Learning objectives

To review the basic anatomy of the peritoneum and the common pathways of disease spread through the peritoneal cavity.

To review the imaging findings suggestive of peritoneal carcinomatosis in CT.
Background

THE PERITONEUM

The peritoneum, the largest serous membrane of the body, is composed of a single layer of mesothelial cells supported by connective tissue, which lines the inner surface of the abdominal cavity (parietal peritoneum) and envelopes the majority of the abdominal organs (visceral peritoneum). The peritoneal cavity refers to the potential space between these two layers.

The peritoneum and its associated reflections, mesenteries and omenta support the intraperitoneal organs and subdivide the peritoneal cavity into spaces that communicate with each other and determine the flow of fluid and location of peritoneal diseases.

PERITONEAL CARCINOMATOSIS

Peritoneal carcinomatosis is the most common malignant process involving the peritoneum and usually heralds a poor prognosis. Intraperitoneal propagation of malignant cells can occur via direct spread, peritoneal seeding or hematogenous and lymphatic dissemination. The most common sites of origin of malignant peritoneal seeding are the gastrointestinal tract (stomach, colon and pancreas) and the ovary.

Computed tomography (CT) is the most frequently used modality to access for peritoneal metastases and its possible complications.
Findings and procedure details

ANATOMY: PERITONEAL SPACES

The peritoneum consists of a single layer of mesothelial cells lining the abdominal and pelvic walls (the parietal peritoneum) and covering the external surface of most abdominal organs (the visceral peritoneum). The peritoneal cavity is the virtual space between these two layers.

The compartmentalization of the peritoneum by its reflections and mesenteries commands the direction and flow of fluid within the abdominopelvic cavity.

The two main peritoneal compartments - supramesocolic and inframesocolic - are separated by the transverse mesocolon (Fig. 1 on page 9).

THE SUPRAMESOCOLIC COMPARTMENT

Divided by the falciform ligament into the right and left supramesocolic spaces (Fig. 2 on page 9).

The right supramesocolic space is further divided into:

- **Right subphrenic space**: extending over the diaphragmatic surface of the right liver lobe to the right coronary ligament (posteroinferiorly) and the falciform ligament (medially).

- **Right subhepatic space**: bounded superiorly by the inferior surface of the liver and communicating freely either with the right subphrenic space and the right paracolic gutter. The posterior right subhepatic space (Morrison's pouch, Fig. 3 on page 10) extends posteriorly to the peritoneum overlying the right kidney and is the most dependent portion of the peritoneal cavity in the supine position.

- **Lesser sac** (Fig. 4 on page 11): located posterior to the lesser omentum, stomach, duodenum and gastrocolic ligament and anterior to the pancreas. Communicates with the rest of the peritoneal cavity through the epiploic foramen (of Winslow).

The left supramesocolic space is divided into four compartments in communication:

- **Left perihepatic space**: further divided into the left anterior perihepatic space, bounded medially by the falciform ligament, posteriorly by the liver and anteriorly by the diaphragm; and the left posterior perihepatic space, bounded posteriorly by the lesser omentum, extending from the surface of
the liver into the fissure for the ligamentum venosum. The left perihepatic space communicates superiorly and to the left with the left subphrenic space and inferiorly with the peritoneal cavity over the surface of the transverse mesocolon.

- **Left subphrenic space:** divided into the left anterior subphrenic space, which lies between the stomach and the left hemidiaphragm; and the left posterior subphrenic space, which covers the superior and inferolateral borders of the spleen and is bounded inferiorly by the phrenicocolic ligament and superiorly by the gastroplenic ligament.

**THE INFRAMESOCOLIC COMPARTMENT** *(Fig. 5 on page 12)*

Divided by the root of the small bowel mesentery into:

- **Right inframesocolic space:** between the transverse mesocolon superiorly and to the right and the small bowel mesentery inferiorly and to the left.

- **Left inframesocolic space:** Larger than the contralateral right inframesocolic space, is in communication with the pelvic cavity to the right of the midline. The sigmoid mesocolon forms a barrier to the left of the midline.

