Ovarian tumors are classified by the World Health Organisation into three main groups depending on whether they develop from the epithelial surface of the ovary (epithelial tumors), from germ cells (germ cell tumors), the ovarian stroma or the sex cords (sex cord-stromal tumors) (fig. 1).

The aim of this iconographic review was to illustrate the macroscopic-MRI correlations of ovarian tumors to identify certain key characteristic features of these tumors on MRI.

This iconographic review was performed using a file of images obtained on a Siemens 1.5 T MRI with TSE T2-weighted axial, coronal and sagittal sequences, axial T1-weighted sequences and axial T1 images with and without fat suppression and after gadolinium injection (4 mm thick slices, FOV 200 mm, matrix 320, intravenous injection of an antispasmodic drug).

Epithelial tumors

Epithelial tumors are the most frequent ovarian tumors, representing 60 % of all ovarian tumors and 85 % of malignant tumors. The prevalence increases with age, with a peak between 60 and 70 years old. They develop on the coelomic epithelium and cysts on the surface of the ovary. They can be classified into 5 morphological types: serous, mucinous, endometrioid, clear cell and transitional cell or “Brenner tumors”. The two most frequent histomorphologic types are the serous and mucinous forms. Each histomorphologic type has three corresponding histoprognostic types: benign, borderline (or low malignant potential) and invasive.

Serous and mucinous epithelial tumors

Sixty percent of serous tumors are benign, 15 % are borderline and 25 % are malignant.
Eighty percent of mucinous tumors are benign, 10-15 % are borderline and 5-10 % are malignant (1).

**Benign forms**

**Macroscopy**

Benign serous tumors are usually cystic (cystadenomas) but may also present as a half-solid, half-cystic (cystadenofibroma) or more rarely mainly solid (adenofibroma). Bilateral tumors suggest serous tumors. Serous cystadenomas are uni or bifocal, with thin walls of less than 3 mm (1). The mucinous cystadenoma is a larger sized cystic tumor which is usually unilateral and multifocal (fig. 2). The cystadenofibroma associates a cystic component which is often multifocal and a solid fibrous portion (2, 3). This tumor is difficult to diagnose because of the irregular presence (50 % of cases) of a solid component (which resembles a cystadenoma) and in certain cases, the latter can mimic a malignant form of the disease on imaging (4) (fig. 3). Cystadenofibromas are rare (2 % of ovarian tumors) essentially serous, more rarely mucinous or even endometrioid (2). Adenofibromas are white fibrous microcystic tumors.

**MRI**

Serous cystadenomas appear as a high intensity signal on T2-weighted images and may be unifocal or bifocal. Signals of foci are homogenous (fig. 4). Normally cystadenofibromas have a solid fibrous part which is linear or nodular, but with even contours and which characteristically results in a low intensity signal on T2-weighted images (2, 3) (fig. 5). Adenofibromas are solid tumors resulting in a low intensity signal on T2-weighted images (microcysts appear as high intensity signals); The different foci of mucinous cystadenomas have different signals on T1- and T2-weighted sequences depending on their contents (protein, mucinous) (1, 5, 6) (fig. 6).

A benign epithelial tumor is suggested in the presence of:
- A cystic tumor which is often bilateral, uni or bifocal with a thin wall, homogenous signal intensity with no solid component = serous cystadenoma;
- A cystic multifocal tumor with different signal intensities on MRI and no solid component = mucinous cystadenoma;
- A complex multi-cystic tumor with a small solid component, regular and linear with a clearly low intensity signal on T2-weighted images, with moderate and delayed enhancement = cystadenofibroma.

**Borderline forms**

Borderline forms are found in patients who are 10 to 15 years younger (1, 7, 8) than patients presenting with malignant forms, or around 45 years old. These tumors are defined by an epithelial proliferation without stromal invasion.

**Macroscopy**

These tumors are characterised by the presence of vegetations or endocystic or exocystic papillary excrescences covering the surface of the ovary. These papillary excrescences are more frequent in borderline forms but are non-specific. In macroscopic series, they were found in 20 to 26 % of benign tumors (fig. 7 and 8), 62-78 % of borderline tumors (fig. 9) and 59 to 92 % of malignant forms (6, 9). The number of foci in mucinous tumors seems to be correlated to a more aggressive form of the tumor in borderline and malignant tumors (5) (fig. 10).

