Chapter 6

Imaging of Colonic and Rectal Cancer

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Additional information is available at the end of the chapter

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Abstract

Colorectal cancer is one of the most common cancers worldwide. Thus, its early detection through screening and diagnostic techniques is the key in managing this condition. For this to be possible, it is necessary to know the risk factors and to choose the appropriate screening and diagnostic techniques for each case. Imaging also plays a key role in treatment planning by assessing both local and distance extension of the disease.

The aim of this chapter is to make an overview of the currently available imaging techniques for diagnosis of colorectal cancer (ultrasound, computed tomography—CT, magnetic resonance imaging—MRI, and positron emission tomography—PET/CT), focusing on specific and technical elements, benefits, costs, and limitations of each technique.

Keywords: colon, rectum, imaging, ultrasonography, CT, MRI

1. General

1.1. Epidemiology

Colorectal cancer (CRC) is a major human health issue. Globally, it ranks third in incidence after lung and breast cancers. In developed areas such as North America, Australia, New Zealand and Western Europe, it appears even more frequently, being ranked the second [1, 2]. In terms of etiology, it is divided into two categories: genetic and non-genetic. The non-genetic ("sporadic") category is the most common one (~70–80%), its known cause being the malignant transformation of the adenomatous polyps. This phenomenon occurs over years, related to an unstable lifestyle. An improper diet (low in fruit and vegetables and high in red meat and saturated fat), consumption of toxic products (alcohol and tobacco), obesity,

sedentarism, as well as the presence of inflammatory bowel diseases (ulcerative colitis and Crohn's disease) are all considered as being predisposing factors [3, 4]. In recent years, a decrease in the mortality from colorectal neoplasia and an increase in the survival by up to 5 years has been reported. These are due to the evolution of early detection techniques through screening, as well as to the improved therapeutic procedures. Even if in this disease the prognosis is better than in other cancers, the main concern regards its management which should be directed toward prevention and early diagnosis.

1.2. Techniques used for early detection

Screening methods used are in full development. They are classified into biological assays (for the detection of occult stool blood, DNA, RNA, and feces protein) and colorectal exploration techniques. Among the biological assays, the one used for the detection of occult blood in the stool is the most widely used because of its accessibility, low-cost, and proven effectiveness in reducing the CRC incidence and mortality (by ~15–33%) [4]. The assay for the detection of DNA, RNA, and some proteins in plasma and feces represents another biological category. Due to the variability of literature data related to their diagnosis value as well as their high cost, their usefulness on a large scale is still reduced [4]. The genetic syndromes with increased risk of CRC (the familial adenomatous polyposis and the hereditary non-polyposis colorectal cancer—Lynch syndrome) can be diagnosed through different genetic assays.

In the category of the colorectal exploration tests, optical colonoscopy is the method of choice. This technique is used as a screening assay at different time intervals depending on the probability of disease occurrence. One of its major advantages is the possibility of polyps biopsy/resection (in spite of the high cost and low acceptance by the population!) [4].

Other colorectal exploration assays include imaging methods. The techniques used are the double-contrast irrigoscopy and the CT virtual colonoscopy (CT colonography). It is currently recommended to replace the double-contrast irrigoscopy with the CT virtual colonoscopy because of a lower discomfort and a better tolerance, as well as its increasing affordability [5, 6]. There are studies that are showing an increased sensitivity (96%) of the CT virtual colonoscopy, similar to the optical colonoscopy, but the values vary depending on the lesion size [6].

1.3. Criteria to be included in the screening programs

The population at an average risk of developing CRC is represented by subjects older than 50 years old, without other associated risk factors. They can be followed up annually for the detection of occult stool blood, as well as by flexible sigmoidoscopy (only for the left colon, technique that does not require special preparation). The combination of the two assays may be carried out every 5 years. Other availabilities are double-contrast irrigoscopy and virtual colonoscopy done every 5 years, or optical colonoscopy, every 10 years [5–7].

The population with increased risk of developing CRC is represented by subjects with personal or familial history of CRC or adenomatous polyps, those with genetic syndromes, or patients with chronic inflammatory diseases. Each of them can benefit from a customized screening program. The screening program must begin at the age of 40, or 10 years earlier than the age

of the youngest relative affected by the disease. The American College of Physicians recommends the use of the optical colonoscopy as a screening method for the high risk population group, noting that the choice of the tests must be carried out according to the risk/benefit ratio, affordability, and the patient's preferences. In addition, it is recommended to cease the screening in patients over 75 years old or those with a life expectancy of less than 10 years [7].

2. Imaging in colorectal cancer

This category contains a series of diagnostic procedures, the main purpose being that of providing information in the form of images. Every method has specific physical principles, technology, benefits, costs, and limitations. For this reason, each method should be discussed separately.

2.1. Transabdominal ultrasonography (ultrasound)

The ultrasound examination of the digestive tract is a challenge for the performing physician. This is because of the sinuosity of the bowel loops that makes it difficult to perform a full examination using a transducer with a small surface, as well as because of the high air content of the digestive tract, source of sonographic artifacts. It should also be kept in mind that the ultrasound appearance of the digestive structures varies from one time of the examination to another because of the intestinal peristalsis. The ultrasound examination of the digestive tract highly depends on the experience and patience of the examiner, to a much higher extent than the exploration of parenchymal organs. Ultrasonography is the imaging technique with the best space and time resolution in the assessment of the digestive wall, higher than computer-assisted tomography or magnetic resonance imaging. Depending on the frequency of the transducer, we can identify three layers of the wall (when using the convex probe) or five layers (when using the linear probe). Thus, the difficulties of examining the whole digestive tract are offset by a more accurate appreciation of the details.