- **Paracolic gutters:** peritoneal recesses situated between the posterior abdominal wall and the ascending and descending colon. The right paracolic gutter is larger than the left and communicates superiorly with the right subhepatic and subphrenic spaces (from the supramesocolic space). The left paracolic gutter is partially separated from the left subphrenic spaces by the phrenicocolic ligament.

- Both communicate inferiorly with the pelvic peritoneal spaces.

**THE PELVIC PERITONEAL SPACES**

- The peritoneum reflects inferiorly over the dome of the bladder, the anterior and posterior surfaces of the uterus and the upper vagina (in females) and the superior portion of the rectum. The urinary bladder divides the pelvic cavity into the left and right paravesical spaces.

- In women, there are two potential spaces of fluid accumulation: posteriorly to the bladder (uterovesical pouch) and the rectouterine pouch (of Douglas) *(Fig. 6 on page 13).*

- In men, there is one potential space of fluid collection only, the rectovesical pouch *(Fig. 7 on page 14).*

- The pelvis is the most dependent portion of the peritoneal cavity in the erect position.
ANATOMY: PERITONEAL FLUID CIRCULATION

The normal peritoneal cavity contains a small volume of sterile fluid. The clearance of this physiologic fluid is potentiated by upward circulation to the subphrenic spaces (where the subphrenic lymphatics provide the majority of the lymphatic clearance from the peritoneal cavity). This upward movement is driven by fluctuations in the intraabdominal pressure caused by diaphragmatic movement during normal respiration. While initially the peritoneal fluid collects in the gravity dependent spaces (pelvic peritoneal spaces, such as the rectouterine and rectovesical pouches), it then ascends through the paracolic gutters to reach the subphrenic compartments. The right paracolic gutter is the preferred way up because the phrenicocolic ligament acts as a partial barrier on the left and the falciform ligament prevents passage of fluid from the right to the left subdiaphragmatic compartments. Fluid is then driven inferiorly to the inframesocolic space, completing the circuit.

In pathologic conditions (e.g. ascites), fluid usually is located in well-defined areas of stasis: the pelvic recesses, the right lower quadrant (the ileocecal junction and the right paracolic gutter), and the superior aspect of the sigmoid mesocolon. Thus, these anatomic landmarks should be thoroughly evaluated when looking for peritoneal carcinomatosis (Fig. 8 on page 15).

SPECTRUM OF CT FINDINGS IN PERITONEAL CARCINOMATOSIS

Diffuse metastatic seeding of the peritoneal cavity is relatively common with abdominopelvic tumors and neoplastic processes can disseminate through this space with relative ease. As neoplastic cells freely circulate in peritoneal fluid, driven by gravity and diaphragmatic pressure gradients, there are some characteristic locations of intraperitoneal seeding such the dome of the liver; the concave surfaces of the anterior abdominal wall; the omentum; the transverse mesocolon; the small bowel mesentery; and the dependent portions of the pelvis. On the other hand, direct invasion to the peritoneum occurs through direct extension of gastrointestinal primary malignancies or tumor extension through the peritoneal ligaments and mesenteries. Hematogenous spread can also occur from extraabdominal tumors, such as melanoma, breast or lung carcinomas. Lymphatic dissemination is probably a minor route of spread of gastrointestinal tumors to the peritoneal cavity.

CT is almost 90% sensitive in the detection of peritoneal neoplastic lesions greater than 5 mm in diameter, decreasing significantly for lesions less than 5 mm. CT manifestations of peritoneal carcinomatosis are protean, and include:

PERITONEAL THICKENING AND NODULARITY
• Peritoneal thickening and tumor nodules personify typical peritoneal carcinomatosis (Fig. 9 on page 16).

• May range from infiltrative masses to multifocal discrete nodules that may be missed on CT (Fig. 10 on page 17).

• Lymphadenopathy may also be a prominent feature (Fig. 11 on page 18).

ASCITES

• Common finding in peritoneal carcinomatosis.

