Ovarian tumors in children and adolescents: A series of 41 cases

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**Abstract**

**Objective:** Pictorial review with a detailed semiological analysis of ovarian tumors in children and adolescents to provide a relevant diagnostic approach.

**Patients and methods:** Retrospective study (2001–2011) of 41 patients under the age of 15 who underwent surgery for an ovarian mass with a definite pathological diagnosis.

**Results:** Sixty-two percent of the lesions were benign, 33% were malignant and 5% were borderline. Germ cell tumors were most frequent (77.5%), followed by sex cord stromal tumors (12.5%) and epithelial tumors (7.5%). Malignant tumors were more frequent in children between 0 and 2 years old. On imaging, calcifications and fat were specific for germ cell tumors; the presence of a mural nodule was predictive of a mature teratoma ($P < 0.001$). Predictive factors for malignancy were clinical, including abdominal distension ($P < 0.01$) or a palpable mass ($P = 0.05$), biological, including increased hCG and/or AFP levels ($P < 0.001$) and radiological, including tumors larger than 12 cm ($P < 0.05$), tumoral hypervascularity ($P < 0.01$) and voluminous ascites ($P < 0.01$).

**KEYWORDS**

Ovary; Tumor; Imaging; Children; Adolescents

**Abbreviations:** MRI, Magnetic resonance imaging; CT, Computed tomography; MGT, Malignant germ cell tumor; AFP, Alpha-fetoprotein; hCG, Human chorionic gonadotropin; Se, Sensitivity; Sp, Specificity; PPV, Positive predictive value; NPV, Negative predictive value.

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The diagnosis of ovarian tumors in pediatrics is often difficult and delayed because of non-specific symptoms and diverse presentations on imaging.

These rare tumors occur in an estimated 2.6/100,000 girls per year, excluding functional lesions [1,2]. Ten to 20% are malignant [3–6] and they represent 3% of cancers in girls under the age of 15 [7]. The World Health Organization has classified these tumors into three main groups according to whether they develop from epithelial cells, germ cells or sex cord stromal tumors. Primary or secondary locations are possible in leukemias or lymphomas [8,9].

Nevertheless, understanding of ovarian tumors in this age group is limited and the goal of this study was to analyze the diagnostic value of imaging features and suggest a diagnostic approach to ovarian masses in children or adolescents.

Patients and methods

Patients

This retrospective study was performed from April 2001 to September 2011 based on pediatric surgical archives at the Bicêtre Hospital. Inclusion criteria were:

- patients under the age of 15 at diagnosis;
- a definite pathological diagnosis for each lesion;
- initial pre-treatment imaging available for analysis (ultrasound, CT or MRI).

Data collection

Data were obtained from the medical files of patients in the hospital’s digital filing system. The following information was obtained: age at diagnosis, stage of puberty (puberty defined as the presence of a menstrual cycle), medical history, symptoms, adnexal torsion or tumor rupture (surgical data), serum levels of AFP, total hCG, free β-hCG, CA 125, inhibin B and the presence or not of an inflammatory syndrome as well as a pathological diagnosis. Lesions were classified as benign, borderline or malignant.

Imaging results were all reassessed with an evaluation guide (EP). Imaging criteria included:

- the diameter of the mass at its widest axis;
- the cystic features of the lesion (multicompartmental cysts were considered to be pure cysts), solid (no cystic component) or mixed and the proportion of different components (more or less 50%);
- the presence of tumoral calcifications, intratumoral fat, compartments, blood, papillary vegetations (millimetric) or mural nodules (centimetric);
- whether the lesion was vascularized or not;
- associated abnormal endometrial thickening (in prepubescent children suggesting an abnormally pubescent uterus, or more than 15 mm thick in post-pubescent patients);
- the presence of ascites (considered to be voluminous if not limited to the pelvis);
- topographic criteria included: the presence of single, multiple or bilateral lesions, and any extra-ovarian extension (peritoneum, lymph nodes).

Three age groups were defined: 0–2 years old, older than 2 and not pubescent and pubescent.

