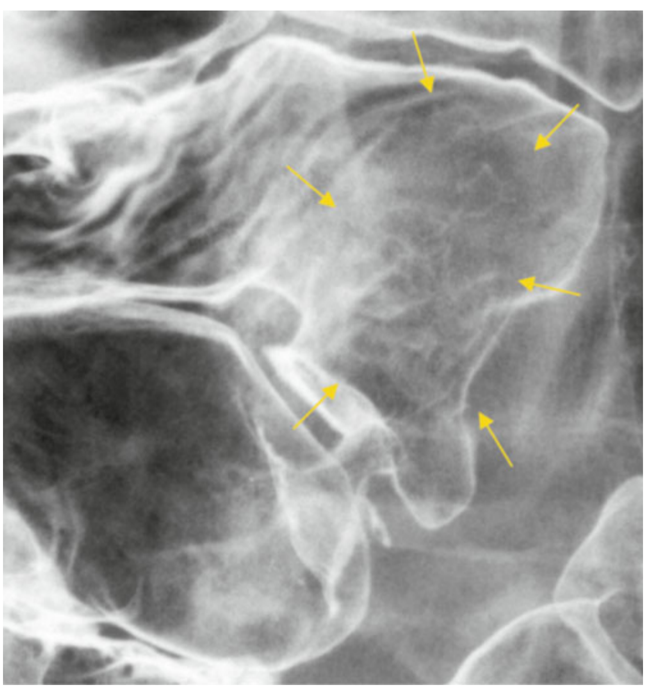

Fig. 2.7 Double-contrast image of small intestinal tuberculosis. Ileal stenosis seen in intestinal tuberculosis. Kerckring's folds have disappeared on the proximal side of the stenotic area, and the mucosal surface is roughened (areas of atrophic scarring). Shallow depressions can be seen in the same area (*arrows*)

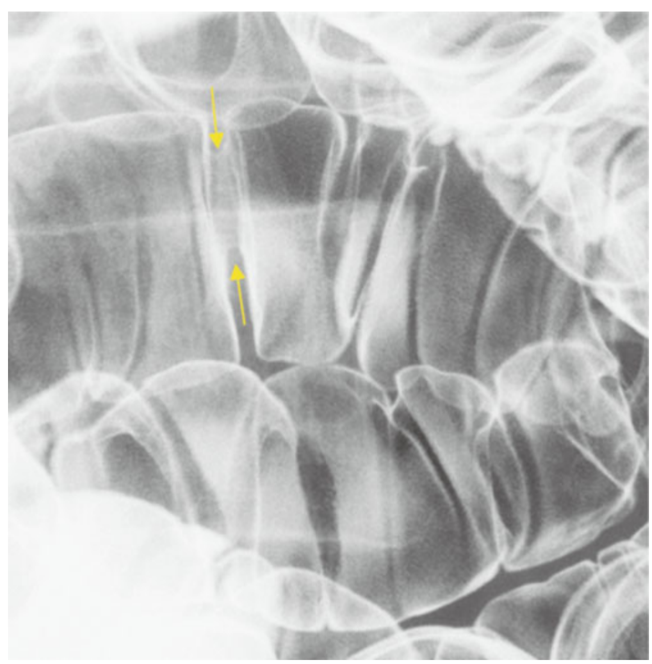

Fig. 2.8 Annular stenosis seen in NSAID-induced enteropathy. Abnormal Kerckring's folds seen in NSAID-induced enteropathy. The disposition of folds is inconsistent, with uneven spacing and width. Mild membranoid stenosis is also evident (*arrows*)