A typical form: borderline tumors may also present as a mixed cystic multifocal tumor with a solid component, which is difficult to differentiate from a stage I malignant tumor (7). Specific form: surface serous papillary borderline tumors (10) are a tumoral sub-type which only develop exophytically on the surface of the ovary, while the ovary remains morphologically normal. It may be accompanied by ascites and invasive or non-invasive peritoneal seeding.

**MRI**

Vegetations appear as moderate intensity signals on T2-weighted images. They vary in number and are enhanced after gadolinium injection, so that they can be differentiated from any intracystic debris (fig. 9). Sometimes these vegetations may be pseudo-cystic (fig. 11). In surface papillary serous borderline tumors, the tumor may be large with a moderately intense signal on T2 weighted images of microlobulated contours forming “bunches” which are enhanced after contrast.
Fig. 3: Bilateral cystic ovarian tumors with solid portions (thick arrow) and vegetations (thin arrow) = bilateral serous cystadenofibromas.

- **a** Sagittal T2-weighted image.
- **b** Axial T1-weighted image.
- **c** Axial T1-weighted fatsat gadolinium enhanced image.
- **d** Axial T2-weighted image.

Fig. 4: Serous cystadenoma.

Unifocal thin walled cyst, homogenous signal.

- **a** Sagittal T2-weighted image.
- **b** Axial T2-weighted image.
- **c** Axial T1-weighted image.
- **d** Axial T1 fat sat gadolinium enhanced image.
Fig. 5: **Serous cystadenofibromas.**
Bilateral multifocal bilateral cysts with small solid linear components, clear low intensity T2 signal.

- **a** Axial T2-weighted image.
- **b** Axial T1-weighted image.
- **c** Axial T1 fat sat gadolinium enhanced image.

Fig. 6: **Mucinous cystadenoma.**
- **a** Sagittal T2-weighted image: voluminous, multifocal liquid tumor. The presence of small endocystic vegetations on the posterior of the cyst that are sometimes visible in benign tumors.
- **b** Axial T2-weighted image.
- **c** Axial T1-weighted image: foci with different signals.
- **d** Axial T1 fat sat gadolinium enhancement of the wall and septa.
Fig. 7: Bilateral serous benign tumors with a few small papillary endocystic projections.

a Coronal T2-weighted image centered on the right ovary.
b Coronal T2-weighted image centered on the left ovary.
c Axial T2-weighted image.
d Axial T1 fat sat gadolinium.
e Surgical sample.

Fig. 8: Benign epithelial adenofibroma type tumor with surface papillary excrescences.

a Axial T1-weighted image.
b Axial T1 fat sat gadolinium enhanced image.
c Axial T2-weighted image.
d Surgical sample (arrow = ovary, arrowhead = vegetations)
Fig. 9: Borderline bilateral serous tumors with profuse exo-vegetations (thick tumor) and especially endocystic (thin arrow).

a Axial T1-weighted image.
b Axial T2-weighted image.
c Coronal T2-weighted image.
d Sagittal T1 fat sat gadolinium: enhancement of vegetations.
e Macroscopic tissue sample.

Fig. 10: Voluminous mucinous borderline tumor.

a Axial T2-weighted image.
b Axial T1-weighted image: foci with different signals.
c Axial T1 fat sat gadolinium enhanced image.
d Surgical sample: necrotic hemorrhagic.
Although there is no stromal invasion in these borderline forms, 20% to 40% of the time there is peritoneal seeding (non invasive in 90% of cases) more frequently in exophytic forms (8, 11).

A borderline epithelial tumor is suggested in the presence of:

- Vegetations or papillary excrescences, specific for epithelial tumors ++++. More frequently found in borderline tumors but non specific: in a series of 58 tumors with vegetations there were 26 benign tumors, 13 borderline tumors and 19 malignant tumors showing the higher frequency of benign tumors (9);
- The number and size of papillary excrescences are predictive factors of malignancy (12);
- Numerous septa in a multicystic tumor with foci with different signal intensities on MRI, the number of septa in mucinous tumors has been correlated with tumoral aggressivity.