Data analysis

The Chi² test was used to compare qualitative variables, with Yates correction for groups of fewer than 5. The Mann Whitney test was used to compare quantitative variables and a ROC curve was obtained. \( P \leq 0.05 \) was considered to be significant.

Results

Forty-one patients were included in the study. None of the patients were excluded.

Patient characteristics are summarized in Table 1 and the distribution of different types of lesions is summarized in Table 2.

Thirty-nine patients had a single lesion, one patient had a mature bilateral teratoma, and one patient had multiple bilateral sclerosing stromal tumors (0.5–5 cm); only the largest tumor was considered for analysis. Thus, 42 lesions were studied.

The patient with sclerosing stromal tumors had a history of metastatic medulloblastoma with suspected Gorlin syndrome (hereditary disease characterized by a group of developmental anomalies and a predisposition to develop different tumors).

Fig. 1 shows the distribution of the different types and classes of lesions in relation to age and stage of puberty.

Abdominal distension and the presence of a palpable mass were significantly associated with malignancy (Table 3). Fifteen patients (36.5%) presented with the clinical signs of a surgical emergency with nausea and vomiting; the presence of vomiting was significantly associated with ovary torsion \( (P < 0.001) \). The five cases with fever corresponded to three benign tumors associated with adnexal torsion and partial or total necrosis of the ovary and two malignant tumors with signs of necrosis on histology. One tumor was discovered by chance during an ultrasound for an inguinal hernia. One patient with hemorrhagic shock had a
ruptured immature teratoma. Early puberty was a complication in malignant tumors (a juvenile granulosa cell tumor and the only unclassifiable mixed tumor); a mature teratoma was discovered by chance because of an indication for ultrasound. One case of virilization with no signs of puberty was found in one of the patients with sclerosing stromal tumors. Post-pubertal metrorrhagia revealed a sex cord tumor with annular tubules.

**Biology**

Preoperative serum levels of AFP and hCG were available in all patients. AFP levels were increased in all malignant germ cell yolk sac-type tumors (or presenting with a component of this type of tumor) and in immature teratomas. An increase in HCG levels was observed in the seminoma and an immature teratoma. An increase in these markers (AFP and/or hCG) suggested a malignant germ cell tumor (MGT) \((P < 0.001)\) with a sensitivity of 78%, a specificity of 100%, a PPV of 100% and a NPV of 94%.

Inhibin levels were determined in two patients; it was normal in the juvenile granulosa cell tumor and elevated in the unclassifiable mixed germ cell and sex cord stromal tumor.

CA 125 serum levels were determined in 10 patients. They were increased in the two immature teratomas, two juvenile granulosa cell tumors, the case of hemorrhagic infarction

<table>
<thead>
<tr>
<th>Lesions</th>
<th>Benign</th>
<th>(n)</th>
<th>Borderline</th>
<th>(n)</th>
<th>Malignant</th>
<th>(n)</th>
<th>Tumors (n) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Germ cell tumors</strong></td>
<td>Mature teratomas</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sex cord and stromal tumors</strong></td>
<td>Sclerosing stromal tumors</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Epithelial tumors</strong></td>
<td>Mucinous cystadenomas</td>
<td>1</td>
<td>Mucinous cystadenofibromas</td>
<td>1</td>
<td></td>
<td>3 (7.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mucinous intestinal—type tumors</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Other tumors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Non-tumoral lesions</strong></td>
<td>Hemorrhagic cyst</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pseudotumoral hemorrhagic infarction</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>26 (62)</td>
<td></td>
<td>2 (5)</td>
<td></td>
<td></td>
<td>14 (33)</td>
</tr>
</tbody>
</table>
of the ovary and in the borderline mucinous intestinal-type tumor.

**Imaging**

Initial imaging included twenty-seven abdominal plain films (APF) 40 ultrasounds, 27 CT scans and 12 MRI. Four patients underwent surgery based on sufficient ultrasound results (without CT scan or MRI). Twenty-six of the 27 CT scans were performed immediately following injection of an iodated contrast medium \( (n = 6) \) or before and after injection \( (n = 20) \). All MRI \( (n = 12) \) examinations included fat-suppressed T1- and T2-weighted sequences and an examination performed on at least two spatial planes. Eleven MRI were performed before and after gadolinium injection with fat-suppressed T1-weighted sequences.

