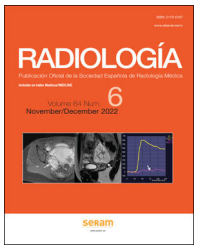
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RADIOLOGY THROUGH IMAGES

How to measure peritoneal carcinomatosis

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Abstract Peritoneal carcinomatosis (PC) is the spread of a tumour in the peritoneum, sometimes originating from a primary tumour (mesothelioma, peritoneal serous carcinoma) and other times arising from a metastasis from another organ (ovary, colon, appendix, stomach). While it was previously considered incurable, significant improvements have been made thanks to new techniques such as cytoreductive surgery with hyperthermic intraperitoneal chemotherapy (HIPEC). Patients who can benefit from these treatments are identified by radiologists who use imaging techniques such as computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET-CT). It is important to have an awareness of the different forms of presentation, methods of quantifying tumour burden (peritoneal carcinomatosis index, PCI), and criteria for unresectability for an accurate assessment of the disease's status. All this information should be shared and discussed in multidisciplinary boards for optimal and consensus-driven decision-making.
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PALABRAS CLAVE
Carcinomatosis peritoneal;
Quimioterapia hipertérmica intraperitoneal;
Tomografía computarizada;
Índice de carcinomatosis peritoneal

Carcinomatosis peritoneal, cómo medirla

Resumen La carcinomatosis peritoneal (CP) implica la propagación tumoral en el peritoneo, originada tanto por tumores primarios (mesotelioma, carcinoma seroso del peritoneo) como por metástasis de otros órganos (ovario, colon, apéndice, estómago). Aunque antes se consideraba incurable, gracias a nuevas técnicas como la cirugía citorreductora con quimioterapia intraperitoneal (HIPEC), se han mejorado de forma significativa las perspectivas. Para identificar a los pacientes que se benefician de estos tratamientos el papel del radiólogo es fundamental y se apoyará en técnicas de imagen como la tomografía computarizada (TC), resonancia magnética (RM) y tomografía por emisión de positrones (PET-TC). Es necesario conocer las distintas formas de presentación, la forma de cuantificar la carga tumoral (índice de carcinomatosis peritoneal,

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ICP) y los criterios de irresecabilidad para una adecuada valoración del estado de la enfermedad. Todo esto debe ser trasmitido y puesto en común en comités multidisciplinares para una actuación óptima y consensuada.
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Introduction

Peritoneal carcinomatosis (PC) is the term used to describe tumoural involvement of the peritoneum. It includes both primary malignant tumours (such as mesothelioma and serous carcinoma of the peritoneum) and secondary involvement from other tumours, mainly ovarian, colorectal, appendiceal and gastric in origin.[1]

PC was traditionally considered an advanced disease with a very poor prognosis and no available treatment options. However, the development of new techniques such as cytoreductive surgery (CRS) combined with hyperthermic intraperitoneal chemotherapy (HIPEC) or early postoperative intraperitoneal chemotherapy (EPIC) has represented a major breakthrough for patients, leading to a significant improvement in survival rates.[2,3] These treatments involve extensive resections and involve a high risk of morbidity and mortality, making thorough patient selection essential. This is where imaging techniques and the involvement of the radiologist within multidisciplinary committees are crucial.[3] The aim of this article is to review the various presentations of PC and to examine the tools available for an appropriate assessment of the disease.

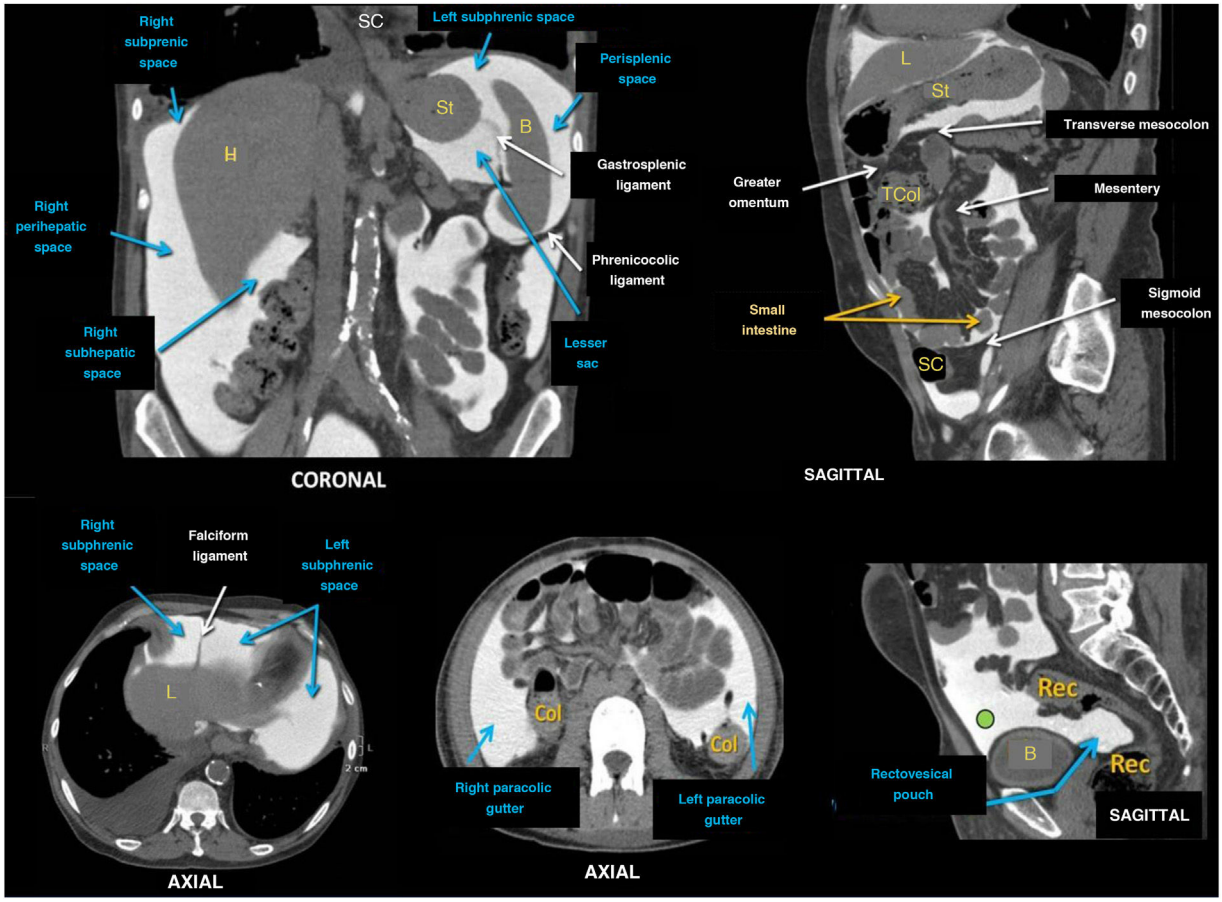


Figure 1 CT abdominal image showing peritoneography. In this technique—used particularly in patients undergoing peritoneal dialysis—a diluted contrast and saline solution is introduced into the peritoneal cavity to assess the distribution and dynamics of the fluid. This allows for a detailed assessment of the various anatomical spaces. The main peritoneal compartments and spaces at risk for peritoneal carcinomatosis are highlighted. B: bladder, Col: ascending/descending colon, L: liver, Rec: rectum, SC: sigmoid colon, Sp: spleen, St: stomach, TCol: transverse colon.