Malignant forms

Macroscopy

The association of a predominantly solid component, with thick irregular walls and septa (13), calcifications, necrotic and hemorrhagic degeneration suggests cystadenocarcinoma type malignancies (1).

MRI (fig. 13 and 14)

The presence of thick septa and a voluminous solid tumor suggests a malignant tumor, but a certain number of stage I malignant tumors do not have these features. In a series comparing 19 borderline tumors and 19 stage I malignant tumors; a threshold value of 4.5 mm thick septa provided a diagnosis of malignant forms with a sensitivity of 55% and a specificity of 94%; while a threshold value of 28.5% of solid tumor provided a diagnosis of malignant forms with a sensitivity of 55% and a specificity of 82% (7). The number of septa, mural nodules or vegetations are not a specific sign for one or the other of these two malignant forms (7).

In this case, lymph node invasion will be looked for, or peritoneal carcinosis while keeping in mind that peritoneal lesions may also be present in borderline forms.

A malignant epithelial tumor is suggested in the presence of solid-cystic tumors with thick walls and septa (> 4 mm), an irregular solid portion > 28 mm, hemorrhagic degeneration,
Fig. 12: *Right borderline serous micropapillary type ovarian tumor (arrow = vegetations).*

- **a** Axial T1-weighted image.
- **b** Axial T1 fat sat gadolinium enhanced image.
- **c** Axial T2-weighted image: surface papillary excrescences attached to an ovary with normal morphology.
- **d** Surgical sample.

Fig. 13: *Serous cystadenocarcinoma.*

- **a** Axial T2-weighted image.
- **b** Axial T1 fat sat gadolinium enhanced image: enhancement of thick wall and solid parts of tumor.
peritoneal seeding and adenomegalies; false positives: cystadenofibromas with an atypical solid portion.

Other less frequent forms of epithelial tumors

Endometrioid tumor
The histomorphological type “endometrioid” is malignant in 97% of endometrioid adenocarcinomas which represent 10% to 15% of ovarian cancers. Its peak prevalence is also in women between the ages of 50-60 years old.

Macroscopy
The tumor lacks specificity and presents as a large (10-20 cm) solid-cystic multifocal mass which is unilateral in 70% of cases, and frequently associated with hemorrhagic degeneration (fig. 15).

MRI
The solid portion of this tumor is rapidly and intensely enhanced (1). An association with hyperplasia or endometrial carcinoma is described in 15% to 20% of cases, thus endometrial thickening should be looked for (1). Associated ovarian endometriosis is also described in 23% of cases, and occurs in patients who are 5 to 10 years younger than average (6).

Clear cell tumors
Clear cell carcinomas are also a unique histoprognostic form of clear cell tumors and represent 5% of ovarian carcinomas, often with a better prognosis than others, because most are discovered at stage I (1).

Macroscopy
These tumors present in the form of a cyst which is often unifocal with a few solid, often rounded protrusions.

MRI (fig. 16)
The signal of the cyst on T1-weighted images varies. An association with ovarian endometriosis is described in nearly 40% of cases (6). An endometrioma with a mural nodule or with a solid component suggests malignancy (1, 6).

Transitional cell epithelial tumors or “Brenner tumors”
They are benign in 98% of cases and occur in patients in their 50’s.
Fig. 15: Endometrioid carcinoma of the left ovary.
(ovary = thick arrow, solid portion = long arrow, cystic portion = short arrow).

a Axial T1-weighted image.
b Axial T2-weighted image.
c Axial T1 fat sat gadolinium enhanced image.
d Surgical sample.

Fig. 16: Clear cell carcinoma.
Unifocal cystic tumor with enhancement of solid rounded protrusion.

a Axial T2-weighted image.
b Axial T1-weighted image.
c Axial T1 fat sat gadolinium enhanced image.
d Axial T1 fat sat gadolinium enhanced image.
Macroscopy
These tumors usually present in the form of small sized (less than 2 cm) well circumscribed, solid, fibrous, often partially calcified tumors containing microcysts. They more rarely present as a multifocal cystic tumor with a solid component (1).

