Imaging of Peritoneal Carcinomatosis: A prospective study to define correlation between surgical and radiological Peritoneal Cancer Index in patients before HIPEC and Peritoneectomy.

Award: Cum Laude
Poster No.: C-2528
Congress: ECR 2015
Type: Educational Exhibit
Authors: B. Chamokova\textsuperscript{1}, M. Ciolina\textsuperscript{2}, A. Pichi\textsuperscript{2}, M. Iannitti\textsuperscript{2}, P. Baldassari\textsuperscript{2}, C. Cavallini\textsuperscript{2}, D. Diacinti\textsuperscript{2}, F. Iafrate\textsuperscript{2}; \textsuperscript{1}Moscow/RU, \textsuperscript{2}Rome/IT
Keywords: Neoplasia, Metastases, Education and training, Structured reporting, Comparative studies, CT, Pelvis, Abdomen
DOI: 10.1594/ecr2015/C-2528

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Learning objectives

- To review CT appearance of peritoneal carcinomatosis underlying specific sites that radiologists need to check for creating structural report
- To correlate surgical and radiological peritoneal cancer index (PCI)
- To propose a new reporting schema

Background

Pretreatment and preoperative assessment of peritoneal carcinomatosis (PC) can be very challenging. CT imaging is able to provide accurate information on morphology, size, and location of peritoneal implants, lymph node enlargement, and presence of ascites.

A detailed preoperative assessment of PC is essential to provide the surgeon with a detailed information and allow to evaluate the radiological Peritoneal Cancer Index (PCI). This score correlates with patient prognosis, and the ability to calculate it using CT before the treatment can provide a guidance in patients therapeutic management.

It allows to differentiate patients who are candidates for surgical intervention with hyperthermic intraperitoneal chemotherapy (HIPEC) from those with a high radiological PCI and who are referring for a systemic chemotherapy.

MDCT remains the modality of choice for primary staging, especially in patients with poor compliance for diagnostic examinations, providing a great deal of information about a large volume of tissue in just a few minutes and permitting assessment of metastatic extraperitoneal disease.

Main advantages of MDCT:

- wide availability
- short execution time
- relatively low cost
- ability to perform multiplanar reconstructions
- ability to choose slice thickness
- high spacial resolution
- few or absent artifacts

Main disadvantages:

- low contrast resolution
• moderate sensitivity for implants < 5 mm
• diagnostic accuracy strictly dependent on CT technique and radiologist's experience

**MDCT imaging technique:**

CT imaging is routinely performed using MDCT, particularly a 64-detector row scanner. Patient preparation comprises fasting for 6 hours, oral administration of at least 500 ml of water 15-20 min prior to the examination, and IV administration of hyoscine butylbromide (Buscopan) can be considered. CT scanning is performed with the patient in the supine position from the diaphragm to the ischial tuberosities before and after IV administration of contrast media. The arterial phase is preferred if hypervascular primary tumors are suspected and to better depict vascular infiltration of implants located adjacent to vascular structures. A delayed phase, acquired from 5 to 10 min after contrast injection, can increase contrast resolution in some small implants. Axial and other multiplanar reformatted (MPR) images are useful to detect peritoneal disease and check the common peritoneal site of pathological involvement and different patterns of appearance.

For creating a structured report radiologist should be aware of the route of ascities, with the most common areas of arrested flow, with the most common sites and patterns of peritoneal carcinomas.

**The route of the ascites spreading:**

• Ascitic fluid gravitates to a dependent areas within the pelvis
• The negative pressure gradient between the abdomen and pelvis allows fluid to enter the paracolic gutters
• From the pelvis, the major flow of fluid enters the right paracolic gutter then right subhepatic space and goes onto the right subphrenic space (particularly its posterior aspect, the Morison pouch)
• From the right paracolic gutter, fluid also flows through the Morison pouch and the omental foramen to the omental bursa
• The left paracolic gutter is shallower and limited by the phrenicolic ligament resulting in limiting extension into the left subphrenic space

It is stated that 90% of peritoneal fluid is cleared at the subphrenic space by the submesothelial lymphatics. This lymphatics on the both sides of the diafragm are interconnected.

**Sites of arrested flow:**
Four gravity-dependent sites resulting in arrested flow of ascites is commonly found because of tumor seeding:

- Rectouterine space (pouch of Douglas)
- Right lower quadrant (region of ileocecal junction)
- Left lower quadrant (superior aspect of sigmoid mesocolon)
- Right paracolic gutter

The stasis of ascites at these sites leads to seeding of the malignant cells at these critical areas.