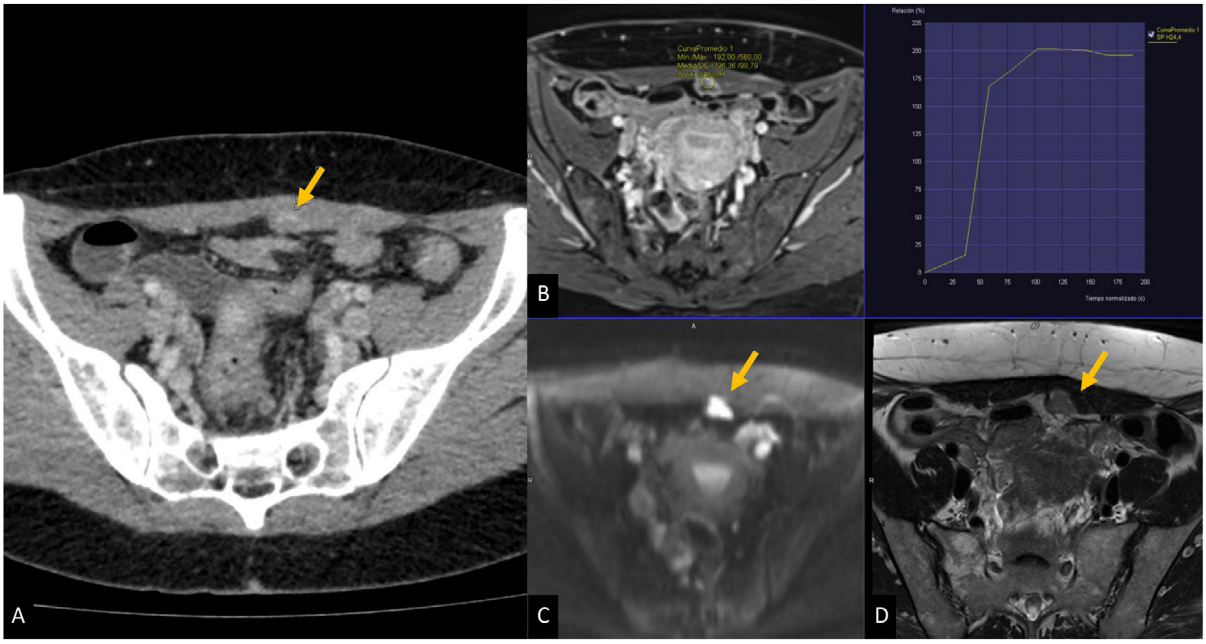


Figure 2 A 58-year-old woman diagnosed with ovarian carcinoma. Peritoneal tumour deposit adjacent to the posterior surface of the left rectus abdominis muscle (arrows). In the axial contrast-enhanced CT image (A), the tumour deposit cannot be easily distinguished from the muscular plane of the abdominal wall. However, in the T1-weighted fat-saturated gadolinium-enhanced MRI sequence (T1FSGd+) with its corresponding perfusion curve (B), diffusion-weighted sequence (C), and axial T2 sequence (D), the tumour deposit is more readily identified.

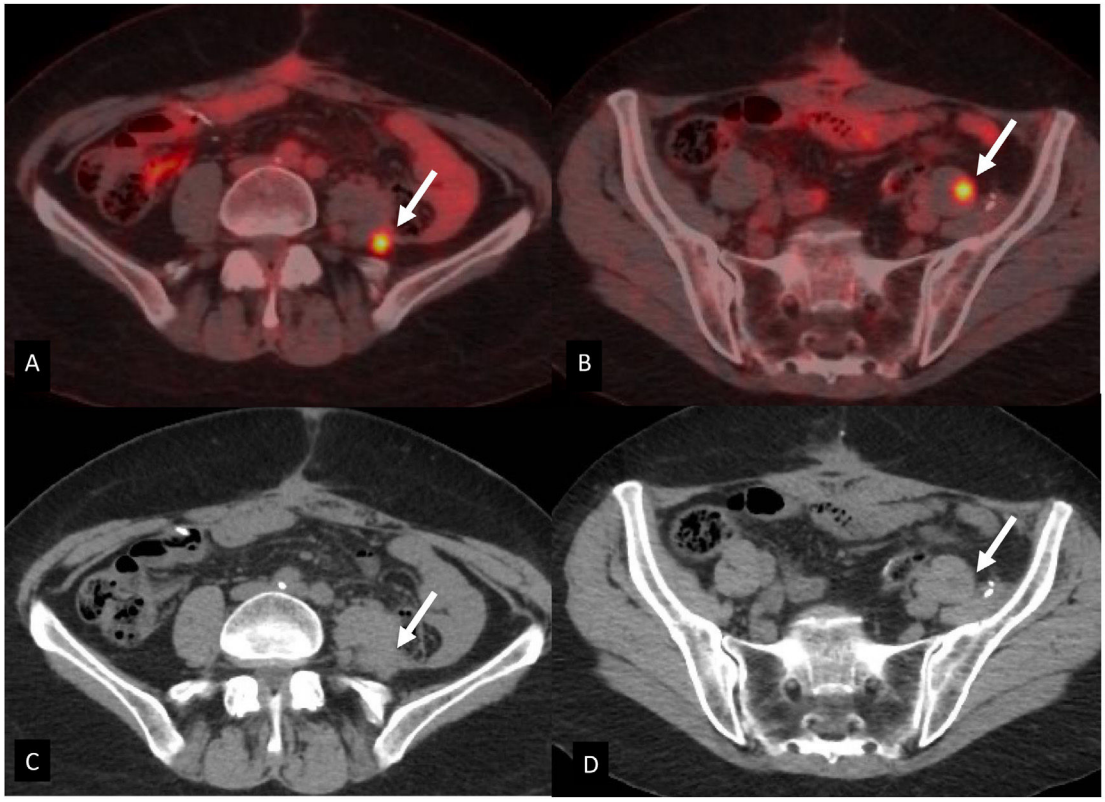


Figure 3 Comparative study between PET/CT (A and B) and CT (C and D) for small tumour deposits. Two nodular deposits adjacent to the left iliopsoas muscle (arrows) are easily identified on the metabolic component of the PET/CT, but may go unnoticed on a routine CT scan. PET/CT facilitates the detection of small tumour deposits, particularly those adjacent to and of similar density to the abdominal musculature and bowel loops.