• Loculation is one of the most helpful features indicating a malignant etiology, as well as thickening, nodularity and contrast enhancement of the peritoneal reflections.

OMENTAL "CAKE" (Fig. 12 on page 19, Fig. 13 on page 20)

• Refers the thickened and nodular appearance of the greater omentum, which displaces bowel away from the abdominal wall.

• Most commonly arises from metastatic ovarian, gastric or colon cancer.

PSEUDOMYXOMA PERITONEI (Fig. 14 on page 21, Fig. 15 on page 22)

• Refers to a clinical syndrome characterized by the presence of thick gelatinous material on the surfaces of the peritoneal cavity.

• Arises from moderately or poorly differentiated mucinous carcinomas of the gastrointestinal tract (mostly from the appendix), gallbladder, pancreas or ovary.

• Rare condition, occurring more commonly in women (mean age at diagnosis - 49 years).

• On CT, it is described as low attenuation ascites that typically exerts mass effect on adjacent structures with scalloping of solid viscera or displacement of hollow viscera.

• Calcifications may be present.

PERITONEAL IMPLANTS (Fig. 16 on page 23, Fig. 17 on page 24, Fig. 18 on page 24)

• Soft tissue masses that can appear as solitary or multiple nodules that can coalesce and form plaques near the surface of the viscera.

• Implants may enhance with intravenous contrast administration.
• Most common locations are the right diaphragmatic surface, right paracolic gutter, bowel, omentum and pelvic cavity.

• Extension of omental disease into the anterior abdominal wall may result in umbilical masses (Sister Mary Joseph nodule - Fig. 19 on page 25).

• Krukenberg tumor (Fig. 20 on page 26) is a rare subtype of metastatic tumor to the ovary, usually arising from signet-ring type gastric cancer.
Fig. 1: Anatomy of the peritoneal cavity: Coronal CT image of a patient with large volume ascites depicts the division of the supramesocolic and inframesocolic compartments by the transverse mesocolon (arrow). Also seen are the small bowel mesentery and the sigmoid mesocolon (curved arrows).

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Fig. 2: Anatomy of the peritoneal cavity: The supramesocolic compartment. Axial and Coronal CT images illustrating (1) the right and (2) left supramesocolic spaces, divided by the falciform ligament (arrow). On the right, note also the subphrenic (1) and subhepatic (3) spaces, communicating freely with each other and with the ipsilateral paracolic gutter (*).

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**Fig. 3:** Anatomy of the peritoneal cavity: Morrison’s pouch (4), also known as right posterior subhepatic space, extends posteriorly over the right kidney and is the most dependent position of the abdominal cavity in the supine position.

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Fig. 4: Anatomy of the peritoneal cavity: The lesser sac (5) is depicted in these axial and coronal images.

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Fig. 5: Anatomy of the peritoneal cavity: The inframesocolic compartment. Axial and Coronal CT images illustrating (6) the right and (7) left inframesocolic spaces, divided by the small bowel mesentery (arrow). The left inframesocolic compartment (7) communicates with the pelvis to the right of the midline, as the sigmoid mesocolon (curved arrow) forms a barrier to the left of the midline. Note also both paracolic gutters (*), the right one communicating freely with the right subhepatic and subphrenic spaces. Both gutters extend inferiorly to the pelvic peritoneal spaces.

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**Fig. 6**: Anatomy of the peritoneal cavity: The pelvic recesses. Sagittal scan in a female patient with medium-volume ascites shows the more anterior vesicouterine pouch (8) and the rectouterine pouch (Douglas) (9). These are the most dependent portions of the peritoneal cavity in the upright position.

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Fig. 7: Anatomy of the peritoneal cavity: The pelvic recesses. In men, the rectovesical pouch (10) is the only potential space for fluid collection in the pelvic cavity.

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Fig. 8: Where to look for ascitic fluid in the peritoneal cavity? These are the four most common well-defined areas of stasis (asterisks): The right paracolic gutter and the ileocecal junction, the pelvis and the superior aspect of the sigmoid mesocolon.