Ultrasonography is, on many occasions, the first method of choice for patients with abdominal pain, bowel movements impairments, or other symptoms in the abdominal area [8]. It is a very accessible method, non-irradiating and painless, easily accepted by the patient, and widely available. Also, in many cases, it provides very useful information for patient diagnosis, allowing the exclusion of other diseases with similar symptoms to the CRC. The examining physician must be familiar with the ultrasound appearance of the colon cancer, which is that of a parietal hypoechoic thickening with loss of normal stratification [9]. The extent of the affected colonic wall is variable. Also, the tumor formation can be eccentric, circumferential, or semicircumferential. The colonic lumen can be stenosed [**Figure 1**]. At palpation with the transducer, the modified region may show an increased stiffness. The pericolic fat has, if invaded by tumor, an "infiltrated" (hyperechogenic) appearance. Peritumoral adenopathies can also be highlighted, with malignant aspect—being hypoechogenic and round [9]. The anorectal administration of contrast fluid (water enema) known as hydrosonography will increase the performance of ultrasonography in diagnosing colon cancer [10] [**Figure 2**]. A

study on 145 patients showed a sensitivity of 79.06% and a specificity of 92.15% for ultrasound in the diagnosis of colon cancer [11], performances which can be improved by the use of hydrosonography. Studies demonstrate that using water enema, the accuracy of the ultrasound in the T staging of the colon cancer increases to 88% and the tumoral infiltration of the lymph nodes can be predicted in approximately 70% of cases.

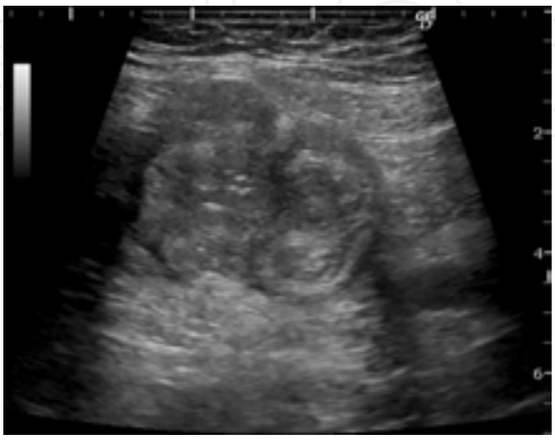

Figure 1. Transabdominal ultrasonography. Appearance of colon cancer.

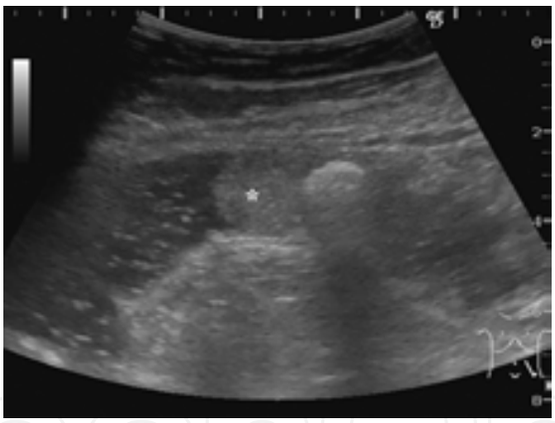

Figure 2. Transabdominal ultrasonography. Appearance of polypoid tumor. The ultrasonographic image is optimized by hydrosonography (anorectal administration of water).

Asserting the existence of a colonic tumor does not represent a complete diagnosis. We also need to know if the pathological process in the colon is a candidate for a treatment with curative purpose or the disease is in an advanced stage and the patient can only receive palliative treatment. The main reason for which we consider incurable a colon tumor process is the presence of distant metastases. Most often, colon cancer leads to liver metastases [12]. Even if the imaging method recommended for the staging of the colon cancer is computed tomography, ultrasound still plays an important role because it is the first imaging technique currently used. Ultrasound examination improved by the intravenous administration of contrast agents has a complementary role to computed tomography in the characterization of small, hypo-

vascular liver lesions, difficult to be characterized by the means of computed tomography. The ultrasound appearance of the hepatic metastases from colorectal tumors is variable. They are most commonly hypoechoic, but they can also be iso- or hyperechoic [**Figure 3**]. They are, in most of the cases, surrounded by a hypoechoic halo. The presence of the halo around a focal liver lesion makes it very likely that the lesion is malignant [13]. Sensitivity of ultrasound in the diagnosis of liver metastases is, according to various studies, between 53 and 72%. It is much improved, reaching values of 80–90%, after the administration of an intravenous contrast agent [14, 15]. After the administration of ultrasound contrast media, most of CRC liver metastases will have a hypovascular appearance. In the arterial phase of the examination, they will show peripheral enhancement like a "halo". Later, during portal/venous phases, this peripheral enhancement will wash out, remaining hypoechoic compared to the liver parenchyma. The portal and especially the late phase will be very important in liver metastases diagnosis; in these phases, they appear like "black spots" on the hyperechoic and shiny background of the normal surrounding parenchyma that captured avidly the contrast agent [**Figure 4**].

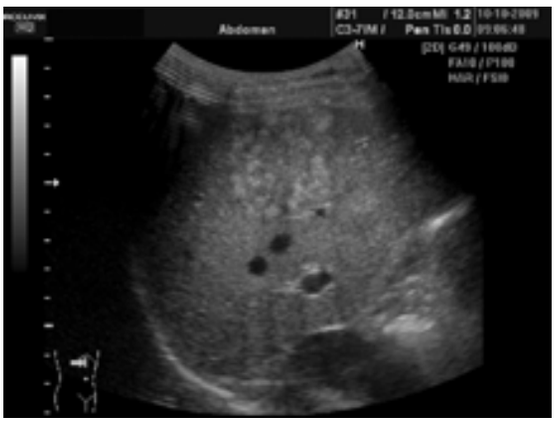

Figure 3. Transabdominal ultrasonography (gray scale). Appearance of liver metastases.