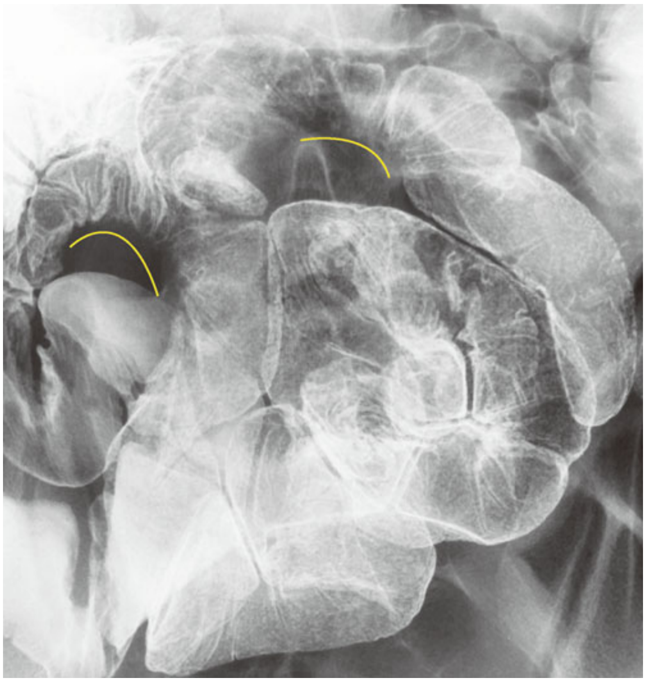

Fig. 2.9 Herlinger's method. Small intestine contrast image obtained by using Herlinger's method from a patient with Crohn's disease during remission (after total parenteral nutrition therapy). Longitudinal ulcerative scarring and lateral deformity can be seen, but dilution and degradation of the barium mean that the properties of the mucosal surface cannot be determined

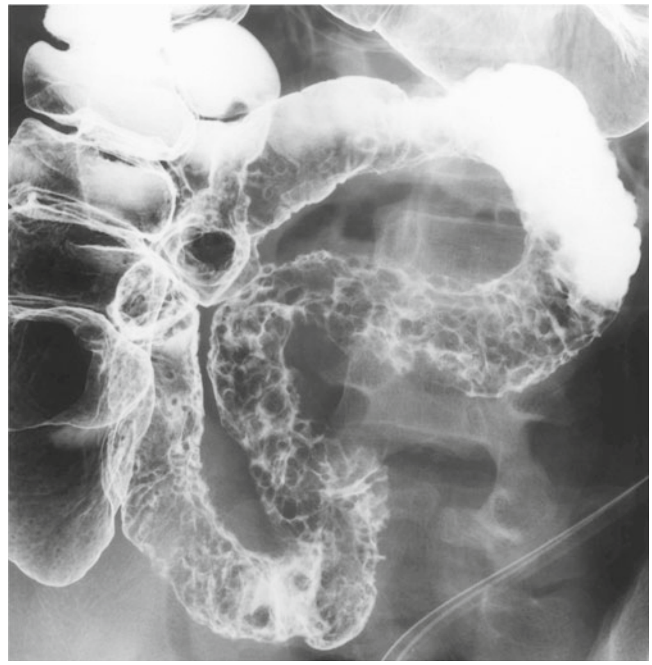

Fig. 2.10 Cobblestone appearance of the ileum visualized by retrograde ileography. Retrograde ileography image taken following on from colonoscopy. The typical cobblestone appearance of Crohn's disease is evident mainly from the terminal ileum to the intrapelvic ileum, together with lateral deformity

