PICTORIAL REVIEW / Genito-urinary imaging

Mucin-producing tumors of the ovary: MR imaging appearance

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Abstract Mucin-producing tumors of the ovary can be either primary epithelial mucin-producing tumors or ovarian metastases from a remote adenocarcinoma usually originating from the gastrointestinal tract. The purpose of this pictorial review is to describe the main types of primary or secondary mucin-producing tumors of the ovary and to provide MR imaging diagnostic criteria in order to guide further therapy.

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Mucin-producing tumors of the ovary can be either primary epithelial mucin-producing tumors or ovarian metastases from a remote adenocarcinoma usually originating from the gastrointestinal tract.

The World Health Organization’s classification of ovarian tumors differentiates the following four main categories: epithelial tumors, germ cell tumors, sex-cord and stromal tumors, and ovarian metastases (Boxed text 1).

Epithelial tumors represent 60% of all ovarian tumors and 85% of malignant tumors [1]. They originate from the surface epithelium of the ovary. Their classification depends both on the cell type of the epithelium, of which there are five (serous, mucinous, endometrioid, clear cell and Brenner cell), and on the histological degree of malignancy (benign, borderline and malignant). Epithelial mucinous tumors make up between 15 and 20% of ovarian lesions depending on the series. Ovarian metastases represent approximately 5% of all ovarian tumors. The ovary is a common site for metastases. The primary cancers that give ovarian mucinous metastases, originate from the gastrointestinal tract [2].

Differential diagnosis between these primary and secondary mucinous lesions is critical for optimizing treatment planning: indeed, if the radiologist concludes that the ovarian lesion is secondary, complete staging will be performed to find the primary cancer, particularly by fibroscopy and coloscopy. Treatment will then start with initial chemotherapy. On the other hand, if the radiologist concludes that the tumor is a primary ovarian tumor, an additional CT examination will be performed to look for peritoneal carcinomatosis, and then the treatment will begin with initial pelvic surgery. However, it is sometimes difficult to differentiate between

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Boxed text 1: WHO classification of ovarian tumors.

<table>
<thead>
<tr>
<th>Classification of ovarian tumors</th>
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<tr>
<td><strong>Epithelial tumors</strong></td>
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<tr>
<td>Serous tumors</td>
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<tr>
<td>Mucinous tumors</td>
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<tr>
<td>Endometrioid tumors</td>
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<tr>
<td>Clear cell tumors</td>
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<tr>
<td>Brenner tumors</td>
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<tr>
<td><strong>Germ cell tumors</strong></td>
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<tr>
<td>Teratoma</td>
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<tr>
<td>Mature (dermoid cyst)</td>
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<tr>
<td>Immature</td>
</tr>
<tr>
<td>Dysgerminoma</td>
</tr>
<tr>
<td>Embryonal carcinoma</td>
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<tr>
<td>Yolk sac tumor (endodermal sinus tumor)</td>
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<tr>
<td>Choriocarcinoma</td>
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<tr>
<td><strong>Sex-cord and stromal tumors</strong></td>
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<tr>
<td>Gonadal stromal tumors</td>
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<tr>
<td>Fibroma</td>
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<tr>
<td>Thecoma (Fibrothecoma)</td>
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<tr>
<td>Sclerosing stromal tumor</td>
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<tr>
<td>Sex-cord tumors</td>
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<tr>
<td>Granulosa tumors</td>
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<td>Sertoli-Leydig cell tumors</td>
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<td><strong>Metastases</strong></td>
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primary and secondary mucinous lesions with both imaging and histopathological analysis.

The purpose of this pictorial review is to describe the main types of primary or secondary mucin-producing tumors of the ovary and to provide MR imaging diagnostic criteria, in order to guide further therapy.

Epithelial mucinous tumors of the ovary

Epithelial mucinous tumors of the ovary represent 15 to 20% of all ovarian tumors. These tumors are considered mucinous because their epithelium secretes mucin. Depending on the histological degree of malignancy, epithelial mucinous tumors may be benign cystadenomas (85%), borderline cystadenomas (10%), or mucinous cystadenocarcinomas (5%). The benign forms occur preferentially between 30 and 50 years of age and the borderline and malignant forms between 40 and 70. Epithelial mucinous tumors have the following common characteristics: they appear multilocular both macroscopically and in images, and they are large, often exceeding 10 cm [3]. Unlike serous lesions, they are generally unilateral. Occurrence associated with a Brenner tumor is classic [4].