Ultrasound was the primary imaging technique in 95% of cases \( (n = 39/41) \) and always identified a mass. APF identified calcifications with a sensitivity of 76%, a specificity of 100%, a positive predictive value (PPV) of 100% and a negative predictive value (NPV) of 71%.

The mean size (largest axis) of benign lesions was 113 mm \((20–317, \text{median } 90 \text{ mm})\), while that of borderline and malignant lesions was 162 mm \((47–270, 170)\). In multiple bilateral sclerosing stromal tumors, only the size of the largest lesion was taken into account to determine the

**Table 3** Predictive factors of malignancy.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Benign lesions</th>
<th>Borderline or malignant lesions</th>
<th>( P )</th>
<th>Se (%)</th>
<th>Sp (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Palpable mass</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>11/25</td>
<td>12/16</td>
<td>0.05</td>
<td>75</td>
<td>56</td>
<td>52</td>
<td>78</td>
</tr>
<tr>
<td><strong>Distended abdomen</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>5/25</td>
<td>11/16</td>
<td>&lt;0.01</td>
<td>69</td>
<td>80</td>
<td>69</td>
<td>80</td>
</tr>
<tr>
<td><strong>Enhancement and/or vascularization on doppler US</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>6/21</td>
<td>12/15</td>
<td>&lt;0.01</td>
<td>80</td>
<td>71</td>
<td>67</td>
<td>83</td>
</tr>
<tr>
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<td>6</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tumor components</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predominantly cystic</td>
<td>19</td>
<td>7</td>
<td>0.06</td>
<td>56</td>
<td>73</td>
<td>56</td>
<td>73</td>
</tr>
<tr>
<td>Predominantly solid</td>
<td>7</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Voluminous ascites</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0/25</td>
<td>5/16</td>
<td>&lt;0.01</td>
<td>31</td>
<td>100</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td><strong>Size of the lesion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \geq 12 \text{cm} )</td>
<td>8</td>
<td>11</td>
<td>0.04</td>
<td>69</td>
<td>69</td>
<td>58</td>
<td>78</td>
</tr>
<tr>
<td>(&lt; 12 )</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Se: Sensitivity; Sp: Specificity; PPV: Positive predictive value; NPV: Negative predictive value.
different parameters. The threshold of 121 mm provided a better discrimination between malignant forms (or borderline) and benign forms ($P = 0.04$) (Table 3).

Distribution of the cystic and solid features of the lesions was not predictive of histological types ($P = 0.06$) (Table 3, Figs. 2 and 3). The presentation of juvenile granulosa cell tumors ($n = 3$) varied (one cystic, one solid, one mixed) but epithelial tumors ($n = 3$) were always predominantly cystic.

Compartments were found in 17/31 germ cell tumors (55%), two of the five sex cord stromal tumors (40%), all epithelial tumors, hemorrhagic infarction of the ovary and hemorrhagic cysts. No intracystic papillary vegetations were found.

A mural nodule protruding from a cystic lumen was only found in germ cell tumors: 77% of mature teratomas ($n = 17/22$) and two MGT (Fig. 4). This was highly predictive of a mature teratoma ($P < 0.001$) with a specificity of 90%, a sensitivity of 77%, a PPV of 89% and a NPV of 78%.

Tumoral enhancement and/or vascularization on Doppler ultrasound were significantly associated with malignancy ($P < 0.01$) (Table 3, Fig. 5).

Intratumoral fat was only detected on CT scan (density below $-20$ HU and usually near $-100$ HU) or MRI (hypersignal on T1- and T2-weighted sequences that disappeared after fat suppression) in the group of germ cell tumors: 88% of the mature teratomas evaluated on CT scan or MRI ($n = 15/17$) as well as immature teratomas (Table 4, Figs. 4 and 6).

Intratumoral calcifications were only detected on ultrasound, CT scan or APF in the group of germ cell tumors: 73% ($n = 16/22$) of mature teratomas, 67% ($n = 6/9$) of MGT (Table 4, Fig. 6). Calcifications could correspond to ossifications, teeth or calcified material. Teeth were found in the macroscopic examination of seven mature teratomas and a tooth bud in an immature teratoma; these were difficult to identify on imaging.