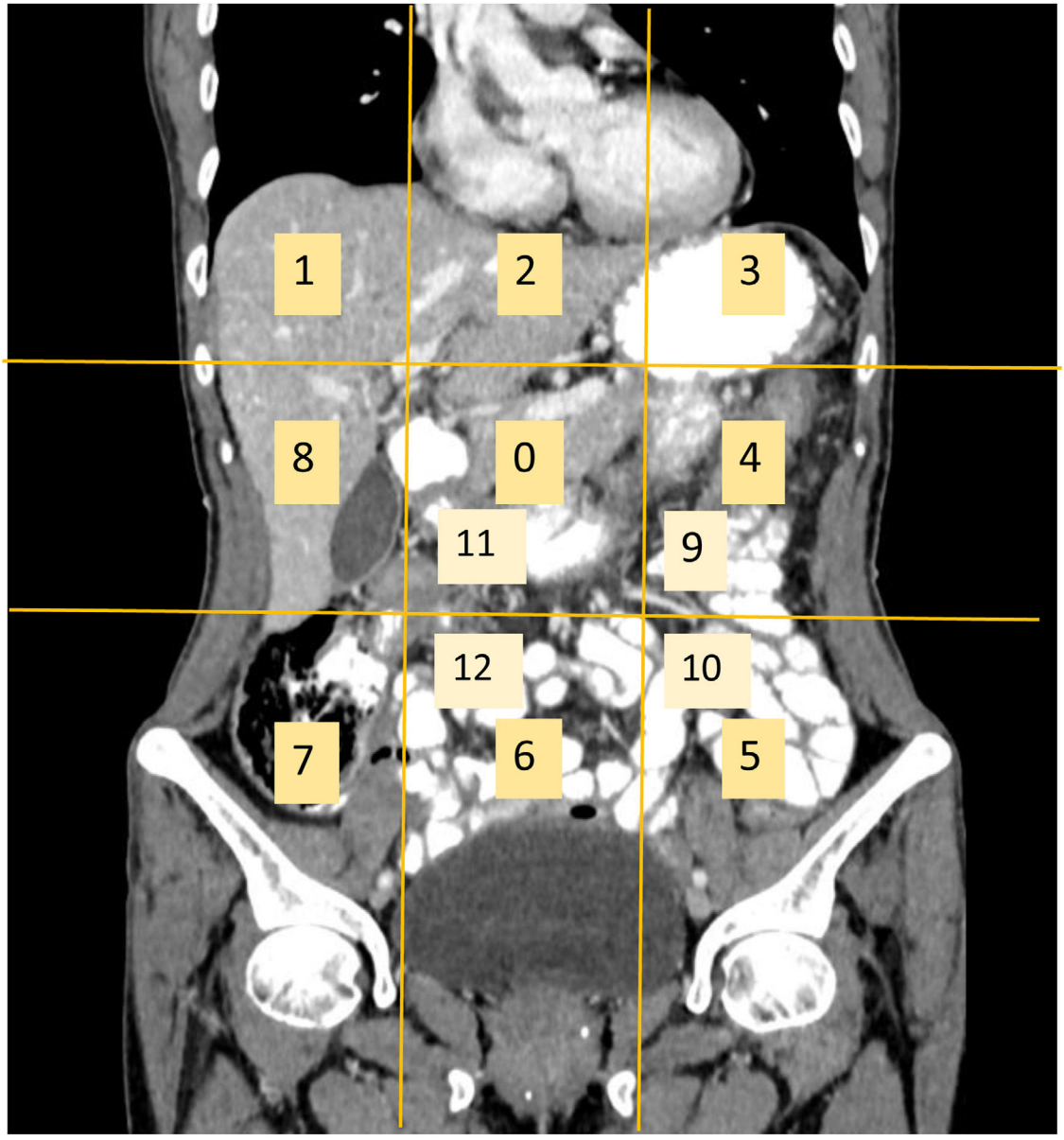


Figure 4 Representation of abdominal regions used for calculating the peritoneal carcinomatosis index (PCI). 0: central, 1: right upper; 2: epigastrium; 3: left upper; 4: left flank; 5: left lower; 6: pelvis; 7: right lower; 8: right flank; 9: upper jejunum; 10: lower jejunum; 11: upper ileum; 12: lower ileum. In each of these areas, the largest injury is determined and assigned a score: LS0 if no visible lesion, LS1 if < 0.5 cm, LS2 if it measures between 0.5–5 cm, and LS3 for lesions > 5 cm or confluent lesions. The sum of the scores in each region gives us the PCI.

Anatomy and physiopathology

The peritoneum is a serous membrane that lines the abdominal cavity (parietal layer) and the intraperitoneal organs (visceral layer). A virtual space lies between the two layers which contains a thin film of fluid that lubricates the peritoneal surfaces.[3,4] When the peritoneum does not cover the abdominal wall or the organs, it forms a series of folds that contain fat, vascular and lymphatic structures, and nerves. This space is known as the subperitoneal space, and it is one of the main entry points for pathological processes, including PC.[4]

A solid understanding of the peritoneum's anatomy and pathophysiology is essential to better understand the mechanism of PC and how tumour deposits are distributed.

Imaging techniques

Imaging studies of PC include computed tomography (CT), magnetic resonance imaging (MRI) and positron emission tomography/CT (PET/CT).

CT is the most widely used technique in most centres for the preoperative assessment of PC. It is a widely available, fast and cost-effective technique that allows for excellent