Benign mucinous cystadenoma

Histological appearance

Mucinous cystadenoma typically presents as a unilateral, multilocular, voluminous, cystic, ovarian lesion. Macroscopically, the content is mucoid (Fig. 1). A benign mucinous cystadenoma has no solid portion. Its wall is smooth but may sometimes have a few papillary projections [1].

Microscopically, a benign mucinous cystadenoma is lined by a tall columnar epithelium, with basal nuclei secreting mucin. This layer is seen in large cystic structures, the lumen of which is filled with a considerable quantity of mucus. In 5% of cases, benign mucinous cystadenomas can be combined with other ovarian tumors: Brenner tumors and dermoid cysts.

MRI appearance

On MRI benign mucinous cystadenoma typically presents as a large, multilocular, cystic, ovarian lesion. Some loculi are spontaneously hyperintense on T1-weighted MR images (related to the variable concentration of mucin in the loculi). These loculi are more or less grouped together sometimes giving a “honeycomb” or “stained glass” pattern [1,5] (Fig. 1). The criterion indicating a benign lesion is the absence of areas of tissue (the absence of irregular septa or solid portions) [6]. Papillary projections are uncommon and when present, are very small and difficult to see with imaging [7].

Borderline mucinous cystadenoma

Histological appearance

This is a multilocular cystic ovarian lesion characterized by the presence of irregular septa and papillary projections. Borderline mucinous cystadenoma papillae are often smaller than the serous type, sometimes only visible on microscopic examination [1,8]. The microscopic appearance of a borderline tumor is that of cystic structures bordered by a proliferating epithelium with discreet to moderate cytornuclear atypia with no stromal invasion (Fig. 2).

MRI appearance

The MRI appearance is very similar to benign mucinous cystadenoma: a multilocular cystic mass with large loculi of variable intensity on T1-weighted MR images. The presence of irregular septal or groups of small papillary projections point toward diagnosis of a borderline mucinous lesion [9]. The small papillary projections are most often hypointense on T2-weighted MR images. The presence of a large number of loculi can also point toward the borderline type [10].

Mucinous cystadenocarcinoma

Histological appearance

Mucinous cystadenocarcinoma is an invasive malignant tumor presenting as a large (>10 cm), multilocular, cystic lesion, which is usually unilateral. Mucinous cystadenocarcinoma is rarely bilateral (7%). The criteria indicating a cystadenocarcinoma are the presence of one or more solid parts (tumor nodule) and irregular septa. Microscopically, the cytological criteria of malignancy are associated with desmoplasia, indicating the invasive character of the carcinoma. It is often difficult to detect the presence of areas of invasion and multiple samples have to be obtained, due to
MRI of ovarian mucin-producing tumors

Figure 1. Benign mucinous cystadenoma; a: T2-weighted MR image in the sagittal plane; b: T2-weighted MR image in the axial plane; c: T1-weighted MR image in the axial plane; d: T1-weighted fat-suppressed MR image in the axial plane after intravenous administration of a gadolinium chelate shows presence of loculi of variable intensity (arrows); e: photograph shows gross appearance after opening; f: multilocular cystic lesion with thick mucoid content and no solid part. Histological appearance (×20 magnification), cyst wall lined by a single layer of columnar epithelium with a secretory pole. Absence of cytonuclear atypia.