MRI
The fibrous form results in a clearly low intensity signal on T2-weighted images which is more marked than in other solid fibrous tumors (6) but is non-specific, and also present in fibrothecal type tumors. Enhancement is weak and discretely heterogenous after injection of contrast medium. They may be associated with other ovarian tumors in 30 % of cases, often mucinous tumors in the same ovary (1, 6).

Germ cell tumors
Germ cell tumors are the second most frequent group representing 20 % to 30 % of ovarian tumors. They develop from germ cells and are divided into two categories: teratomas (multiple tissue and single tissue) and non-teratomous tumors.

Mature cystic multiple-tissue teratoma (dermoid cyst)
This is the only benign germ cell tumor and it represents 95 % of germ cell tumors (1). It occurs in young women (an average of 30 years old), is unilateral in 90 % of cases and slow growing (14). The mature cystic teratoma is a benign ovarian tumor most frequently found in women under the age of 45 (1, 20).

Macroscopy
This tumor associates ectodermic (pilosebaceous parts, teeth), mesodermic (fat, osteocartilagenous tissue, muscle) and/or endodermic (thyroid tissue, bronchial or gastrointestinal epithelium) debris. It presents in the form of a unifocal cystic tumor in 88 % of cases (1, 14). The wall is thin and smooth with a tissular protubercence on the internal side, or a Rokitansky nodule, which has hair and body hair sprouting from it and my contain osteocartilagenous tissue or teeth (present in 31 % of cases) (1, 6, 14). The presence of fat in an ovarian tumor is basically pathognomonic of a mature teratoma. The fat may be present in several forms (14):

- sebum produced by pilosebaceous annexes that fill the cavity of the cyst (which is liquid at body temperature, and semi-solid during macroscopic examination).
- fatty tissue in the walls of the cyst or the Rokitansky nodule.
- finally, spheres of lipid material which may be quite numerous (more than 100) floating in the cystic lumen corresponding to a collection of lipid material around a nidus of debris, hair, or desquamous material (14, 15).

MRI
The fatty component results in a high intensity signal on T1-weighted images which disappears during fat saturation which is the key diagnostic feature (1, 6, 14, 16) (fig. 17).

Fifteen percent of teratomas have no intracavitary sebaceous component (17). In this case the cavity is filled with various secretions, depending on the type of teratoma (digestive, bronchial, colloid secretions…). In half of these teratomas without intracavitary sebum, the fatty component is only present in the wall of the cyst or the Rokitansky nodule in the form of focal fatty areas (fig. 18) that may be easier to see on in-phase and out-of-phase gradient echo sequences than on fat saturated sequences (14, 15). No fat is found in seven percent of teratomas, making diagnosis a
problem. In rare cases mature teratomas have a fatty component alone, mimicking a lipoma (17). After injection of contrast medium, cyst enhancement varies. Normally the walls and septa are enhanced. The Rokitansky nodule may be weakly enhanced or not: the periphery of the nodule (cutaneous surface) is often enhanced while the central part (adipose tissue, muscles, teeth) is not. The mature teratoma may be associated with another germ cell tumor resulting in a combined tumor (with different histological components which have all developed from the same stem cell), a mucinous tumor or a cystadenocarcinoma resulting in a combined tumor (composed of two histologically different components which are adjacent with no mixed histological interface) (17).

**The other germ cell tumors**

The remaining 5% of tumors include immature multiple tissue teratomas, single tissue teratomas (ovarii stroma, carcinoid tumors, neuroectodermic tumors) and non teratomatous tumors (dysgerminomas, embryonic carcinomas, vitelline tumors). Immature multiple tissue teratomas are rare malignant tumors in young women (14, 19), (in their twenties). They are fast growing, with frequent capsular rupture (1, 14). There is the mature form (dermoid cyst) characterized by a predominantly solid component (composed of immature neuroectodermic tissue) necrotic hemorragic degeneration and large scattered undifferentiated calcifications (not located on the Rokitansky nodule) associated with previously described mature ecto-mesoendodermic elements (14, 18). Normally there is no liquid cystic component (13). Ovarian goiters (struma ovarii) represent 2.7% of teratomas. This entity should be suspected in the presence of multilocular cysts with multiloculated surfaces with a solid component and with certain foci that produce high intensity signals on T1-weighted images (colloid). There may be hypervascular portions to the tumor (14, 19). Dysgerminomas are solid multilobular tumors filled with fibrovascular septa which may include calcifications and necrotic elements. In 5% of cases, syncytiotrophoblast cells in the tumor are the cause of increased Beta HCG in plasma (1).