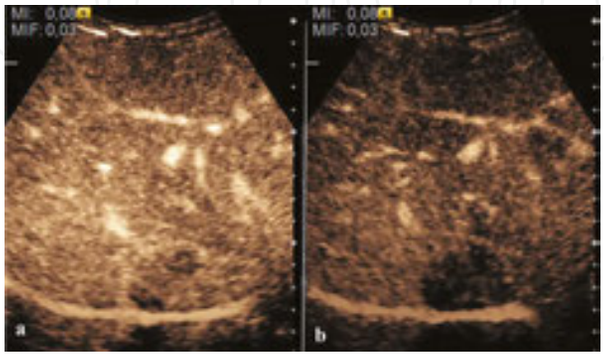

Figure 4. Transabdominal ultrasonography with i.v. contrast agent (CEUS). Liver metastases. Peripheral enhancement after contrast administration in the arterial phase (a) and wash-out in the late phase (b).

During abdominal ultrasound in patients with colon tumors, the retroperitoneum must also be assessed. The area between the inferior vena cava and the aorta is the location of metastases in 1–2% of patients with colon cancer. The assessment of this area can be difficult in overweight patients and those with overlap of gas-distended bowel loops. The presence of ascites in a patient with colon tumor raises the suspicion of peritoneal carcinomatosis. The carcinomatosis nodules will be sought mainly in the interhepatophrenic area, at the level of peritoneal recesses, and in the rectovesical space. Searching small-sized carcinoma nodules also requires the assessment of the anterior peritoneum using the high-frequency linear probe [16] [**Figure 5**].

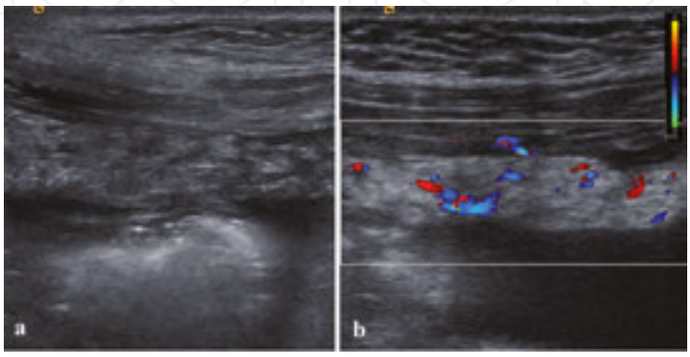

Figure 5. Peritoneal carcinomatosis. Examination was performed with high frequency probe. (a) gray scale ultrasonography and (b) color Doppler ultrasonography).

2.2. Transrectal ultrasonography

This is strictly a staging procedure. The rectal ultrasound exploration is only possible through endocavitary approach. The transperineal approach may be used in case of stenosing or prolapsing low rectal tumors in the anal canal, or if the patient shows intolerance to endocavitary procedure. In women, the rectum exploration can be achieved also by endovaginal examination [17]. The preferred ultrasound approach is transrectal, because of the visualization of the five parietal layers and the surrounding organs in the pelvis. From a technical standpoint, the ultrasound device must be equipped with a mechanic and rotating transducer with the frequency between 5–10 MHz. Attached to it there is a rubber bag filled with water (~30–60 ml) (dedicated transducer). In this way, the region to be assessed can be explored more accurately, the ultrasound beam being perpendicular to the rectal wall [18]. Alternatively, the endocavitary transducer for general use can be utilised (adapted equipment). In this case, the ultrasound waves are emitted at an angle of 135 degrees to the plane of the rod, and the obtained information is indicative. However, because of the multidirectional orientation of the examination plan, this equipment can be used to explore larger rectal tumors and even those located in the upper rectum.

There are several ultrasound procedures useful in the diagnosis of rectal tumors. Among them, the ultrasound in "gray scale" allows the analysis of morphological features (the affected parietal layers) [**Figure 6**]. Doppler ultrasonography and contrast-enhanced ultrasonography (CEUS) provide information about tumor microcirculation by analyzing specific parameters

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[19–21] [**Figure 7**]. 3D ultrasound assesses the position of the tumor mass, and it provides the performance of measurements in the three space dimensions using a special transducer [22] [**Figure 8**]. Sonoelastography is a newly emerging technique and its principle is based on the analysis of the target tissue response (in our case, the tumor tissue) when compressed. Thus, this technique provides information about the degree of the tumor stiffness and surrounding tumoral adenopathies [**Figure 9**, **Figure 10**].

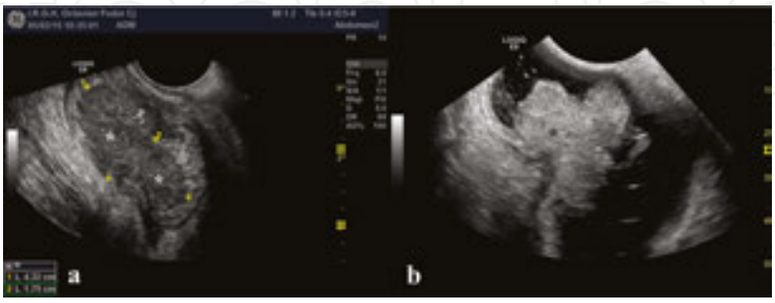

Figure 6. Rectal tumor (a and b). Endorectal gray scale appearance (asterisk).

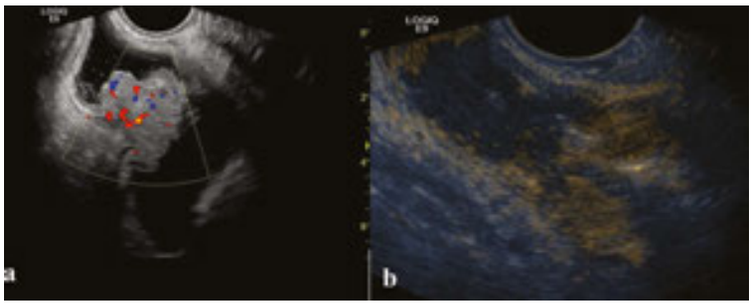

Figure 7. Rectal tumor investigated with Doppler ultrasound (a) and with CEUS (b). The contrast examination is performed after radiotherapy. Note the partial response to the treatment.