Figure 2. Borderline mucinous cystadenoma; a: T2-weighted MR image in the sagittal plane; b: T1-weighted fat-suppressed MR image in the axial plane; c: T1-weighted fat-suppressed MR image in the axial plane after intravenous administration of a gadolinium chelate shows a group of loculi (black arrow) and irregular septa (white arrow); d, e: photographs show gross appearance before (d) and after (e) opening. The tumor is a multilocular cystic lesion with mucoid content and many papillary projections (arrow); f: histological appearance (×10 magnification), more or less cystic glandular structures edged by a multistratified epithelium and containing moderate cytonuclear atypia are present.
Figure 3. Mucinous cystadenocarcinoma; a: T2-weighted MR image in the axial plane shows solid portion of intermediate signal intensity (arrows); b: T1-weighted MR image in the axial plane; c: diffusion-weighted MR image in the axial plane shows solid portions of hypersignal intensity (arrows); d: T1-weighted fat-suppressed MR image in the axial plane after intravenous administration of a gadolinium chelate shows enhancing portions (arrows); e: photographs show gross appearance before opening. The tumor is cystic with a solid portion (arrow) of firm consistency and necrotic content; f: histological appearance ×10 magnification. There is dense tumor proliferation with stromal invasion and presence of marked cytonuclear atypia.

the frequent association of benign, borderline and malignant parts within the lesion (Fig. 3).

MRI appearance
On MRI mucinous cystadenocarcinoma typically presents as a multilocular cystic lesion containing a solid part of intermediate intensity on T2-weighted MR images, hyperintense on diffusion-weighted images, and, on perfusion sequences, with a type-3 enhancement curve (earlier enhancement relative to the myometrial curve) [11] (Fig. 3). The spread elsewhere (lymph node or peritoneum) is also an indication of a malignant lesion.

Differential diagnosis
The principal differential diagnoses for epithelial mucinous tumors are ovarian metastases and serous epithelial tumors.

Ovarian metastases
The main primary sites of ovarian metastases are the colon, stomach, breast, and appendix. The macroscopic and imaging appearance of these lesions varies with the primary cancer. Two types of secondary ovarian lesion should be clearly separated: ovarian metastases where the major component is solid, and metastases which are predominantly cystic.

Predominantly solid metastases (Krukenberg tumors)
Predominantly solid secondary lesions or Krukenberg tumors (KT) will not be covered in detail in this review. Indeed, they rarely pose a problem of differential diagnosis with epithelial mucinous tumors.

KT is often erroneously used for all ovarian lesions secondary to a primary gastric tumor or even for all ovarian metastases, but this term has a strict anatomopathological definition: signet ring cells making up at least 10% of the tumor. The typical macroscopic appearance is a fibrous stromal component, explaining the predominantly solid appearance on MRI. The primary sites of KT, in decreasing order, are the stomach, and more particularly gastric limatitis plastica, the colon, and the breast.

Predominantly cystic metastases (non-Krukenberg type)
These are ovarian mucin-producing metastases. Only certain primary cancer sites produce this type of ovarian metastatic lesion. In decreasing order, they are the colon, the pancreas, the stomach and the appendix [2,12]. Mucus-secreting ovarian metastases of the gall bladder, cervix and lungs are rare and are not covered in this review.

The radiologist’s main objective is to differentiate between primary mucinous ovarian tumors and cystic metastasis from a gastrointestinal tract cancer, because therapeutic management is different. The two main criteria
The keeping of and eral mucinous lesions are generally larger and very commonly unilateral (>80%). It has been suggested that bilateral lesions or unilateral lesions <10 cm indicate a metastatic origin whereas unilateral lesions measuring >10 cm indicate a primary epithelial origin [3,13].

These Seidman criteria have since been tested on a series of 74 cases [14]. The authors concluded that the “lesion measuring less than 10 cm or bilateral involvement” criterion was of good diagnostic value for secondary locations. On the other hand, the “unilateral lesions measuring more than 10 cm” criterion seemed to be less reproducible. Indeed in this series, of 21 unilateral lesions >10 cm, 13 were primary and 8 secondary lesions. The authors recommend always keeping the possibility of a secondary lesion in mind, even in the presence of a unilateral voluminous lesion [14].

In case of multilocular cystic lesions of the ovary, with no solid portion, the radiologist should look for lymph node or peritoneal involvement, particularly on diffusion-weighted MR sequences, which would indicate secondary locations. The potential primary sites (the appendix, stomach, and colon) should also be carefully examined. CT examination may also help the radiologist look for a primary origin. Fibroscopy and colonoscopy may also be performed before treatment depending on local preferences.