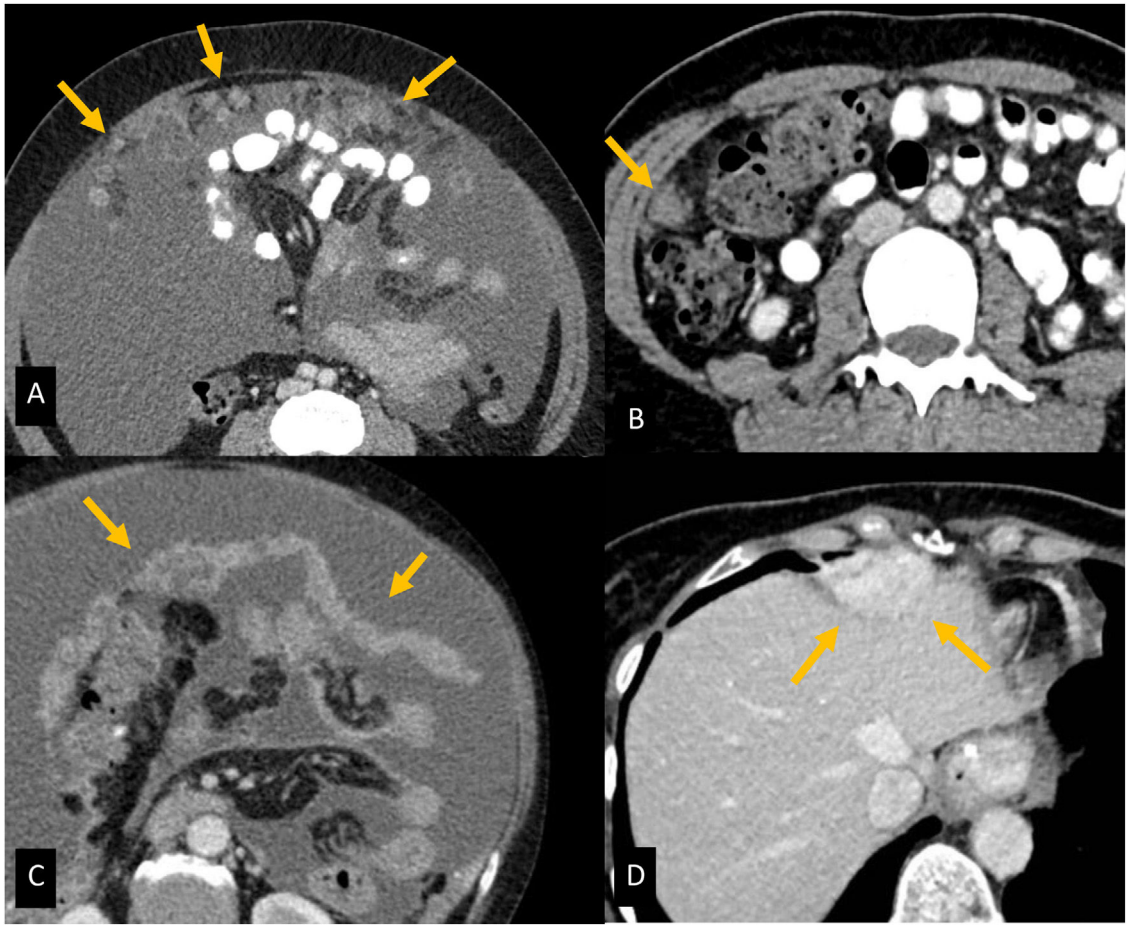


Figure 5 Examples of different types of peritoneal carcinomatosis involvement according to its morphology (abdominal CT images with intravenous and oral contrast in A and B).A) Multiple nodules in the greater omentum. B) Nodule in the right paracolic gutter. C) Plaque-like tumour deposits in the greater omentum and D) Plaque-like tumour deposits in the perihepatic region.

Important: there are four main routes through which malignant cells can spread: direct or contiguous spread, haematogenous (emboligenic) dissemination, lymphatic spread, or seeding via ascitic fluid.[5] This last route is the most significant form of dissemination in PC, and its dynamics are influenced by factors such as gravity, intestinal peristalsis and diaphragmatic movement. Ascitic fluid moves between the peritoneal recesses in specific directions, accumulating in areas of least resistance, greatest stasis and highest absorption—such as the greater omentum, the subphrenic space, the right paracolic gutter and the rectovesical pouch—which are key sites to investigate for disease involvement (Fig. 1).

multiplanar reconstructions. Intravenous contrast is recommended; however, the use of oral contrast is more debated, as the opacification of the loops could limit the evaluation of the peritoneal spaces. Another option is the use of negative contrast. Overall sensitivity and specificity are high, at 83% and 85% respectively[6]; however, these values drop to between 11% and 28% for lesions smaller than 0.5 cm.[7,8] It also has limitations in the assessment of tumour deposits that have plaque-like morphologies or are located in areas such as the pelvis and the small intestine.

MRI has become increasingly established in recent years as the preferred preoperative technique in many centres. It yields better results than CT in detecting small tumour deposits and those located in areas such as the subdiaphragmatic regions or the intestinal serosa, with very good surgical correlation.[9–11] These favourable results are partly due to two sequences: diffusion-weighted imaging and dynamic contrast-enhanced imaging.[9] (Fig. 2) Its drawbacks include long examination times, lower availability, high costs, increased radiologist time, and the need for a higher level of expertise. It can also present technical challenges, including motion artifacts from both patient movement and peristalsis, although these can be mitigated with antiperistaltic agents such as Buscapina®. The presence of ascitic fluid also degrades image quality, with more pronounced dielectric effect artifact observed in 3T scanners.[11]

PET/CT is recommended for the assessment of disease recurrence after treatment due to its excellent specificity.[12] Like all imaging tests, it also has certain limitations, such as low radiotracer uptake in lesions smaller than 5 mm and in mucinous tumours (Fig. 3).

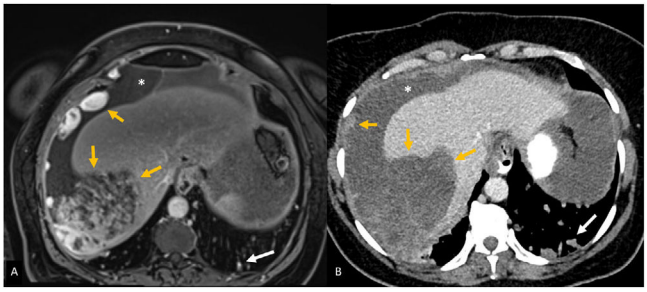


Figure 6 A 55-year-old woman diagnosed with uterine sarcoma. MRI images with T1FSGd+ (A) and CT with intravenous and oral contrast (B). Multiple subdiaphragmatic and perihepatic tumour deposits are seen, forming a mass that presses against the hepatic dome with a scalloped outline (orange arrows). Carcinomatous ascites (*) and multiple pulmonary metastases (white arrow) are also observed.

Surgical techniques/peritoneal carcinomatosis index

In the 1980s, a team led by Sugarbaker developed the CRS[13] technique for the removal of macroscopic peritoneal tumours. The surgery involves extensive visceral resections, including peritonectomies, combined with targeted

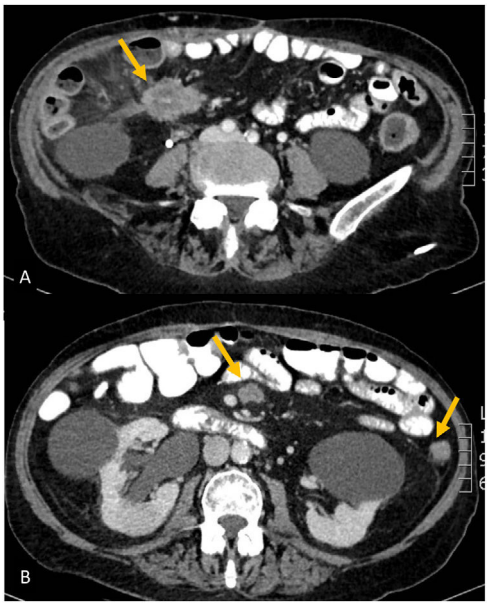


Figure 7 A 62-year-old woman diagnosed with ovarian neoplasm. Abdominal CT with intravenous and oral contrast (A and B). Multiple solid tumour deposits (orange arrows) with heterogeneous contrast enhancement are observed, situated within the mesenteric fat.