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**Fig. 9:** Peritoneal carcinomatosis: Thickening and nodularity of the peritoneum. Axial CT image from a patient with widespread metastases from gallbladder carcinoma showing diffuse thickening, enhancing and nodularity of the peritoneum (arrows). This is a typical finding in peritoneal carcinomatosis.

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Fig. 10: Peritoneal carcinomatosis: Discrete infracentimetric right subphrenic nodule which was assumed to represent peritoneal carcinomatosis in a patient with widespread metastatic melanoma. Note the hypoattenuating liver lesion (*) representing distant metastization. There was also medium-volume ascites (not shown).

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**Fig. 11:** Mesenteric lymphadenopathy. Axial and coronal scans of a female patient with breast cancer shows ascites and multiple rounded lymph nodes in the small bowel mesentery.

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Fig. 12: Peritoneal carcinomatosis: Omental "cake". Mild thickening and fat stranding around the greater omentum (arrow) in a female patient with a history of serous adenocarcinoma of the fallopian tube.

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**Fig. 13:** Peritoneal carcinomatosis: Omental "cake". More expressive thickening and enhancement of the greater omentum, displacing the bowel away from the abdominal wall. Axial (a) and sagittal (b) scans from a 17 year-old male, illustrating voluminous ascites as well as marked thickening of the greater omentum (arrows) from signet-ring cell gastric adenocarcinoma. Axial (c) CT image from a female patient with a history of adenocarcinoma of the gallbladder showing similar findings.

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Fig. 14: Peritoneal carcinomatosis: Pseudomyxoma peritonei. Axial CT image of a patient with a history of mucinous adenocarcinoma of the appendix shows small amount of perihepatic and perisplenic fluid. Note the mass effect (scalloping) on the posterior surface of the liver (arrow). This is characteristic of pseudomyxoma peritonei.

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**Fig. 15:** Peritoneal carcinomatosis: Pseudomyxoma peritonei. There is loculated heterogeneous ascitic fluid in the right lower quadrant with areas of gross calcification. These findings are suggestive of pseudomyxoma peritonei in this patient with a history of appendiceal mucinous adenocarcinoma.

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**Fig. 16:** Peritoneal carcinomatosis: Nodular implant. Axial and coronal view in a female patient with a history of mixed Mullerian tumor. Note the nodular lesion with peripheral rim enhancement and necrotic center in the small bowel mesentery (arrow). Mild ascites is also present. These findings are suggestive of peritoneal carcinomatosis.

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**Fig. 17:** Peritoneal carcinomatosis: Nodular implants in Douglas pouch. Axial and coronal CT images in a female patient with advanced adrenocortical carcinoma showing ascites and multiple enhancing nodular masses in the rectouterine recess, representing peritoneal implants.

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Fig. 18: Peritoneal carcinomatosis: Implant. Axial image of a patient with a history of colonic adenocarcinoma, illustrating an ill-defined enhancing mass (arrow) in the rectovesical pouch, invading the rectum and posterior bladder wall. There was left hydronephrosis (not shown), consistent with invasion of the ureteral meatus.

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Fig. 19: Peritoneal carcinomatosis: Sister Mary Joseph nodules. Two axial CT images in a patient with gastric adenocarcinoma illustrating soft tissue enhancing nodules in the umbilical region (arrows). There was also ascites and a 15 mm nodularity in the peritoneum (curved arrow). These findings are suggestive of diffuse carcinomatosis through the peritoneal cavity.

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**Fig. 20:** Peritoneal carcinomatosis: Krukenberg tumors. Axial scans of the right (a) and left (b) adnexa and coronal view (c) in a female patient with a history of gastric adenocarcinoma of the signet-ring cell type illustrating voluminous bilateral heterogeneous enhancing masses (arrows). On the left, there is central necrosis (*).

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Conclusion

Peritoneal carcinomatosis can present with a multiplicity of imaging appearances at CT and its recognition is fundamental for the accurate staging of most gastrointestinal and gynecological malignancies. Understanding the basic anatomy of the peritoneal cavity and the spectrum of imaging findings of this entity may improve its correct diagnosis.
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