### Colorectal adenocarcinoma metastases

**Histological appearance**

Ovarian metastasis of colorectal carcinoma mimics the mucinous cystadenocarcinoma type of epithelial mucinous tumor. It appears as a tumoral proliferation consisting of variably sized glandular structures, lined with a multi-stratified epithelium with marked cytonuclear atypia. There are often large areas of tumor necrosis known as “dirty necrosis”, a good indication of secondary ovarian lesions.

Even histologically, the differential diagnosis between a primary malignant mucinous tumor and metastasis of a colorectal adenocarcinoma is not easy. Immunohistochemistry can be performed: being positive for CK20 and negative for CK7 antibodies suggests a metastatic origin from a colorectal cancer.

**MRI appearance**

On MRI, the stained glass appearance of a multilocular lesion with loculi on T1-weighted MR images of variable intensity is typical. The quantity of solid component varies [15] and necrotic components which are hyperintense with T2-weighted MR images are often seen. If the solid part is absent, the MRI appearance may be very similar to that of a benign mucinous cystadenoma. Injection of gadolinium shows enhancement of the septa and the solid part when present but again, the appearance may be similar to a mucinous cystadenocarcinoma (Fig. 4). In this situation, Seidman’s criteria [3] are useful for guiding the diagnosis between a primary or secondary origin.

**Metastases of gastric neoplasia**

**Histological appearance**

It is important to differentiate between gastric limitis plastica (diffuse adenocarcinoma) and the intestinal type where the secondary ovarian lesions have different
are lesions predominantly marked characteristics [16]. The anatomopathological appearance is set out in Table 1 [16]. Patients with gastric linitis plastica are significantly younger (a mean of 40 years old), and the gastric neoplasia is generally occult, often revealed by predominantly solid, Krukenberg type, secondary pelvic masses. On the contrary, patients with intestinal type lesions are older (generally over 50), and the primary site is known. Generally, the intestinal type of ovarian metastases are predominantly multilocular cysts with a mucoid content and a solid part [17] (Fig. 5). Histological examination shows carcinomatous structures surrounded by cells with marked atypia and a mucosecretion vacuole.

### Table 1
Comparison of the characteristics of ovarian metastases of gastric linitis plastica, and intestinal type adenocarcinoma.

<table>
<thead>
<tr>
<th>Gastric primary</th>
<th>Gastric linitis plastica</th>
<th>Intestinal type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean age</strong></td>
<td>40</td>
<td>50 and over</td>
</tr>
<tr>
<td><strong>Ovarian metastases</strong></td>
<td>Krukenberg</td>
<td>Intestinal type</td>
</tr>
<tr>
<td><strong>Solid component</strong></td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td><strong>Cystic areas</strong></td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td><strong>Microscopic appearance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signet ring cells</td>
<td>&gt; 10%</td>
<td>Absent or rare</td>
</tr>
<tr>
<td>Mucinous glands</td>
<td>Rare</td>
<td>Numerous</td>
</tr>
</tbody>
</table>

MRI appearance

Ovarian metastases of an intestinal type gastric adenocarcinoma closely mimic epithelial mucinous lesions, are predominantly cystic, and contain many loculi of variable intensity on T1-weighted MR images. An enhanced solid component may be seen, but is not systematically present [17] (Fig. 5).

### Other primaries

There are few descriptions in the literature of the radiological appearance of other secondary lesions, whether mucinous or not. Macroscopically, their appearance varies from predominantly pure cystic lesions, to predominantly solid KT lesions. Histologically, pancreatic or biliary metastases are very often mucinous lesions similar to colorectal metastases [15].