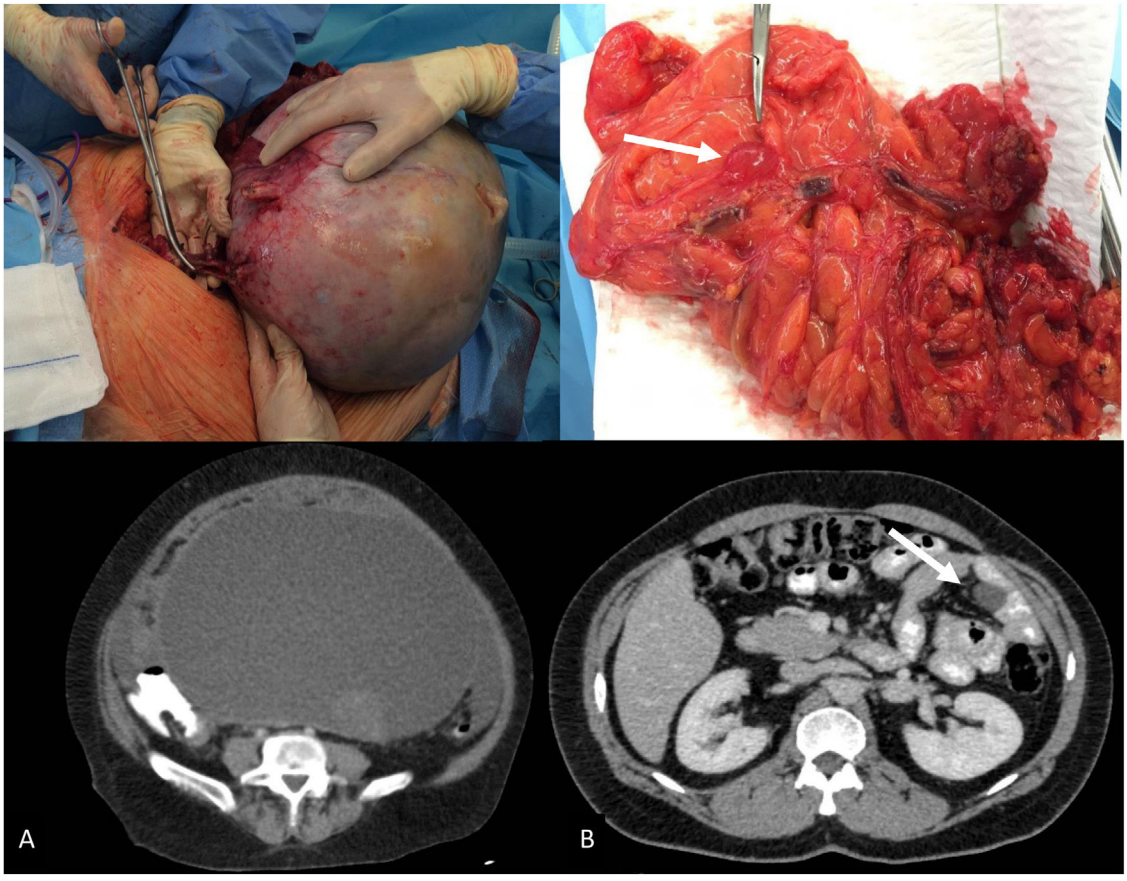


Figure 8 Correlation of contrast-enhanced abdominal CT images with surgical specimens from two patients with peritoneal cystic deposits A) A large, single cystic deposit that almost completely occupies the abdominal cavity, displacing adjacent structures. B) A small peritoneal tumour deposit (arrow) in the mesenteric fat adjacent to a bowel loop.

intraperitoneal chemotherapy administered under hyperthermia (40–42°) to maximise its effectiveness and reduce toxicity (HIPEC). This approach enables high local concentrations of chemotherapeutic agents with lower systemic toxicity, while the elevated temperatures enhance their cytotoxic effect.[14] It is the preferred technique for managing peritoneal mesothelioma and pseudomyxoma peritonei. It is also a therapeutic option in selected patients with ovarian tumours, gastrointestinal tumours (colon, gastric), and, in exceptional cases, neuroendocrine tumours.[14,15]

To objectively and accurately assess tumour burden, the Peritoneal Carcinomatosis Index (PCI) was developed—a scoring system that evaluates the size and distribution of tumour deposits[16] across 13 regions (9 abdominopelvic and 4 intestinal) (Fig. 4). It is calculated intraoperatively, but it can also be assessed preoperatively using the radiological PCI. This process involves assessing each region for signs of disease and assigning a score according to the size of the lesions, with a maximum possible score of 39. Depending on the tumour origin, the cut-off point varies; a score below 20 is considered predictive of a good surgical outcome in colonic carcinomatosis, whereas this threshold drops to 10 in cases of gastric origin.[17] In the case of ovarian cancer, there is no consensus in the literature and it is acknowledged that the threshold may vary depending on the surgical team. However, some authors have proposed that scores equal to or greater than 24 are associated with incomplete resections.[18]

The PCI is a parameter that has been shown to be an independent prognostic factor, with good correlation between laparoscopic findings and preoperative radiologi-



Figure 9 A 67-year-old woman diagnosed with ovarian neoplasm. Abdominal CT with intravenous and oral contrast. Multiple peritoneal tumour deposits in the upper abdomen (A) and pelvis (B) with calcifications (arrows).

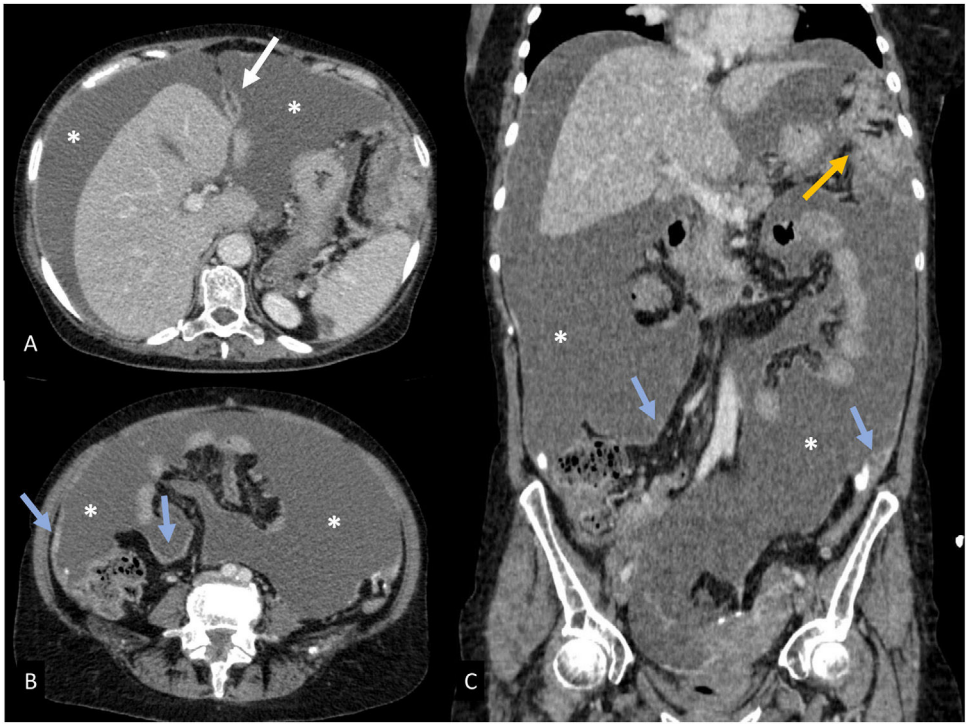


Figure 10 A 60-year-old woman diagnosed with serous ovarian carcinoma. Contrast-enhanced abdominal CT, axial images of the upper abdomen (A), mid-abdominal region (B), and coronal section of the abdomen (C). Abundant multicompartimental carcinomatous ascites (*) associated with diffuse peritoneal thickening (blue arrows), tumour deposits in the falciform ligament (white arrow), and nodules in the peritoneum and greater omentum (orange arrow).