**Peritoneal carcinomatosis can have a wide range of appearances on CT including:**

- Increased volume of peritoneal fluid
- Loculated ascites
- Enhancement or thickening of parietal peritoneum
- Discrete peritoneal masses which may enhance or calcify
- Serosal deposits along bowel wall
- Omental infiltrates ranging of subtle nodularity through to "omental cake"

**Different patterns of peritoneal carcinomatosis:**

**Ascites:** The presence of ascites within the peritoneal cavity is usually one of the first indications of peritoneal carcinomatosis. In patients with PC, increased peritoneal fluid, or ascites, is usually seen. In some cases, ascites is little or absent. The mechanism of fluid formation includes increased capillary permeability, fluid production, and obstructed lymphatic vessels with decreased absorption. At CT and MRI scans are acquired with the patient in the supine position during and after inspiration. That is why fluid accumulates especially in subdiaphragmatic spaces, paracolic gutters and epiploon retro-cavity.

**Micronodular:** Tiny 1-5 mm milky spots of peritoneal implants diffusely involving the tunica serosa and subserosal fat. Greater omentum, lesser omentum, and mesentery are typically involved.

**Nodular:** Nodules with a diameter > 5 mm diffusely involving the tunica serosa and subserosal fat. Nodules have an oval shape with rounded contours or present a stellate pattern, with star-shaped appearance and speculated margins.

**Plaque like:** Confluence of multiple nodular implants forms irregular soft-tissue thickenings of inconstant extension that coat abdominal viscera and peritoneal walls, usually scalloping liver and splenic surfaces and presenting a lower attenuation than
the parenchyma on contrast-enhanced scans. It is typically found in subdiaphragmatic spaces and better depicted on coronal reformatted images.

**Mass like**: Confluence of multiple nodular implants, usually in the pelvis, leads to formation of tissue mass that can reach sizes of several centimeters. When a single mass is approximately 10 cm in diameter or larger, it is called a bulky tumor.

**Omental cake**: Omental cake can be defined as a stratified consolidation of the omental fat due to diffuse nodular involvement of the greater omentum combined with a fibrotic tissue reaction.

**Teca aspect and ileal freezing**: Small bowel loops appear completely enveloped by a thickened layer of visceral peritoneum that covers the bowel loops as a sleeve, a condition called Teca aspect. Sometimes, neoplastic tissue that completely coated the small bowel loops causes small bowel obstruction with consequent dilatation of proximal loops - a condition called "ileal freezing".

**Infiltration of the small bowel mesentery** with carcinomatosis may eventuate in characteristic patterns that occur as the soft-tissue tumor replaces normal mesenteric fat. As tumor infiltrates the small bowel mesentery, the mesentery becomes stiff and loses its normal undulations, whereas a unchanged elastic small bowel mesentery allows for a free spread of bowel loops. This pattern appears like stars in the sky and is referred to as "stellate mesentery".

**Morphological categories of the implants:**

- solid
- cystic
- calcified
- mixed

**Images for this section:**
**Fig. 1:** Normal posterior peritoneal reflections and intraabdominal spaces. Cut-surface of the transverse mesocolon (arrow) divides the peritoneum into supramesocolic and inframesocolic compartments. The root of the small bowel mesentery (arrowhead) divides the inframesocolic space into the right and left infracolic compartments. The small bowel mesentery has an oblique orientation from the ligament of Treitz in the left upper quadrant to the ileocecal junction in the right lower quadrant. The sigmoid mesentery serves as a watershed to direct peritoneal fluid into the pelvis.
Fig. 2: Peritoneal fluid preferentially flows into the gravity-dependent areas and then ascends through the paracolic gutters reaching the subphrenic spaces. From the pelvis, most of the fluid ascends via the right paracolic gutter into the right subphrenic space, because the left paracolic gutter is shallow and disconnected with left subphrenic space by the phrenicocolic ligament. The direct passage from the right to the left subphrenic space is prevented by the falciform ligament. In case of ascites fluid collects in well-defined areas of stasis or arrested flow (asterisk): the peritoneal recesses of the pelvis,
the right lower quadrant (at the ileocecal junction), the superior surface of the sigmoid mesocolon and the right paracolic gutter.
Findings and procedure details

In patients with PC accurate preoperative assessment is essential to determine a «road map» for choosing an optimal type of treatment and to ensure optimal outcome. Rather often it is difficult to define an exact extent of carcinomatosis in cases of micronodular dissemination, but it is crucial to detect the most precisely the spread of the peritoneal implants, moreover in those patients undergoing to cytoreduction surgery. Contraindications such as infiltration of organs resulting in incomplete cytoreduction have to be ruled out.