### Pseudomyxoma peritonei

### MRI appearance

Ovarian involvement is common in cases of pseudomyxoma peritonei. The origin of these lesions has been discussed for a long time, but today it is agreed that the ovarian lesions are secondary, and the site of the primary lesion is the appendix. This appendicular tumor obstructs the appendix, becomes complicated by a mucocele, then by spreading to the peritoneum. Secondary ovarian implantation is typical, and for a long time was wrongly considered to

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**Figure 5.** Bilateral ovarian metastases from gastric adenocarcinoma; a: T2-weighted MR image in the axial plane; b: T1-weighted MR image in the axial plane; c: diffusion-weighted MR image in the axial plane; d: T1-weighted fat-suppressed MR image in the axial plane after intravenous administration of a gadolinium chelate. On the left, presence of a solid portion, which is hypointense on T2-weighting image, hyperintense on diffusion-weighted image, and enhancing after gadolinium injection (arrows), corresponding to the area indicated by the forceps on the macroscopic view on Fig. 4e; e: photograph shows gross appearance of the tumor which is a right ovarian mass with no solid part. Forceps indicates solid portion on a, b, c and d; f: histological appearance ×20 magnification. The tumor contains a moderately differentiated adenocarcinomatous proliferation composed of glands and tumor trabeculae.
be the primary site. Where involvement is unilateral, the right ovary is more readily affected, probably due to the proximity of the appendix [18].

Macroscopically, involvement is typically bilateral, with voluminous multilocular lesions. These loculi contain mucin bags of jelly [2]. Microscopic examination shows pools of mucus that may include strips of mucinous epithelium with a variable degree of atypia depending on the grade of the tumor [19].

MRI appearance
There are several MRI features indicating pseudomyxoma. These include ascites, peritoneal nodules which can be distinguished from the adjacent ascites on T2-weighted MR images and after intravenous administration of a gadolinium chelate [20,21], scalloping of peritoneal organs, particularly the liver [20–22], and common ovarian involvement in the form of multilocular cystic lesions, mimicking a primary mucinous lesion [15]

Serous epithelial tumors

Histological appearance
The typical appearance of a serous tumor is a unilocular cyst with a pure liquid content, smaller than primary mucinous lesions (Fig. 6). In some cases, it may be paucilocular. As for mucinous lesions, papillary projections are possible and suggest a borderline serous lesion. These papillary projections are generally larger, and more easily seen than those observed in mucinous lesions. The presence of a solid portion can suggest a serous cystadenocarcinoma but benign solid portions have also been described in cases of ovarian cystadenofibroma. Finally, bilateral involvement is more common than for mucinous lesions.

Microscopically, these tumors are covered by serous epithelial cells (without mucosecretory activity) with a central nucleus. Benign tumors consist of cystic or papillary structures covered by a layer with no atypia, mitosis, or epithelial budding. Borderline forms have at least two of the four signs described above (papillary projections, atypia, mitosis or epithelial budding), without stromal invasion. Serous adenocarcinomas are characterized by stromal invasion and many atypia.

MRI appearance
On MRI, benign serous cystadenoma typically presents as a uni- or pauci-locular cyst, with a purely liquid content, uniformly hyperintense on T2-weighted MR images (Fig. 6). The presence of papillary projections suggests a borderline type. A solid portion may be seen in benign cystadenofibroma lesions or in malignant serous cystadenocarcinomas. Where a solid part is present, indications of a benign cystadenofibroma are hypointensity of the solid portion on T2-weighted MR images, the absence of hyperintensity on diffusion-weighted images, and a type-1 enhancement curve on perfusion imaging [1]. On the contrary, a tissue portion enhancing with a type-3 curve must be suspected of being a serous cystadenocarcinoma [11].

Conclusion
Presence of a multilocular cystic ovarian lesion with loculi of varying intensity on T1-weighted MR images must suggest a mucin-producing ovarian lesion. MRI can provide
additional useful diagnostic information that helps discriminate between the different entities. The differential diagnosis is often tricky due to overlapping in radiological appearance of these lesions. The radiologist has a pivotal role as he should distinguish between primary and secondary tumors, integrating the clinical context to heighten diagnostic capabilities. The size of the lesions and their unilateral or bilateral character may also guide the radiologist but these criteria are not perfect. Presence of a mucinous lesion must systematically lead to a search for a primary gastrointestinal tract lesion (appendix, colon, stomach) and to lymph node or peritoneal involvement.

**Disclosure of interest**

The authors declare that they have no conflicts of interest concerning this article.

**References**