Intratumoral blood was detected in three patients on MRI and presented as a hypersignal on T1-weighted sequences that disappeared after fat suppression. These included a hemorrhagic cyst, hemorrhagic infarction of the ovary and a juvenile granulosa cell tumor (Fig. 3).

Voluminous ascites was found in 5 malignant tumors, including four ruptures; it was significantly associated with malignancy ($P < 0.01$) (Table 3).

Abnormal endometrial thickening was found in two of the three cases of granulosa cell tumors with, in one case, the association of a prematurely pubescent uterus (Fig. 7). The appearance of the uterus was normal in all other types of tumors.

The results of assessment of tumor extension showed retroperitoneal lymph node extension in a seminoma. No other metastases were identified.

**Surgical results**

In 12 cases associated torsion was identified during surgery that had not been detected on preoperative imaging: 75% ($9/12$) were associated with a mature teratoma, 8.5% ($1/12$) with a malignant tumor and 16.5% ($2/12$) with a non-tumoral lesion.

In five cases a spontaneous tumor rupture was discovered during surgery: four malignant tumors and the hemorrhagic cyst.

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**Figure 2.** Sclerosing stromal tumors. Premenarchal 12-year-old girl with a history of metastatic medulloblastoma presenting with signs of virilization (acne, low voice and significant weight gain). Presence of enhancement of masses following gadolinium injection (arrows). a: axial MRI T2-weighted images (WI); b: axial T1-WI; c and d: axial T1-WI with fat suppression after gadolinium injection. Two stage surgical treatment (bilateral annexectomy).

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Figure 3. Juvenile granulosa cell tumor. Postmenarchal 14-year-old girl presenting with abdominal pain. Increased CA 125. Normal inhibin, AFP and HCG values. Cystic and tissue mass that enhanced after gadolinium injection with hematic sediment indicating hemorrhage (arrows), associated with voluminous ascites. a: ultrasound (US); b: axial MRI T1-WI; c: axial T1-WI with fat suppression; d: axial T2-WI; e: coronal T1-WI with fat suppression after gadolinum injection. Surgical treatment (right annexectomy and omentectomy) associated with chemotherapy because of spontaneous tumor rupture.

Figure 4. Mature teratoma. Premenarchal 12-year-old girl presenting with abdominal pain. a: US: diagnosis suspected in the presence of a cystic mass with echogenic mural nodule, confirmed by MRI; b: coronal T2WI; c: axial T1WI; d: coronal T1WI with fat suppression before gadolinium injection and e: after injection: presence of fat in the Rokitansky protuberance (black arrows). Linear central nodule enhancement following gadolinium injection (white arrow). Conservative treatment with tumorectomy.
Discussion

Ovarian tumors in girls and adolescents represent a very heterogeneous group of histopathological entities. Large pediatric series (more than 40 cases) are rare with very few descriptions of imaging results [3,4,6,10]. Two older series were mainly based on ultrasound [6,10]. The studies by Brookfield et al. [3] in 1037 malignant ovarian tumors and by Oltmann et al. [4] in 424 ovarian masses mainly evaluated treatment. Several excellent imaging reviews have recently been published, but without analysis of a series [5,9,11].

The frequency of different pediatric ovarian tumors observed in this series is similar to existing results in the literature. Germ cell tumors represent more than 80% of ovarian tumors (77.5% in this series). Mature teratomas, or dermoid cysts, are the most frequent tumors and the only benign germ cell tumor. The MGT are, in fact, often mixed [5,8,12]. Sex cord and stromal tumors represent 5–10% of ovarian tumors (12.5% in this series). Benign tumors are unusual in this pediatric population and the most frequent malignant tumors are granulosa cell tumors [5,13]. Epithelial tumors (approximately 10% of ovarian tumors, 7.5% in this series) are rare before puberty and usually benign [14].