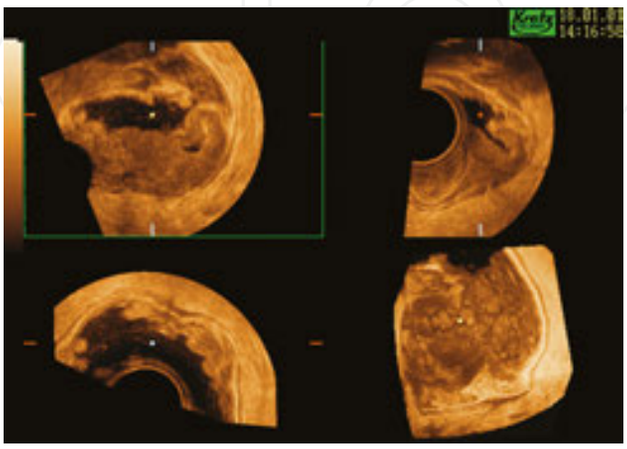

Figure 8. Rectal tumor—multidirectional tridimensional appearance.

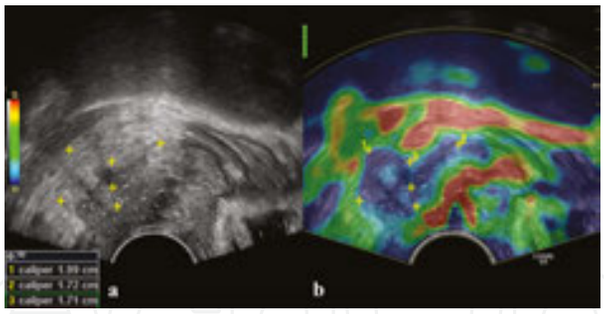

Figure 9. Rectal tumor. Gray scale ultrasound (a) and sonoelastographic examination (b). To be noticed the perirectal fat invasion.

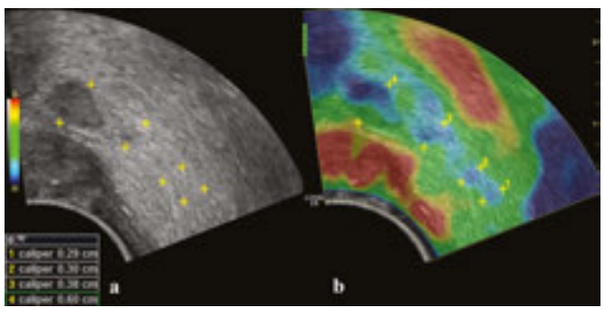

Figure 10. Neoplastic perirectal lymphadenopathies (a and b). Sonoelastographic appearance (real-time elastography, color, contact elastography). The marked rigidity of perirectal adenopathies, characteristic of malignancy, is noticed.

The examination takes place after a previous preparation of the patient by an evacuation enema. The patient is positioned in the left lateral decubitus, and the transducer is inserted into the rectum. To optimize the ultrasound image, water can be introduced previously, intrarectally (200–300 ml), but this applies only to patients with sphincter continence and to the compliant ones [22]. Transrectal ultrasound enables the visualization, tracking and assessment of tumor extension to the rectal wall and adjacent organs. The ultrasonographic appearance of rectal infiltrative tumors consists in the presence of circumferential or focal parietal thickening, along with the loss of parietal stratification. Proliferative tumors appear as endoluminal hypoechogenic masses. At the Doppler investigation, they have a disorganized vascularization. At the sonoelastography examination, the tumors are rigid. The staging of rectal cancer through transrectal ultrasound can only be performed locally (T and N stage) because of the reduced field of view of the method. The assessment of tumor invasion in the rectal wall is possible by ultrasound, with an overall diagnosis accuracy of approximately 80–95% [23]. However, the diagnostic performance of the method varies depending on the T stage, being higher for the diagnosis of the rectal tumors in early stages (T1 and T2). This is mainly because of the increased spatial resolution, enabling the differentiation of the rectal wall layers [24]. For the diagnosis of advanced stages, the MRI is preferred because it allows a better visualization of the mesorectum fascia, the peritoneum, and the surrounding organs [25]. Because of the reduced field of view of the transrectal ultrasound, the assessment of the tumoral attaint of the mesorectal fascia is difficult [23]. The tumoral invasion within lymph nodes is

another decisive element in determining the therapeutic protocol in patients with rectal cancer. The dimensional and morphological criteria are not sufficient to establish lymph node malignancy. The latest studies show that transrectal ultrasound sensitivity is similar to that of MRI (75.8% versus 77%) for lymph nodes assessment [24, 26].

Among the technical limitations of endocavitary ultrasound is the presence of a tumoral stenosis, which does not allow the transducer to pass the obstacle, thus the tumor cannot be properly assessed. Other limitations are related to post-surgery and post-radiation changes of the rectal wall. The use of the universal endocavitary transducer and the transperineal or transvaginal approach may represent alternative techniques that can provide additional information. Another drawback is differentiating the post-surgery/radiation appearance from a possible tumor residue, or a relapse, and the differentiation of stage T2 from stage T3 can be difficult in some cases because of local inflammatory or fibrotic changes.