obtain, and an inability to separate loops of small intestine despite changing positions, applying pressure, and taking other measures is also common. Retrograde ileography has been devised as a selective contrast method to compensate for these disadvantages of double-contrast imaging. The method was formerly performed following colonoscopy [4], and involved: (1) inserting a lower gastrointestinal endoscopy scope as far as the terminus of the ileum via a sliding tube, and placing a guidewire via the forceps port; (2) withdrawing the scope, and inserting a contrast tube along the guidewire left inside the sliding tube; (3) after the contrast tube had been placed in the terminus of the ileum, inflating the balloon at its tip; and (4) using barium and air from the tip of the tube for selective contrast of the ileum. This method enables high-quality double-contrast images to be obtained using comparatively small volumes of barium and air even for the intrapelvic small intestine, which is difficult to separate (Fig. 2.10). The complexity of using a sliding tube, however, as well as the difficulty of inserting and placing the contrast tube, mean that this method frequently ends unsatisfactorily. In recent years, the use of balloon-assisted endoscopy (BAE) has become widespread, facilitating endoscopic observation of the small intestine and resulting in something of a decline in the significance of conventional retrograde ileography. BAE, however, is also limited in its range of observation in cases of stenosis or severe adhesions that do not permit passage of the scope, and difficulties in assessing lesions are frequently encountered, particularly in inflammatory disorders such as Crohn's disease. In such cases, many institutions introduce a water-soluble contrast agent (such as diatrizoate meglumine (Gastrografin®)) via the forceps port during BAE as a simple way of performing contrast. Good double-contrast images cannot be obtained, however, and investigation by this method frequently ends unsatisfactorily. The authors have devised a special probe for small intestinal radiography (made of polyvinyl chloride, which slides easily and is strong and flexible), and have reported the value of a new technique of retrograde ileography that improves on the conventional method [4]. This technique utilizes the overtube used in balloon endoscopy to enable safe, more selective contrast, and renders the guidewire unnecessary due to the improved probe, providing major improvements to the disadvantages of the conventional method (Fig. 2.11a–d). This approach can also be used following BAE via the peroral approach, and adapted for the jejunum or upper ileum. It may be necessary in future to develop investigative frameworks that utilize BAE and radiography in a complementary fashion, including this technique.