Table 4  Predictive factors of germ cell tumors.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Germ cell tumors</th>
<th>Other lesions</th>
<th>P</th>
<th>Se</th>
<th>Sp</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>19/26</td>
<td>0/11</td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data not available</td>
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<td></td>
<td></td>
<td>73</td>
<td>100</td>
<td>100</td>
<td>61</td>
</tr>
<tr>
<td>Calcifications</td>
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<td></td>
</tr>
<tr>
<td>Yes</td>
<td>22/31</td>
<td>0/11</td>
<td>&lt; 0.001</td>
<td>71</td>
<td>100</td>
<td>100</td>
<td>55</td>
</tr>
</tbody>
</table>

Se: Sensitivity; Sp: Specificity; PPV: Positive predictive value; NPV: Negative predictive value.

Figure 5.  Three examples of malignant ovarian tumors. Seminoma in a premenarchal 10-year-old girl presenting with abdominal pain, a palpable mass, fever and increased HCG levels: lobulated mass with hypervascularity on Doppler US and calcifications (arrow). a: US; b: axial CT (computed tomography) after contrast injection. Yolk sac tumor in a premenarchal 11-year-old girl presenting with abdominal pain, a palpable mass, fever and increased AFP levels. c: axial CT after contrast injection: huge mass with tortuous vascular structures inside (arrow). Granulosa germ cell tumor in a 6-month-old infant presenting with precocious puberty (breast and labial enlargement, endometrial hemorrhage) and abdominal distension. d: axial CT after contrast injection: enhancing mass with extensive ascites. Sex cord tumor with annular tubules in a postmenarchal 12-year-old girl presenting with abdominal pain and intermenstrual bleeding: well-limited mass enhancing after injection. e: axial MRI T2WI; axial T1WI with fat suppression after gadolinium injection.
Teratomas. Mature teratoma in a 12-year-old postmenarchal girl presenting with abdominal pain and a palpable mass; a: axial CT without contrast injection: the lesion is mainly cystic with the presence of fat (white arrow) and calcifications; b: coronal CT after contrast injection: no enhancement. Immature teratoma in a 8-year-old girl presenting with abdominal pain, abdominal distension and AFP, HCG and CA 125 levels. c: axial CT without contrast injection: mainly cystic mass with the presence of fat (white arrow) and calcifications (black arrow); axial CT after contrast injection: enhancement of the solid parts of the tumor. Total annexectomy associated with chemotherapy because of incomplete macroscopic resection.

The prognosis of ovarian tumors in children and adolescents is generally excellent as long as they are managed rapidly, which emphasizes the importance of an early and precise diagnosis. Conservative treatment is indicated in benign tumors, especially since there is a risk of contralateral lesions, especially in mature teratomas. Treatment of a suspicious lesion is surgical (or after chemotherapy in an inoperable lesion) and preserving fertility is a major concern.

Juvenile granulosa cell tumor. Premenarchal 12-year-old girl presenting with abdominal pain, distended abdomen and a palpable mass. Increased CA 125. a and b: axial MRI T1WI without gadolinium injection and T1WI with fat sat suppression after injection: cystic lesion with enhancement of the walls and septa (white arrow); c: sagittal T2WI: marked thickening of the endometrium. Surgical treatment with left ovariectomy.
consideration in children. A diagnostic biopsy is indicated in suspicious inoperable lesions with no increase in tumor markers or in case of bilateral lesions if a hemophagocytosis is suspected [7,8,14].

The frequency of malignant tumors varies in the literature (9.5% and 21%) and is probably overestimated because of a surgical recruitment bias like in this study (33%) [4,6]. The risk of malignant ovarian tumors in pediatrics is considered to increase with age [3,6], except in one study in which the population with the highest risk was between 1 and 8 years old [4]. On the contrary 100% of the tumors in our study were malignant in patients under 2 years old (n = 2) then the rate of malignancy decreased with age. This difference is probably due to the purely “pediatric” population in our series (100% of the patients were under 15 compared to 38% in the study by Brookfield et al. [3]). Also, unlike in other series [3,4,6,10], the absence of malignant epithelial tumors in our study is probably due to a lower proportion of adolescents.