To confirm the diagnosis of a multiple tissue teratoma in a tumor with fatty components:

The only two ovarian tumors which contain fat are mature and immature multiple tissue teratomas; the latter are much rarer and can be differentiated from the mature form by a predominantly solid component and large scattered calcifications.

**Sex cord-stromal tumors**

They represent 8% of all ovarian tumors and are found in all age groups. They can be divided into two groups:
Tumors developing from the gonadal stroma: fibromas, thecomas, sclerosing stromal tumors.

Tumors developing from the sex cord: granulosa cell tumors, Sertoli-Leydig tumors

This group of tumors has the particularity of sometimes being associated with hormonal activity such as the production of estrogens or androgens. The solid component is often seen as a low intensity signal on T1-weighted images and a clearly low intensity signal on T2-weighted images because of the fibrous stroma. Most of these tumors are benign (fibrothecoma, sclerosing stromal tumor) or limited to the ovary at diagnosis (1).

**Fibrothecal tumor group**

This group makes up approximately 90 % of sex cord-stromal tumors. It includes fibromas and thecomas. The latter are often associated with a fibrous component and therefore called fibrothecomas (19). All of these tumors are benign and are found during menopause. The fibroma is the most frequent sex cord-stromal tumor. Unlike fibromas, thecomas or fibrothecomas include estrogen activity in 50 % of cases and more rarely androgen activity in 10 % of cases because of thecal cells (19). These tumors are associated with pleural and peritoneal effusion during Meigs syndrome, which can cause confusion in the diagnosis especially if there is an associated extra-ovarian cancer.

**Macroscopy**

Solid fibrous tumors sometimes include cystic or edematous elements. Calcifications are often observed.

**MRI**

Because they are mainly fibrous, these tumors appear as low intensity signals in T1-weighted images with a characteristic clearly low intensity signal on T2-weighted images (21). Intratumoral cystic and edematous degeneration can be seen in fibrothecomas, which gives them a more heterogenous T2-weighted signal (low, iso and high intensity signal), than fibromas (1, 6, 19). These features can be seen in large fibromas and may be associated with hemorrhagic degeneration which is confusing in case of torsion. After injection of contrast medium, enhancement is weak and delayed in fibromas. Enhancement of fibrothecomas varies, according to whether they are predominantly fibrous or thecal. Thecal cells are hypervascularized (19) (fig. 19). During the premenopausal period, fibromas can often be found developing exophytically alone while the morphology of the ipsilateral ovary remains normal (22).

**Other sex cord-stromal tumors**

They are very rare (no cases in the retrospective surgical series by Bazot including...
168 ovarian tumors, with 16 sex cord-stromal tumors that were fibromas and fibrothecomas (9)).

Sclerosing stromal tumor
This is a rare benign tumor that occurs 80% of the time in young women with irregular cycles between the ages of 20 and 40 (21, 23).

Macroscopy
Often large, it is associated with a cystic component and a solid heterogenous component.

MRI
The solid portion appears as a variable signal on T2-weighted sequences and has characteristic early peripheral enhancement which progresses in a centripetal way (“hepatic hemangioma-like”) (23) so that these tumors can be differentiated from fibrothecal tumors which have slow uptake and weak enhancement and epithelial tumors which have early enhancement and wash out (1, 21, 23).

Sertoli-Leydic cell tumors
They represent 0.5% of ovarian tumors. They are low-grade malignant tumors that occur in women before the age of 30. They are usually unilateral and limited to the ovary in 80% of cases (19). In 30% of cases, this tumor has hormonal activity, the production of androgens, causing a virilization syndrome. It is the most frequent tumor to cause virilization (21).

Macroscopy
It is a well circumscribed unilateral solid or half-solid half-cystic tumor (intratumoral cysts of various sizes).

MRI
The lower the signal intensity on T2-weighted images, the greater the fibrous component of the tumor. Enhancement is not specific, and is relatively homogenous, sometimes except for the intratumoral cysts (fig. 20).