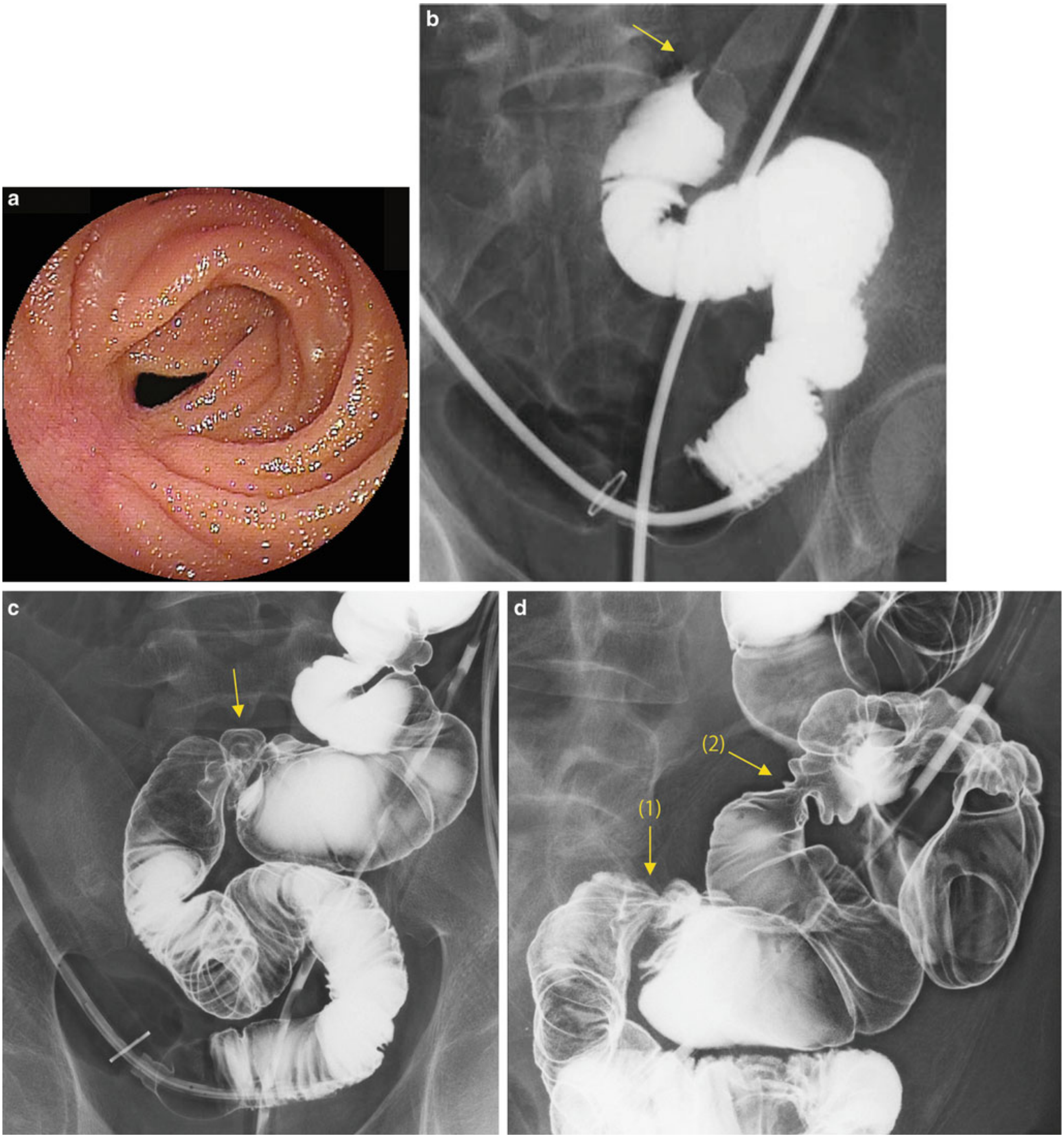

Fig. 2.11 Practice of retrograde ileography using double-balloon endoscopy. (**a**) Double-balloon endoscopy was performed via a peranal approach in a patient with Crohn's disease, but stenosis prevented viewing any further toward the proximal end. (**b**) A contrast tube was placed on the tip of the over-tube, and 100 mL of barium introduced. The site of stenosis (*arrow*) observed endoscopically can be seen. (**c**) After the barium had been observed to flow in retrograde fashion through the site of stenosis (*arrow*), a total of 250 mL of air was slowly introduced. (**d**) Double-contrast observation of the proximal side of the site of stenosis (*1*) showed not only deformation of the intestinal tract, but also a second stenosis (*2*). Endoscopic balloon dilatation was performed the following day, enabling surgery to be avoided

2.3 CT and MRI Diagnostics

In recent years, the development of MDCT has led to dramatic improvements in spatial separability [5, 6]. It is now possible to visualize the gastrointestinal tract clearly by means of CT. Advances in the computers used for data-processing have also enabled detailed multiplanar reconstruction (MPR) based on the information acquired from CT. As CT is minimally invasive, this modality can be applied even when serious conditions such as intestinal obstruction or perforation are suspected (Fig. 2.12). In the field of small intestinal disease, CT is used for a wide range of indications, including obscure gastrointestinal bleeding (OGIB), suspected small intestinal tumor, and inflammatory bowel disease of unknown cause. In some institutions, CT enterography (Fig. 2.13a, b) is performed by filling the small intestinal lumen with a negative contrast agent such as air, water, or polyethylene glycol solution (PEG) or a positive contrast agent (including iodine and barium) to produce three-dimensional images [7–10]. Compared with small intestinal radiography, CT requires less expertise on the part of the practitioner. It can still be performed even if passage is obstructed, and has the advantage of providing information about the intestinal wall and areas outside the digestive tract. However, it is not possible to evaluate tiny bumps and depressions on the mucosal surface. CT also has the disadvantages that visualization of a target location may not be possible, depending on conditions, and that time is required for image production.