2.3. Computer tomography

Abdominal CT (including CT virtual colonoscopy) is one of the imaging options in the diagnosis of colon tumors, allowing their detection, characterization, and staging. Discovering a colon tumor under CT can be accidental or in the context of some complications (intestinal obstruction, invagination, perforation, or fistulization) [27]. In terms of the examining technique, it is recommended to perform a luminal distension, with oral contrast, water or air, along with the intravenous administration of the iodinated contrast agent. Currently, it is preferred to replace the oral contrast agent with water, allowing a better individualization of bleeding and tumor iodophilia [27]. A typical CT appearance of a colorectal tumor is that of a polypoid mass [**Figure 11**] with possible areas of necrosis and air inclusions. Another presentation of CRC is that of an irregular focal or circumferential parietal thickening, associated with endoluminal narrowing or colon stenosis [**Figure 12**]. The local extracolonic invasion is assessed by the infiltration of the pericolonic fat [**Figure 13**]. After the administration of the iodinated contrast agent, both the adenomatous polyps and the adenocarcinomas show iodophilia. In the case of a tumoral occlusion, the colon appears dilated upstream of the stenosis and the transition zone is easily viewed using multiplanar reconstructions. The tumoral perforation is more common in the cecum area, and it is detected by the presence of pneumoperitoneum and the infiltration of pericolonic fat [27]. Local staging (stage "T") of the CRC via

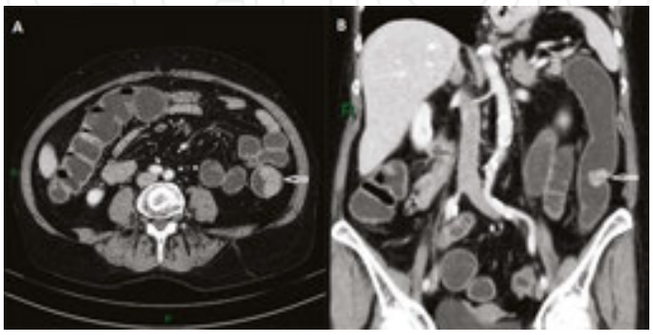

Figure 11. Water enema CT performed to a 50-year-old female patient with suspicion of adenomatous polyps. (a) Axial and (b) coronal images show a polypoid T2 lesion, located on the lateral wall of the descending colon.

CT is difficult because of the impossibility of differentiating its early stages. Erasing the (fatty) cleavage plane between the colon and the surrounding structures (retroperitoneum, anterior abdominal wall, liver, spleen, pancreas, or stomach) suggests their tumoral invasion and it grades the tumor in stage T4 [28].

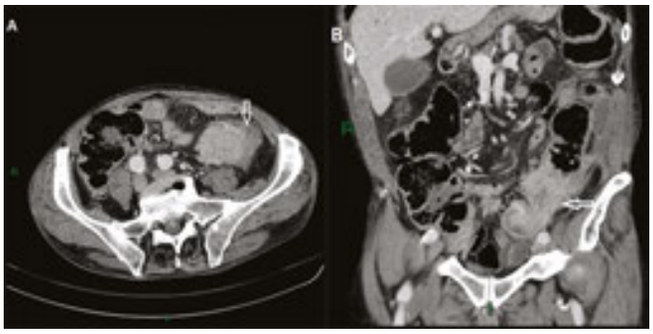

Figure 12. Contrast enhanced abdominal CT performed for suspicion of intestinal occlusion. (a) Axial image (portal phase) shows a voluminous iodophilic sigmoid tumor that obstructs the lumen and seems to invade the peritoneum, associated with a thin layer of perilesional fluid. (b) Coronal image shows perilesional fat stranding and the tendency to invagination.

The value of the method for tumoral staging is centered by its ability to identify the local invasion, the lymph nodes, and parenchymal metastases, firstly in the liver, but also peritoneal, in the lungs and within bones. The size of the lymph nodes is not a good indicator of malignancy because tumor foci may exist in the case of small ones too. However, the alteration of lymph nodes may be suspected in CT when there are associated morphological signs. Thus, the presence of an irregular border, a central necrosis, as well as calcifications or a tendency to conglomerate, may all be suggestive of tumoral lymph node invasion [29]. On the other hand, primary tumor location is closely related to the impairment of certain lymph node stations [27].

The most commonly affected organ by distal dissemination of CRC is the liver. The CT appearance of CRC liver metastases is that of hypodense and hypovascular liver masses as compared with the adjacent healthy liver parenchyma [**Figure 13**]. Sometimes the hepatic metastases reveal the peripheral ring iodophilia during the arterial phase. They may also have a cystic or calcified character; this being often seen in the mucinous colon cancer [27, 29]. CT examination cannot differentiate small liver metastases from benign focal liver lesions. The association of the hepatic steatosis (often seen after chemotherapy) also hinders the diagnosis of liver metastases [30]. However, the abdominal CT with intravenous iodinated contrast, during portal phase, represents the imaging technique of choice for the detection of liver metastases, with high diagnostic accuracy (95%) [5]. The distal dissemination of the (lower) rectal cancer can take place only in the lungs without affecting the liver because of the venous drainage of the rectum (in the inferior vena cava). The chest CT can detect lung metastases that have a unique nodular appearance, sometimes cavitary or calcified. Lymphangitic carcinomatosis associated with pleural effusion is another form of pulmonary metastasis [29, 30]. Peritoneal dissemination is identifiable by the presence of peritoneal thickening and of the

tumoral deposits in the omentum, associated with intra-abdominal fluid collections. Bone metastases are rare, and they have a lytic or mixed appearance (lytic and sclerotic) [30]. Brain metastases from colorectal cancer do not have a specific CT appearance, and they cannot be distinguished in imaging from those with other origin [30].

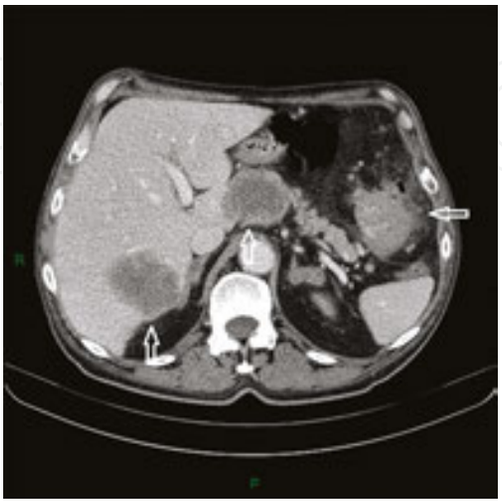

Figure 13. Abdominal CT scan of a 60-year-old male with colon cancer. Axial image (portal phase) shows a tumoral thickening of the colonic wall associated with pericolonic fat stranding, some extra-luminal gas bubbles (tumor perforation) and liver metastases (in segments I and VI).