The PCI, introduced by Jacquet and Sugarbaker, is considered the most accurate system for staging PC from different primary tumor types based on quantification and distribution of peritoneal implants found at laparotomy. According to this method, the abdominopelvic area is subdivided into 13 sections (nine areas plus relating small bowel). PC lesion site is rated on a four-point scale ranging from 0 to 3 points, with a possible maximum score of 39: LS 0, no tumor detected; LS 1, tumor up to 0.5 cm maximum diameter, LS 2, tumor > 0.5 cm up to 5 cm in maximum diameter, LS3, tumor or confluent lesions > 5 cm in maximum diameter (Fig.3).

The PCI score also represents a widely validated and precise quantitative prognostic indicator, predicting whether complete resection of peritoneal implants can be achieved after cytoreductive surgery plus hyperthermic intraperitoneal chemotherapy (CRS plus HIPEC). Assessing potentially nonresectable or nonoptimally cytoreducible disease that can contraindicate CRS plus HIPEC comprises the following diagnostic criteria:

- extensive involvement of the small bowel or mesenteric root
- involved lymph node superior to the celiac axis
- pleural infiltration
- pelvic sidewall invasion
- bladder trigone involvement
- hepatic parenchymal metastases or implants near the right hepatic vein or the porta hepatic
- PCI > 12 for gastric cancer, > 20 for colorectal cancer, > 30 for less-invasive mucinous appendiceal and ovarian cancer.

In our institution 33 female patients (mean age 68 years, age range 43-81 years) were examined prospectively on 64-slice CT system before peritonectomy and hyperthermic intraperitoneal chemotherapy. All of the patients underwent explorative laparotomy (the PCI was less than 30) and were suspected to have PC from primary ovarian cancer. Tumor spread, localization and size were described and documented applying Sugarbaker’s PCI.
Contrast-enhanced multiphase CT examinations were performed covering the whole abdomen and pelvis. The bowel distension was obtained through the administration of neutral oral contrast medium.

All patients received IV injections of 2ml/kg of Omnipac 300, followed by 40 mL of saline solution, with a flow rate of 3.5 mL/s. A multi-slice CT scan (Siemens Somatom Sensation 64, Germany) was used and all scans were performed at 120 kV with 200 mAs as well as applying a care dose. The collimation was 0.6 mm and the slice thickness was 3 mm, with following postprocessing with MPR reconstructions.

The images were assessed by one reader radiologist and correlated with surgical exploration and histopathology for each segment based on the peritoneal cancer index. With the use of developed in our institution scheme we evaluated a concordance of the PCI score between radiological and surgical results, whereby surgical findings were regarded as the Gold Standard. As reported in literature the agreement between surgical and radiological PCI is affected by the fact of small implants (less than 5 mm). Due to the fact that they are so difficult to be detected at CT we decided to create 5 classes of concordance. This subdivision simplifies further statistical evaluation.

All of the scores were divided into five classes according to the differences with the surgical results: 0-6, 7-12, 13-19, 20-24, 25-30.

4 patients had exactly the same score according to the surgical and radiological PCI

15 patients had the discordance, ranged from 1 to 6

9 patients had the discordance, ranged from 7 to 12

5 patients had the discordance, ranged from 13 to 19

Two patients had false-positive CT results and two patients had false-negative CT results (Fig.12,13).

According to the surgical results, extrapelvic peritoneal dissemination of the disease was present in all cases.

The main difference between the surgical and radiological PCI was in cases of micronodular dissemination of implants, without obvious seeding of the peritoneum. These results are in accordance with the previously published studies.

Peritoneal nodularity could be easily missed particularly when in close proximity to adjacent small bowel wall. Peritoneal deposits in the subphrenic space could be easily overlooked if subtle and usually result in scalloping of the liver contour (Fig.4).
It is necessary to scrutinize sequentially all of the abdominopelvic areas which are used for counting PCI, paying special attention to the common sites of peritoneal carcinomatosis, areas of arrested flow and aperistalsis, to the gravity-dependent areas and areas of peritoneal fluid resorption (Fig.7-11).

The most important sites of occult tumor that should be reflected in the report:

- **Gravity-dependent areas** (pouch of Douglas, or retrovesical space, lateral paravesical recesses, right lower quadrant, sigmoid colon, paracolic gutters - predominantly on the right side, root of the small bowel mesentery)
- **Areas of arrested flows or aperistalsis** (subhepatic space, omental bursa, antropyloric area, ileocaecal region, rectosigmoid junction)
- **Areas of peritoneal fluid resorption** (right subdiaphragmatic space, greater omentum)

In absence of ascites, thorough investigation of above mentioned areas is crucial because peritoneal carcinomas maybe very subtle and difficult to identify. The early signs of PC include abnormal peritoneal enhancement, thickening, nodularity).