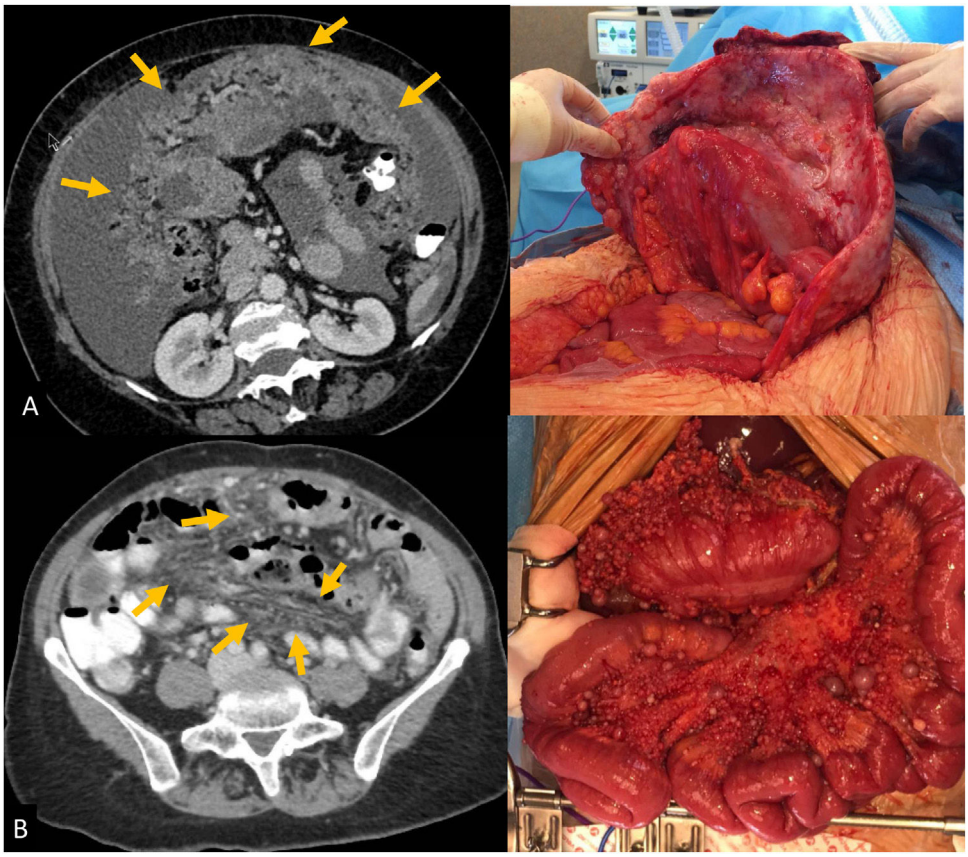


Figure 11 Correlation of abdominal CT images with intravenous and oral contrast with surgical specimens. In the top row (A), extensive and confluent involvement of the greater omentum is observed, classically described as 'omental cake' due to its solid appearance. In the bottom row (B), peritoneal involvement is seen as a millimetric and numerous involvement of the mesentery, also known as miliary involvement.

Important: the key to achieving favourable outcomes lies in meticulous case selection, considering both the tumour's characteristics and extent, as well as patient-specific factors. The most significant prognostic factor is complete tumour resection, with greater survival observed in cases achieving R0 resection (no macroscopic tumour visible at surgery) compared to those with residual macroscopic disease.[15]

cal assessment.[19–22] Accordingly, the PCI should be included in the radiology report, supported by a detailed descriptive assessment.

Different presentations

A thorough description of tumour deposits—both their morphology and location—is essential for accurate disease quantification. In some cases, the findings may be very subtle; adopting a systematic approach—examining by quadrants or following a clockwise sequence—can greatly aid detection, especially when focusing on areas of stasis and anatomically complex regions.

Presentation can vary widely. Based on morphology, tumour deposits can be classified as nodules (< 3 cm), masses (> 3 cm), irregular or nodular peritoneal thickening, and confluent or plaque-like thickening (Fig. 5), scalloping of the visceral surface (Fig. 6) or thickening of the intestinal serosa.[23]

Tumour deposits are usually fairly easy to detect. They most often appear as solid lesions with variable enhancement (Fig. 7). However, tumour deposits originating from mucinous primary tumours may display lower attenuation due to their mucinous content and present with a cystic appearance (Fig. 8), possibly mimicking loculated fluid collections. Calcified tumour deposits may also be seen in cases such as ovarian serous cystadenocarcinoma or gastric carcinoma, as well as in patients that have undergone chemotherapy (Fig. 9).

Carcinomatous ascites is a frequent finding and the report should specify whether or not it is present. In cases where it is, the report should also specify whether it is mild, moderate or severe (Fig. 10).

The presentation of the disease is closely linked to its site of involvement. Diffuse involvement of the greater omentum, known as 'omental cake', is characteristic and results from extensive confluent disease within the infiltrated omental fat. Conversely, when tumour deposits are numerous and measure less than 2 mm, spreading diffusely

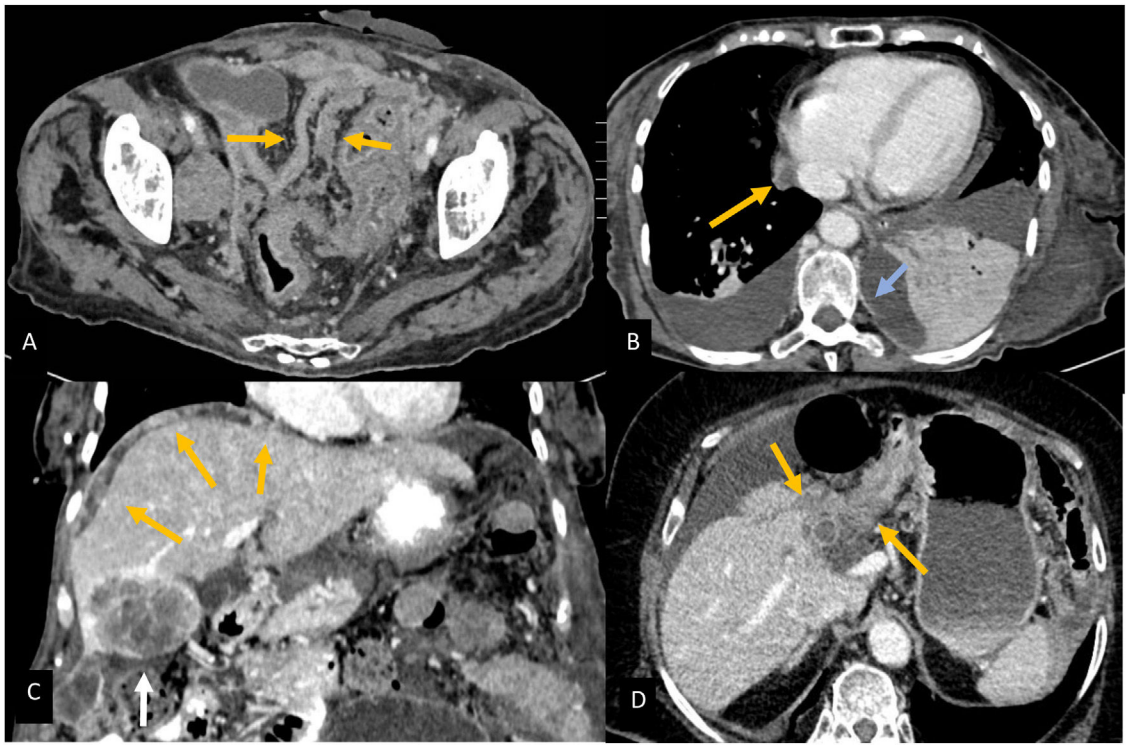


Figure 12 Examples of several patients with unresectable peritoneal disease. A) Extensive involvement of the pelvic peritoneum and significant infiltration of the serosa of several bowel loops (arrows). B) Pericardial nodular deposit, adjacent to the right atrium (orange arrow), and pleural thickening with pleural effusion (blue arrow). C) Multiple subdiaphragmatic tumour deposits in the hepatic dome and hepatic metastases (arrows). D) Diffuse or plaque-like involvement of the gastric antrum and hepatic hilum (arrows).

throughout the omentum and mesenteric fat, the pattern is described as miliary involvement (Fig. 11).