2.3.1. CT virtual colonoscopy

CT virtual colonoscopy is a minimally invasive imaging technique that allows the assessment of both colon and rectum, and also of the extracolonic organs. Its use as a screening method in CRC is much discussed in the literature. Studies about the sensitivity and specificity of this method are varied but the highest values of sensitivity were obtained for the detection of polyps with sizes over 10 mm (95%) [5, 6]. Despite some controversy, CT virtual colonoscopy is useful in elderly subjects with comorbidities, in case of an incomplete optical colonoscopy or if the patient refuses it [5, 6]. Another indication is the evaluation of the entire colon for the exclusion of a synchronous cancer. In addition, a balance of the disease extension can be performed if the examination is made using intravenous contrast agent [5, 31]. The most important contraindications are the acute colic disease (diverticulitis, inflammatory bowel disease in acute stages), presence of intestinal perforation, recent post-polypectomy or immediately after surgery [31, 32]. It is necessary to prepare the colon 24 hours before the examination. This is possible through a diet low in fiber and administration of sodium phosphate, magnesium citrate, or polyethylene glycol. The administration of oral barium or iodine contrast agents allows the "tagging" of the residual stool deposits and the differentiation from colonic polyps. Another method of preparation consists of the use of an oral hyperosmolar contrast agent, thereby achieving an increase in patient compliance [33, 34]. The next step in performing a virtual colonoscopy is the luminal distension by air or by carbon dioxide, under pressure control through a rectal tube. In practice, the carbon dioxide is preferred

because of an increased tolerance of the patient and its absorption in the colon mucosa [31, 34]. The acquired images are analyzed in at least two positions (supination and pronation, sometimes lateral decubitus), which allows the differentiation of the colon polyps from residual stool deposits [34]. The interpretation is done by analyzing the 2D and 3D images, along with virtual endoluminal navigation. There is also a software (Computer Aided Detection—CAD) that automatically detects the lesions in the colon. This facilitates lesion detection but it should not exclude the primary analysis of 2D and 3D images [34]. Lesion characterization and classification is possible using the reporting system according to the model "CT Colonography Reporting and Data System (C-RADS)" [35]. This system allows the location, the morphological (sessile, flat, or pedicle tumor), and dimensional analysis of the detected lesion. C0 suggests an inadequate examination and C1 represents the normal appearance of the colon. C2 lesions represent their indeterminate character and they refer to identification of less than three polyps with the diameter between 6 and 9 mm. C3 lesions are represented by either a polyp over 10 mm, or more than three polyps ranging in size from 6 to 9 mm. C4 lesions describe the presence of a colonic tumor mass, with luminal narrowing or the invasion of adjacent organs [32, 35]. The main disadvantages of this method are irradiation (currently decreasing!) and the impossibility to perform biopsy or to treat the detected lesions. There is also a great variability among examiners in image interpretation because of different levels of experience [33].

2.3.2. Water enema CT

Water enema CT is applicable in the case of an inconclusive or impossible optical colonoscopy [36]. The method involves luminal distension of the colon by water enema for about 3 minutes. Water is introduced through an endorectal tube connected to a bag with a volume of approximately 2 L. Initially, images are acquired without the intravenous administration of contrast agent, followed by a post-contrast acquisition. At the end of the examination, the colonic content is discharged by simply lowering the enema bag. Image interpretation is possible in the axial plane with the reconstruction in all three space dimensions [28]. Luminal distension of the colon with water provides a good contrast between the colonic wall and its luminal content. The tumor-free colonic wall is thin, regular, with a thickness below 3 mm and an enhancement in portal phase [28, 36]. A colorectal tumor may appear as an endoluminal polypoid lesion or as a semi- or circumferential irregular parietal thickening, with heterogeneous iodophilia [28]. Some studies show a high accuracy of the method in differentiating the T1-2 tumors from the T3-4 ones. A study performed on a group of 53 patients reveals that the deep parietal invasion (T3-T4) is suggested by the irregular appearance of the outer (peritoneal) tumor margin associated with an angular transition area to the healthy colon [37]. Besides the loco-regional staging (T), the water enema CT allows the overall assessment of the distal colorectal tumor dissemination, with the simultaneous detection of the liver metastases and peritoneal carcinomatosis [37]. Finally, water enema CT is an imaging technique useful in the CRC diagnosis, staging, and characterization because it is cheap, accessible, and easy to perform. In addition, it is easily accepted by patients and it requires no previous colon preparation [28, 37].

2.4. Colon imaging through magnetic resonance

The situation in which we may incidentally detect a colon tumor upon acquiring MRI scans of the abdomen for other purposes is rare. The MRI appearance of the colic tumor is non-specific. Generally, there is a thickening of the colonic wall, with loss of stratification and a slight hypersignal on T2 sequence with fat suppression. The pericolic fat infiltration and the presence of perilesional adenopathies are important additional signs, which may direct the diagnosis toward a colonic tumoral pathology. From a practical standpoint, however, the radiologist must refer toward gastroenterology and colonscopy every patient without known enteral pathology, with suspect thickening of the colon wall. The preferred imaging technique for the staging of colon tumors is computed tomography. Computed tomography has the advantage that allows, on a single imaging examination, to assess both the abdominal and thoracic cavities, including bones and lungs. However, there are situations where the physician can request abdominal MRI for staging an initial colon cancer.