Another important CT findings that should be highlighted in the report:

Findings, that are potentially nonresectable

- Extensive involvement of the small bowel or mesenteric root
- Involved lymph nodes superior to the celiac axis (cardiophrenic, porta hepatis etc.)
- Pleural infiltration
- Pelvic side wall invasion (should be suspected when the primary tumor lies within 3 mm of the pelvic sidewall or surrounds or distorts more than 90% of the circumference of iliac vessels)
- Bladder trigone involvement
- Hepatic parenchymal metastases or implants near the right hepatic vein
- Implants larger than 2 cm in diameter in the diaphragm, lesser sac, porta hepatis, intersegmental fissure, gallbladder fossa, gastroplenic or gastrohepatic ligament

Findings, that are inaccessible with laparoscopy

- Small metastases in the liver or spleen
- Intraluminal implants in gastrointestinal tract
- Pleural metastases

The presence of subcapsular implants in the region extending from the Morison pouch to the inferior vena cava at the level of the right hepatic vein should be specifically
highlighted in the report because it leads to an increased risk of intraoperative bleeding and can impede optimal debulking.

**Sites that need to be clearly investigated are:**

If one of the following site is involved by disease 90-95% the patient is not operable.

- Treitz Ligament
- Mesenteric Root (Retraction)
- Lesser Sac involvement

**Complications**

- Bowel obstruction/bowel freezing
- Hydronephrosis
- Venous obstruction

**Images for this section:**
**Fig. 3:** Peritoneal cancer index (PCI). Two transverse planes and two sagittal planes divide the abdomen into 9 regions. The upper transverse plane is located at the lowest aspect of the costal margin and the lower transverse plane is placed at the anterior superior iliac spine. The sagittal planes divide the abdomen into three equal sectors. The lines define the nine regions which are numbered in a clockwise direction with 0 at the umbilicus and 1 defining the space beneath the right hemidiaphragm. Regions 9-12 divide the small bowel. Lesion size score is determined after complete lysis of all adhesions and the complete inspection of all parietal and visceral peritoneal surfaces. It refers to the greatest diameter of tumor implants that are distributed on the peritoneal surfaces. Primary tumors or localized recurrences at the primary site that can be removed definitively are excluded from the lesion size assessment. If there is confluence of disease matting abdominal or pelvic structures together, this is automatically scored as L-3 even if it is a thin confluence of cancerous implants.
Fig. 4: "Plaque-like" implants: a) Axial contrast enhanced CT image showing a loculated ascites in the right subphrenic area with a "plaque-like" implant (arrow) over hepatic surface resulting in a scalloping of the liver contour, appearing relatively hypodense in comparison with surrounding parenchyma, due to the presence of a mucinous component. b) Surgical intervention confirms the "plaque-like" implant (arrowhead).
Fig. 5: The small bowel is partially obstructed because the carcinomas encase the walls of the bowel loops. There is a diffuse peritoneal carcinomatosis.
**Fig. 6:** Surgical specimen showing dilatation of small bowel loops due to presence of massive peritoneal carcinomatosis.
**Fig. 7:** Sites that need to clearly be investigated during evaluation of peritoneal carcinomatosis widespread using MDCT. Sites written in red are those, that if involved, represent a contraindication to a surgical treatment.
Fig. 8: Sensitivity and Specificity of Splenic Hylum involvement.
Fig. 9: Sensitivity and Specificity of Right Hemidiaphragm involvement.
**Fig. 10:** Sensitivity of MDCT on Mesenteric Root Involvement.
Fig. 11: Sensitivity of lesions < 5 mm.
**Fig. 12:** An example of false-positive interpretation.
Fig. 13: Results of overestimated lesions.
Conclusion

Knowledge of the peritoneal anatomy together with an understanding of the mechanisms behind malignant tumoural seeding of the peritoneal cavity aids in the interpretation of often complex imaging appearances in peritoneal carcinomatosis.

A systematic approach to reviewing the peritoneal spaces can further improve accuracy of reporting.

New reporting scheme using MDCT need to be used trying to evaluate typical region of the abdomen and some crucial areas like mesenteric root, Treitz ligament, lesser sac that alone can represent a contraindication to surgical treatment.

Personal information

References