Special attention should also be paid to areas of intraperitoneal fluid stasis, such as the mesenteric root, the ileocolic region/right paracolic gutter, the mesosigmoid region and the lesser pelvis. At times, pelvic involvement manifests as a diffuse layer encasing and immobilising the affected structures, a condition referred to as frozen pelvis.

The space between the diaphragm and the hepatic dome, as well as the splenic surface, are also considered problematic areas. Tumour deposits can go unnoticed and are sometimes only suspected due to scalloping of the underlying parenchyma. Other problematic areas include the visceral surface—such as in cases of adnexal deposits—and the surfaces of peritoneal ligaments, including the falciform ligament, the ligamentum venosum and the gastroduodenal or gastrohepatic ligaments.

Pseudomyxoma peritonei merits individual discussion. It involves the accumulation of mucinous tumour deposits and ascites within the peritoneal cavity, most commonly originating from high-grade appendiceal tumours.[24] It presents several characteristic features that aid in its identification. Mucinous ascites are slightly denser than fluid ascites, tend to become loculated, and may show thin septa that enhance after contrast administration along with calcification. It is typically located in areas of peritoneal fluid stasis, such as the pelvis, paracolic spaces, and around the hepatic capsule, producing a characteristic scalloped appearance.

Criteria for unresectability

It is vital to recognise patients with unresectable disease, or those in whom a complete resection would be technically complex or associated with significant postoperative morbidity and mortality. Established criteria for unresectability include complex locations such as the hepatic hilum, the mesenteric root, extensive bowel involvement, pelvic disease with spread to the abdominal wall, widespread retroperitoneal involvement, infiltration of major vessels, bulky lymphadenopathy, extensive visceral involvement (in cases of colon cancer, up to three hepatic metastases not requiring major hepatectomy), and extraperitoneal spread (most commonly to the pleura and pericardium).[25] Nevertheless, it should be taken into account that, due to technological progress and the growing expertise of specialised surgical teams, some criteria are considered relative and may differ between referral centres. Decisions regarding therapeutic management should always be made in consensus by multidisciplinary teams and tumour boards (Fig. 12).

Differential diagnosis

Peritoneal tuberculosis

Peritoneal tuberculosis is one of the main differential diagnoses of PC. In recent decades, there has been an increase in cases in the developed world, partly due to the HIV pan-

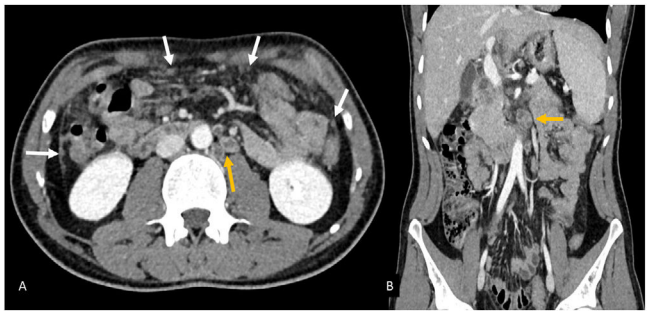


Figure 13 A 30-year-old woman with a long-standing fever and abdominal pain. Contrast-enhanced abdominal CT, axial plane images (A) and coronal plane images (B). Nodular thickening of the parietal peritoneum and omental fat is observed (white arrows), along with necrotic-appearing lymphadenopathy (orange arrows). After fine-needle aspiration via endoscopic ultrasound, *Mycobacterium tuberculosis* was isolated, and the patient showed favorable progression after targeted antibiotic treatment.

demic and the growing use of immunosuppressive therapies. Diagnosis can be challenging at times, as the radiological findings are similar to PC. It can present in three ways: 'wet', with dense ascitic fluid containing a high protein concentration; 'fibrotic', with adherent masses and loculated fluid; and finally, 'dry plastic', which induces a fibrous reaction. The presence of necrotic lymphadenopathy (Fig. 13), splenomegaly, calcifications or involvement of the ileocaecal region are some of the distinguishing features that help support the diagnosis of this disease.[5]

Leiomyomatosis

Disseminated peritoneal leiomyomatosis is a rare, benign condition that occurs more frequently in women of reproductive age with a history of gynaecological surgery. It presents as multiple nodules of smooth muscle tissue within the pelvic peritoneum, and less commonly in the upper abdomen. The absence of lymphadenopathy, ascites, and thickening of the bowel serosa supports its diagnosis over PC.[26]

Splenosis

Most splenosis foci are identified in patients with a history of splenectomy and are asymptomatic, appearing radiologically similar to splenic parenchyma.

Peritoneal lymphomatosis

Diffuse peritoneal involvement in lymphomatous disease is more commonly observed in high-grade lymphomas, in patients with HIV and in Burkitt lymphoma. Radiological signs that support this diagnosis include the presence of non-loculated ascitic fluid, bulky lymphadenopathy, masses encasing vascular structures, splenomegaly, and variable involvement of the gastrointestinal tract[5] (Fig. 14).

Endometriosis

Endometriosis is ectopic endometrial tissue that can be located anywhere within the abdominal cavity, even in the abdominal wall or thorax. MRI is useful for identifying its haemorrhagic content (hyperintense on T1-weighted

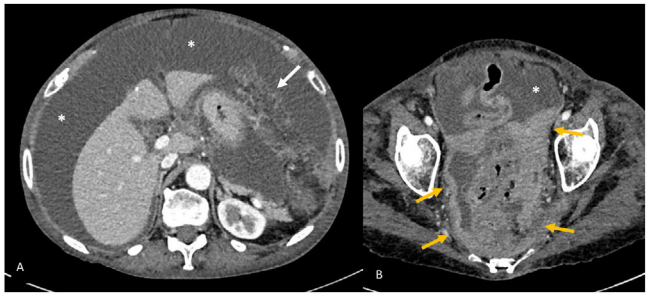


Figure 14 A 73-year-old woman diagnosed with chronic lymphocytic leukemia. Following a deterioration in the clinical condition, a contrast-enhanced abdominal CT is conducted, revealing abundant ascitic fluid (*), nodules in the greater omentum (A, white arrow), and marked plaque-like peritoneal thickening, primarily in the pelvis (B, orange arrows). The histological study and analysis of the ascitic fluid revealed lymphomatous involvement as part of the transformation to diffuse large B-cell lymphoma.