2.5. MRI imaging of the rectum

Because of the critically important information it offers, pelvic MRI examination is mandatory in staging rectal tumors. The sequences to be achieved primarily are the high resolution (HR) T2 weighted images, in all three planes. The examination shall be completed with diffusion sequences. The injection of the intravenous contrast agent is not needed in the local staging of rectal cancer. On the HR T2 sequences, a rectal tumor will appear slightly in hypersignal reported to parietal muscles, and respectively in hyposignal reported to perirectal fat. Because of the existing contrast between the tumor, on the one hand, and the perirectal fat, on the other hand, we do not recommend using the fat suppression. Fat suppression will lead to the underestimation of the perirectal extension of the tumoral process. Most of the times the rectal lumen will also have a content in hypersignal in the plane of the tumor because of mucin secretion. In tumoral stages T1 and T2, tumor growth is limited to the rectal wall [**Figure 14**]. In tumoral stage T1, the tumoral growth does not exceed the submucosa, and in stage T2 it

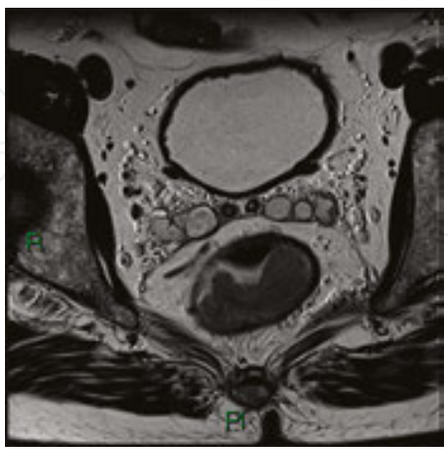

Figure 14. Pelvis MRI, T2 weighted images, axial section. Rectal tumor prominent in rectal lumen. Note that the tumor does not surpass the thin line in hyposignal representing the muscular layer and the perirectal fat is homogeneous. The appearance suggests a T2 stage tumor.

does not exceed the muscularis layer. The MRI examination is not accurate in differentiating tumor stages T1 and T2, but it is very good in determining the existence or absence of the tumoral invasion of the perirectal fat (it can thus differentiate tumors limited to the rectal wall, stages T1 and T2, from the ones extending outside the wall). MRI has a great accuracy in determining the depth of the perirectal invasion [38]. Most of rectal tumors (approximately 80%) will be in T3 stage when imaging diagnosis is performed [**Figure 15**]. Because the depth of the perirectal invasion is an important independent prognostic factor for the survival and chances of curing a rectal tumor, the layering of T3 stage according to the depth of the invasion was necessary (**Table 1**). Thus it is considered that a depth of the perirectal invasion higher than 5mm will lead to a decrease in the survival expectancy at 5 years, from 85 to 54% [39]. The invasion of adjacent organs or structures (bladder, prostate, or seminal vesicles, uterus or ovaries, vagina, peritoneum recesses, the levator ani muscles or the pelvic wall) is considered T4 stage [**Figure 16**]. Apart from a correct local staging, the MRI examination must provide information related to the relationship between the tumor and certain surrounding structures. One of these structures is the mesorectal fascia. A mesorectal fascia without tumoral invasion will allow the total excision of the mesorectum, as this surgical procedure leads to the smallest chance of tumor recurrence. To consider mesorectal fascia as invaded, it is necessary that the tumor exceed it,or that tumoral tissue exists less than 1 mm away from the fascia (the tumoral tissue can be represented either by a direct extension of the tumoral mass, by tumoral deposits within the mesorectum, or by the presence of metastatic lymph nodes). Establishing the invasion or the relationship the tumor has with the mesorectal fascia is one of the advantages of magnetic resonance imaging as compared with transrectal ultrasound. The peritoneum recess is reflected on the upper side of the urinary bladder and on the anterior wall of the upper rectum to form the rectovesical recess. Its invasion is difficult to reveal and it requires knowledge of the normal anatomy. Tumors that will invade the peritoneum will be staged as T4a. Also, MRI examination is superior to transrectal ultrasound in establishing the existence of peritoneal invasion. Furthermore, the existence of invasion of the anal sphincter should be established before surgery because it has great significance in the preoperative planning. It is considered that in the cases of tumoral extension to the rear side of the pubis-rectal muscles,

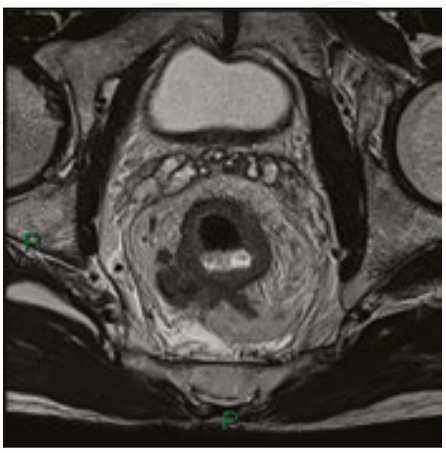

Figure 15. Pelvis MRI, T2 weighted images, axial section. Circumferential rectal tumor, extending into all wall layers and invading the perirectal fat, in right lateral and posterior area.

the surgery with the preservation of the anal sphincter is not feasible. In the case of tumors with sphincter infiltration its extension and the interested structures should be carefully specified on the imaging report because, according to this extension, we will be able to determine whether it is possible or not to perform recto-anal reconstruction procedures or if the patient will be a candidate for the rectum amputation.

Tumoral mass	
Tx	Determination of tumor extension cannot be assessed on the performed examination
T1	Tumor has not spread deeper than the submucosa
T2	Tumor invades muscularis propria, but does not extend into the perirectal fat
T3	Tumor grows through the muscularis propria in mesorectum
T3a	Tumor extends to a depth less than 5 mm beyond the muscularis propria
T3b	Tumor extends 5–10 mm from muscularis propria
T3c	Tumor extends more than 10 mm from muscularis propria
T4a	Tumor invades visceral peritoneum
T4b	Tumor invades organs and structures near the rectum
Adenopathies	
Nx	Lymph node staging cannot be assessed on the performed examination
N0	No obvious metastatic adenopathies
N1a	Tumor invades one lymph node
N1b	Tumor invades two or three lymph nodes
N1c	Tumoral deposits in the subserosa, mesentery, non-peritonealized pericolic, or perirectal tissues without lymph node metastasis
N2a	Metastasis in four up to 6 lymph nodes
N2b	Metastasis in seven or more lymph nodes
M0	No distant metastasis (other than in regional lymph nodes)
M1a	Distant metastasis confined to one organ
M1b	Distant metastasis in more organs or peritoneal carcinomatosis

Table 1. TNM classification adapted from American Joint Committee on Cancer. AJCC Cancer Staging Manual. 7th edition. New York, NY: Springer, 2010.