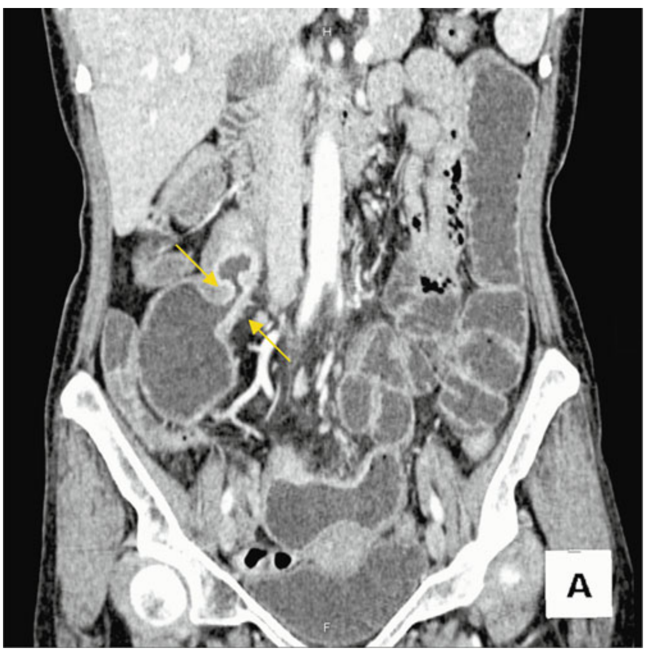

Fig. 2.12 Abdominal CT MPR image. MPR image of a patient with Crohn's disease and intestinal obstruction. The small intestine is visualized to a comparatively wide extent due to the backing up of intestinal fluid. Stenosis of the ileum is evident, with thickening of the intestinal wall, and the intestinal tract is dilated on the proximal side. This was regarded as the culprit lesion

Thanks to advances in MRI equipment that have reduced the time needed for imaging, this modality can now also be applied to small intestinal disease in the same way as CT. Although MRI has many similarities with CT in terms of imaging of the small intestine, its features include superior concentration resolution and the fact that no radiation exposure is involved. In Europe and the United States, there is a tendency to prefer MRI to CT or small intestinal radiography, both of which require radiation exposure, in chronic inflammatory conditions such as Crohn's disease that require repeated scanning. Studies comparing MRI with endoscopy have also been reported [7, 8] and MRI may be used with increasing frequency in future, particularly in Europe and the United States. MR enterography is also regarded as useful [9, 10] as, unlike CT enterography, it offers advantages such as dynamic evaluation, and there are hopes for its future development.

CT and MRI are expected to undergo further advances in engineering in future. At present, MPR imaging, which does not require the introduction of air or liquid, is the main form of imaging in all but a few institutions. There is no sign of the widespread adoption of CT enterography or MR enterography and the methods of dilatation of the small intestine also differ between institutions. Establishment of consistent methods to both enable clear visualization of the small intestine and offer superior simplicity and safety would thus be desirable.