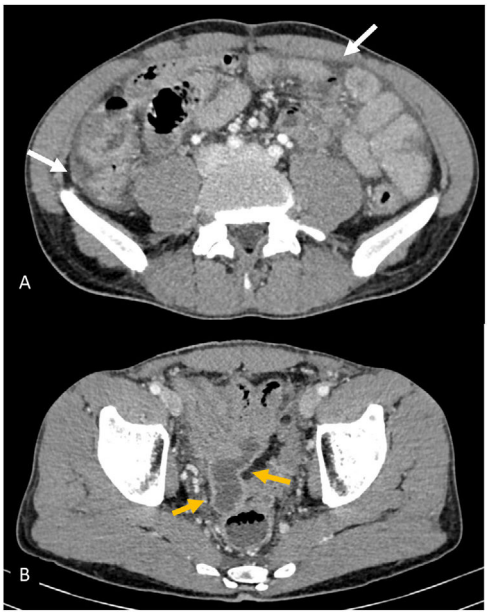


Figure 15 A 42-year-old man with diffuse abdominal pain. In the contrast-enhanced abdominal CT, diffuse thickening of the peritoneum and striation of the omental fat are observed (A, white arrows), along with multicompartimental free fluid, pseudocollection in the pelvis (B, orange arrows). The histological examination and fluid culture following surgery confirmed the presence of *Actinomyces odontolyticus*.

images) and for distinguishing it from potential peritoneal tumour deposits. It typically presents in the ovaries as endometriomas, in the uterus as adenomyosis, and in the pelvis with thickening of the uterosacral ligaments.

Actinomycosis

Abdominopelvic actinomycosis typically occurs in women with an intrauterine device (IUD), with *Actinomyces israelii* being the most common causative organism. Diagnosis is difficult, as the findings are non-specific and resemble those of Crohn's disease, tuberculosis and PC (Fig. 15). A definitive

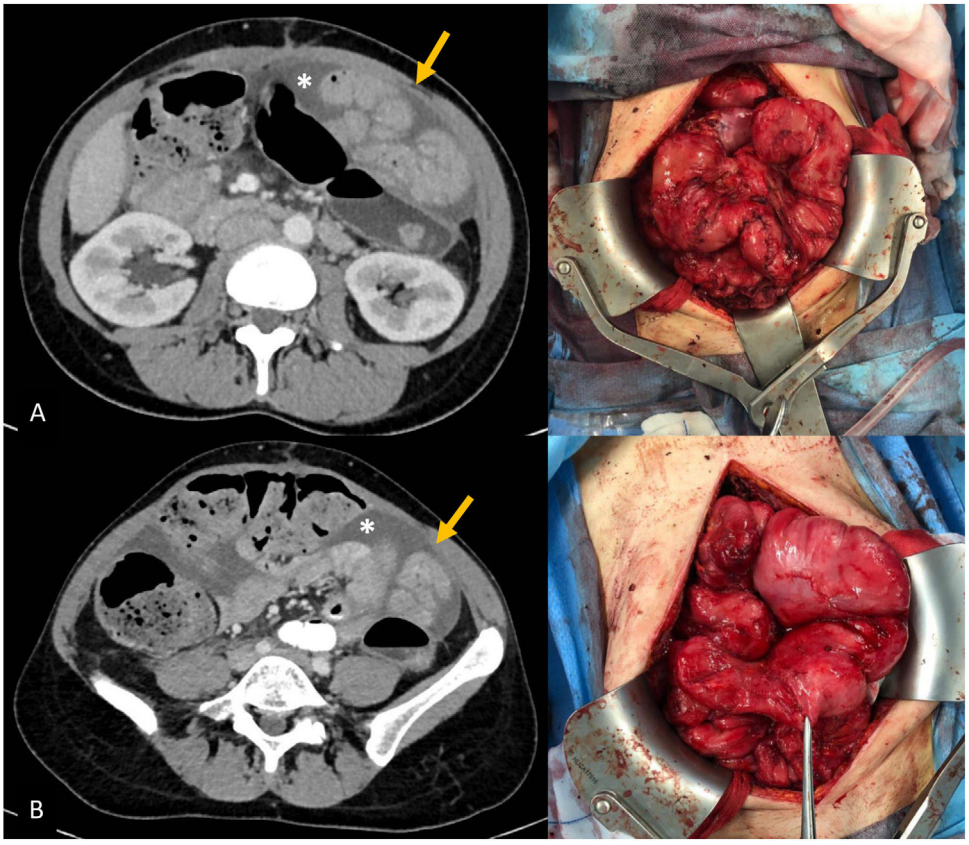


Figure 16 A woman underwent surgery for carcinomatosis of colonic origin, with multiple resections and Hyperthermic Intraperitoneal Chemotherapy. Patient presents with diffuse abdominal pain and symptoms of intestinal obstruction. A contrast-enhanced abdominal CT is performed (axial images A and B), revealing ascitic fluid (*) and a segment of clustered bowel loops in the left side with a congestive appearance (arrows). During surgery, diffuse and fibrous thickening of the peritoneum was identified, causing restricted mobility of the bowel loops, along with subocclusion, in the context of sclerosing encapsulating peritonitis.

diagnosis is established through histological identification of actinomycetes.[27]

Complications: sclerosing encapsulating peritonitis

Patients treated with cytoreductive surgery and HIPEC may develop complications typical of major surgery, such as postoperative bleeding, anastomotic leak, perforation, obstruction or wound infection, with morbidity rates ranging from 28.8% to 53.3%.[28] However, it is important to take into account less common but equally fatal complications, such as sclerosing encapsulating peritonitis. Sclerosing encapsulating peritonitis consists of chronic inflammation of the peritoneum characterised by progressive collagen deposition and a chronic inflammatory infiltrate, leading to fibrous thickening of the peritoneum (Fig. 16). It is a rare complication with unclear pathophysiology and should be considered in cases of obstruction that do not respond to conservative management once tumour recurrence has been ruled out. It commonly manifests as abdominal pain, general discomfort and either complete or partial bowel obstruction. Although medical treatment options exist—such as steroids or tamoxifen, with variable outcomes—surgery is sometimes the only option to release the structures entrapped by this fibrotic/inflammatory reaction.

Conclusions

- The treatment of PC has advanced significantly thanks to cytoreductive surgery and intraperitoneal chemotherapy.
- Accurate radiological assessment and application of the PC index are essential for careful patient selection and surgical planning.
- Identifying unresectability criteria and possessing a solid grasp of the differential diagnosis are essential components of effective disease management.
- All decisions should be made jointly through multidisciplinary teams.

CRediT authorship contribution statement

1 Research coordinators: Alicia Mesa Álvarez, Marina Da Silva Torres.
2 Study concept: Alicia Mesa Álvarez, Marina Da Silva Torres, Estrella Turienzo Santos, Lourdes Sanz Álvarez.
3 Study design: Alicia Mesa Álvarez, Marina Da Silva Torres, Estrella Turienzo Santos, Lourdes Sanz Álvarez.
4 Data collection: Alicia Mesa Álvarez, Marina Da Silva Torres.

5 Data analysis and interpretation: Alicia Mesa Álvarez, Marina Da Silva Torres, Ana Fernández del Valle, Alejandro Cernuda García.
6 Data processing: N/A.
7 Literature search: Alicia Mesa Álvarez, Marina Da Silva Torres.
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9 Critical review of the manuscript with intellectually relevant contributions: Alicia Mesa Álvarez, Marina Da Silva Torres, Estrella Turienzo Santos, Lourdes Sanz Álvarez, Ana Fernández del Valle, Alejandro Cernuda García.
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