Lymph nodes that must be assessed during the staging of a rectal tumor belong to the following groups: mesorectum, superior rectal, inferior mesenteric, internal and external iliac, retroperitoneal, and inguinal areas. The most commonly affected lymph nodes are the ones located at mesorectal level, inside the mesorectal fascia. However, it is also important to mention if we consider that lymph nodes located outside the mesorectal fascia are affected by tumoral metastases—they will have to be surgically excised to avoid relapse, or the preoperative radiation therapy should be done on a broader field. If transrectal ultrasound is considered to have roughly similar performances to MRI in revealing the existence of mesorectal lymph nodes, MRI will certainly be better in diagnosing the presence of lymph nodes located outside the mesorectal fascia. MRI is still limited in revealing the malignant or benign character of the detected lymph nodes. Thus, if we use the classic criterion linked to the size of the lymph nodes, using a limit of 5 mm to differentiate the benign lymph nodes from the malignant ones, we

will have a sensitivity of 68% and a specificity of 78% for the diagnosis of malignancy [40]. The accuracy of this criterion in the differential diagnosis of benign/malignant perirectal adenopathies is more limited as, between 30 and 50% of the metastatic adenopathies have diameters of less than 5 mm [41]. An irregular outline of lymph nodes, associated with non-homogeneity of the signal inside them, would be considered as being a key indicator of malignancy [40].

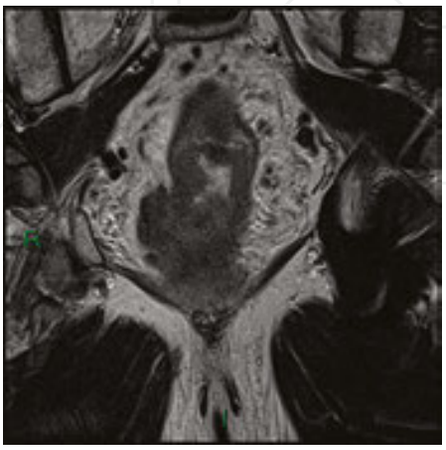

Figure 16. Pelvis MRI, T2 weighted images, coronal section. Rectal tumor with invasion of the perirectal space. Inferior and on the right side the tumor determines the invasion of the levator ani muscles.

2.6. Positron emission tomography (PET-CT)

It is considered that PET-CT does not bring additional information compared with thoraco-abdomino-pelvic CT in the initial staging of colon cancer [42, 43]. There are two situations where PET-CT is recommended in patients with colorectal tumors: (a) patients in which the values of the carcinoembryonic antigen are growing during oncological monitoring and the conventional imaging cannot detect the location of the tumoral recurrence and (b) patients with single liver metastasis, candidates for liver resections. It is considered that, in these patients, performing PET-CT before surgery leads to a decrease in the number of useless laparotomies [44, 45]. It is believed that chemotherapy decreases the sensitivity of PET-CT for diagnosing the colorectal cancer metastases. For this reason, in patients which are potential candidates for liver metastasectomy, we prefer to perform the PET-CT examination before starting chemotherapy to detect other possible tumoral locations.

3. Protocols for the imaging examination of the patient with colon cancer

Most of the times colon tumors are identified through colonoscopy, and imaging helps staging these tumors. If the tumor is located in the colon, the initial staging will be done through abdominal ultrasound and thoraco-abdomino-pelvic CT. In most cases, this will be sufficient for an accurate staging and the images will be later used as reference for the post-treatment examinations. In case lesions detected are considered as being indeterminate, with non-specific

computer-tomographic and ultrasound appearance, it will be necessary to complete with other imaging examinations or sampling via an intraoperative biopsy or percutaneous punctures. The imaging techniques that can be used in this situation are contrast enhanced ultrasound (CEUS), magnetic resonance imaging (MRI) or PET-CT. The rectal tumors will benefit from the high-resolution pelvic MRI or transrectal ultrasound for their initial staging. There are situations in which we will find colon tumor formations incidentally in the course of imaging explorations performed for other purposes or for non-specific symptoms. In these cases, we should be advised first of all on the imaging appearance of such tumors. Then, we shall refer to colonoscopy for the confirmation of the existence of a tumoral process.

The staging of the tumor will be made in the same manner as in the case of the tumors diagnosed through colonoscopy. The imaging monitoring of the patients treated for colonic tumors is made through computerized tomography every 6 months. Because of the difficulties in the detection and diagnosis of small liver metastases through computed tomography, our work team recommends to complete the investigations with a liver ultrasound. The images will be permanently correlated with those obtained prior to the treatment, and the lesions with undetermined appearance will benefit from additional diagnostic investigations, similar to those described in the initial staging of the colon tumors. In the patients with tumors found in a later stage, which cannot benefit from curative treatments, it is recommended that the monitoring by thoraco-abdomino-pelvic computer-tomography be made even more often (every 3 months) to evaluate the efficiency of the administered chemotherapy. If, after a series of examinations, the disease evolution is clear, an early change of the chemotherapy scheme can lead to an increased life expectancy.

The patients with operated rectal tumors, especially those who have received neoadjuvant radiotherapy, may receive the recommendation to undergo the pelvic MRI periodically, complementary to the thoraco-abdomino-pelvic computed tomography. This is because MRI is more accurate, compared with the computed tomography, in the differentiation of the tumoral relapses in the pelvic area from the post-irradiation fibrosis.

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