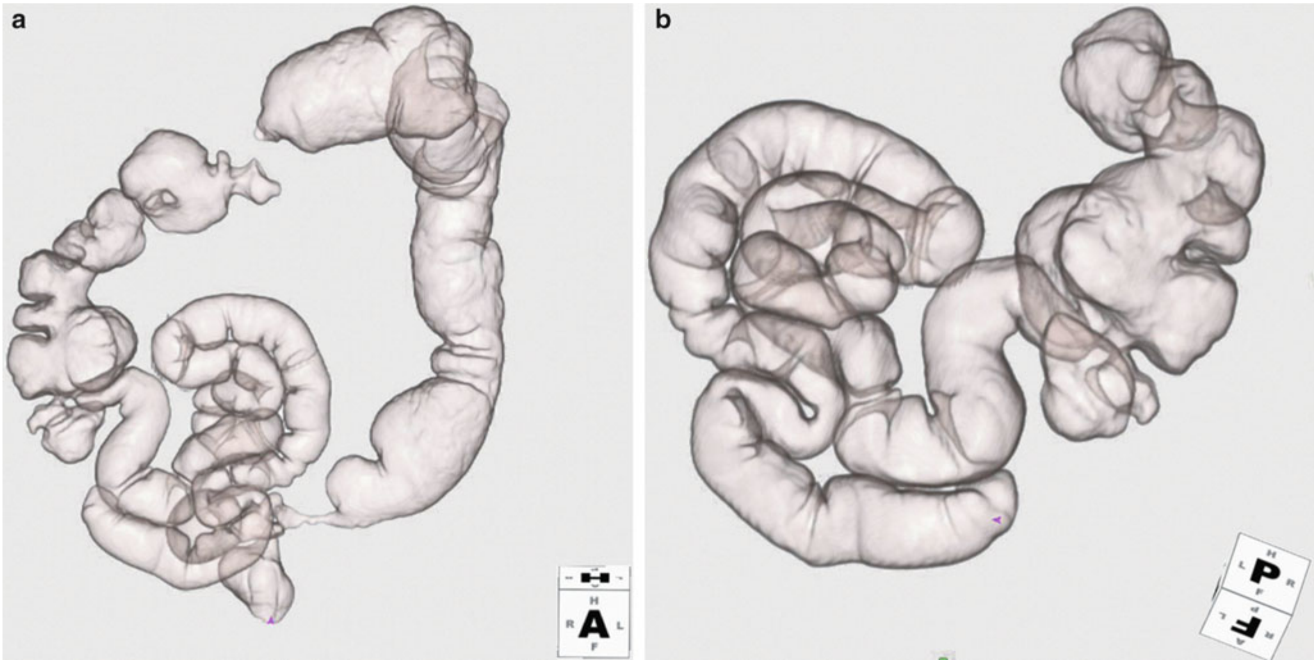

Fig. 2.13 Enterocolonography of large intestine stenosis. (**a**) Enterocolonography image of a patient with Crohn's disease with stenosis of the sigmoid and transverse colon. Air was introduced peranally, and the intestine was observed from the lower ileum to the colon. (**b**) There is clear visualization from the intrapelvic ileum to the terminal ileum, and this can be adjusted to any angle. Active lesions, fistulae, and the like can be ruled out, although it is not possible to evaluate small lesions such as aphthae

References

1. Nakamura U et al. X-ray examination of the small intestine by means of duodenal intubation—double contrast study of the small bowel. Stom Intest. 1974;9:1461–9.
2. Yao T. Double contrast enterolysis with air. In: Freeny PC, Stevenson GW, editors. Malgulis and Burhenne's alimentaly tract radiology. St Louis: Mosby; 1994. p. 548–51.
3. Herlinger H. Enteroclysis technique and variations. In: Herlinger H, Maliglinte DDT, Birnbaum BA, editors. Clinical imaging of small intestine. 2nd ed. New York: Springer; 1999. p. 95–123.
4. Yorioka M et al. Newly devised small bowel sonde for air contrast barium study after enteroscopy. Stom Intest (in Japanese). 2011;46:500–6.
5. Colombel JF et al. Quantitative measurement and visual assessment of ileal Crohn's disease activity by computed tomography enterography. Gut. 2006;55:1561–7.
6. Paulsen SR et al. CT enterography as a diagnostic tool in evaluating small bowel disorders: review of clinical experience with over 700 cases. Radiographics. 2006;26:641–57.
7. Low RN et al. Crohn disease with endoscopic correlation: single-shot fast spin-echo and gadolinium-enhanced fat-suppressed spoiled gradient-echo MR imaging. Radiology. 2002;222: 652–60.
8. Koilakou S et al. Endoscopy and MR enteroclysis: equivalent tools in predicting clinical recurrence in patients with Crohn's disease after ileocolic resection. Inflamm Bowel Dis. 2010;16: 198–203.
9. Umschaden HW et al. Small-bowel disease: comparison of MR enteroclysis images with conventional enteroclysis and surgical findings. Radiology. 2000;215:717–25.
10. Negaard A et al. Magnetic resonance enteroclysis in the diagnosis of small-intestinal Crohn's disease: diagnostic accuracy and inter-and intra-observer agreement. Acta Radiol. 2006;47: 1008–16.