Granulosa cell tumors
They represent 1 to 2% of ovarian tumors and approximately 10% of sex cord-stromal tumors. This malignant tumor is often limited to the ovary at diagnosis and is markedly less apt to invade the peritoneum than epithelial tumors. It is the most frequent malignant sex cord-stromal tumor, and may secrete estrogen (1, 21). This estrogen secretion is not specific and is found less often than in thecomas, sclerosing stromal tumors, certain epithelial tumors (serous, mucinous, endometrioid) and metastases (19). More rarely, these tumors can cause virilization due to androgen secretion. The cystic forms are more apt to cause these symptoms (19). Granulosa cell tumors are classified into two sub-types: juvenile and adult. The juvenile form is rare (5% of granulosa tumors) and occurs in children before puberty. The adult form, which is predominant (95% of granulosa tumors) develops during the menopausal and postmenopausal period (21, 24).

Macroscopy
These tumors are very polymorphic and may be completely solid or multifocal cystic tumors, but are usually mixed, associating solid and cavity areas (21, 25). Necrotic hemorrhagic degeneration may be found, especially in the juvenile form. Unlike epithelial tumors, these tumors never have papillary excrescences.

MRI
Non-specific polymorphous features. Often associated with endometrial anomalies.

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**Fig. 20:** Sertoli-Leydic cell tumor. Solid tumor of the left ovary with intratumoral cyst.

a Axial T1-weighted image.
b Axial T2-weighted image. (high intensity signal on the cyst: arrow).
c Axial T1 fatsat gado-linium enhanced image.
d Surgical tumor sample.
A fibrothecal type tumor (fibroma, fibrothecoma) is suggested by a solid fibrous tumor with a clearly low intensity signal on T2-weighted images with delayed moderate enhancement.

The differential diagnosis Brenner tumors which are often smaller, adenofibromas and cystadenofibromas (with an associated cystic component). The thecal component is suggested if the T2-weighted signal is more heterogenous, with more intense enhancement which may be associated with endometrial thickening (estrogen secretion).

A sclerosing stromal tumor is suggested by a solid fibrous tumor with “hemangioma-like” enhancement in a young woman. A Sertoli-Leydick cell tumor is suggested by a solid or solid-cystic tumor in a young woman with a virilisation syndrome.

A fibrothecal type tumor (fibroma, fibrothecoma) is suggested by a solid-cystic tumor with necrotic-hemorrhagic degeneration.

A granulosa cell tumor is suggested by a mixed tumor with necrotic-hemorrhagic degeneration without vegetations associated with endometrial anomalies.

The purpose of this diagnostic approach is to choose the best possible surgical procedure. Indeed, radical surgery by laparotomy will be performed in a suspected malignant tumor. Conservative treatment (uni or bilateral annexectomy) with omentectomy will be chosen in borderline tumors with an appendectomy in mucinous forms. Celsoscopic removal of a benign tumor that appears to be mucinous will be associated with the use of a collection bag, such as the “endobag” to prevent the risk of disintegration and peritoneal seeding during tumor removal.

Besides conventional morphological imaging, quantitative analysis of tumoral perfusion thanks to dynamic contrast enhanced imaging techniques (26), as well as newer techniques (diffusion imaging, spectroscopy) have the additional potential value of increasing tumor characterisation.

Conclusion

Diagnosis of primary ovarian tumors is sometimes difficult and may be confusing. However, on conventional morphological imaging, certain key points provide precious diagnostic information. The following benign tumors can be identified with certainty: serous cystadenomas (uni or bifocal cyst with a thin wall, mimicking a functional cyst), fibrous tumors with a characteristic low intensity T2-weighted signal (Brenner’s tumor, fibroma and fibrothecoma), mature teratoma (pathognomonic fatty component). The cystadenofibroma may be a false positive of malignant epithelial lesions. The clinical context is always helpful (a young woman with a virilisation syndrome for Sertoli-Leydick cell tumor) with endometrial thickening (estrogen secretion).

A granulosa cell tumor is suggested by a mixed tumor with necrotic-hemorrhagic degeneration without vegetations associated with endometrial anomalies.

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