Although the number of patients with each type of tumor was limited because they are all rare entities, this pediatric series defines the diagnostic value of different imaging features. This study confirms that the presence of fat is specific for germ cell tumors and very frequent (88% of mature teratomas and 100% of immature teratomas) but does not differentiate between benign and malignant tumors. Calcifications are also very specific for germ cell tumors (73% of mature teratomas and 67% of MGT) but calcifications have occasionally been reported in other types of tumors [15] and this feature does not distinguish a benign from a malignant tumor. In particular a tooth bud was found in an immature teratoma in this series. A mural nodule, corresponding to a Rokitansky protuberance appears to be fairly specific for mature teratomas [16–20]. However, in our experience it may be difficult to distinguish from a portion of fleshy tumor tissue. The juvenile granulosa cell tumor can have various, non-specific features, with necrotic and hemorrhagic aspects. [13,15]. It is therefore interesting to identify other diagnostic features such as abnormal thickening of the endometrium or signs of abnormal estrogenic impregnation in a pre-pubertal child [13] (2/3 cases in this series). The other sex cord stromal tumors are rare and there are no specific features. Epithelial tumors are often cystic, as in this series. Papillary vegetations, pathognomonic for epithelial tumors, were not observed in this study. [21].

Besides metastases, which provide a diagnostic sign at much too late a stage, this pediatric study suggests that there are predictive diagnostic imaging criteria for malignant ovarian tumors in children: • tumor enhancement (or vascularization on Doppler ultrasound) must be carefully looked for. Unlike in adults, dynamic imaging studies are not routinely performed in children [4,6]; • the size of a tumor with a threshold of 12 cm, which is much larger than the 8 cm indicated in the literature [4]; • voluminous ascites.

Clinically, the most frequent symptoms are pelvic pain, a palpable mass or abdominal distension. The clinical picture may be a surgical emergency (nausea, vomiting) during torsion or tumoral rupture. Adnexal torsion is the main complication of ovarian tumors, in particular mature teratomas (3.2–16%) [22] but is probably underestimated because none of the 12 adnexal torsions identified during surgery in this series were identified during the preoperative assessment. However, most adnexal torsions are not tumoral and this complication rarely reveals a malignant tumor (8.5% in this series and 1.8% in the literature [23]). Sometimes an endocrine disorder (early puberty, post-pubescent menorrhagia, virilization) reveals sex cord stromal tumors [8,15,24]. Clinically predictive criteria for malignancy were abdominal distension and the presence of a palpable mass. Tumoral markers are essential for diagnosis, emphasizing the importance of testing before any ablation is performed. AFP, which is a sign of the presence of a yolk sac component and hCG, a sign of syncitio-trophoblast cells, are specific for teratomas. An increase in these markers in immature teratomas indicates mixed teratomas in which the yoke sac and/or syncitio-trophoblast components were not identified on histology. Inhibin B is specific for sex cord tumors. CA 125 is not specific [7,25–27].

There are numerous differential diagnoses for ovarian tumors. Functional pathologies may occur at any age and are the most frequent differential diagnosis [9,28,29].Simple adnexal torsion may also occur at any age and presents as a mass. An ectopic pregnancy should always be looked for after puberty and a tubo-ovarian abscess can also resemble a tumor, although there are often signs of infection in these cases [30].

In pediatrics most ovarian masses are detected with ultrasound, which is the first-line test in these cases. Once an organic disease has been identified, MRI, which has no radiation, provides good tissue enhancement and the best evaluation of tumor vascularization [9]. The protocol for adults in the literature includes two T2-weighted sequences including an axial view, a T1-weighted axial view with and without fat suppression and T1-weighted gadolinium-enhanced sequences. A T-2 weighted abdominal-pelvic sequence can be useful to study paraaortic lymph nodes. [31–33]. This protocol is applicable in pediatrics. The use of CT scan should be limited to searching for calcifications that are not detected on ultrasound and to evaluate malignant invasion. [26]. APF is not useful in these cases.

Conclusion

This retrospective pediatric series has identified the imaging features of ovarian tumors in children (Table 5). The features of benign or malignant germ cell tumors were typical including fat and/or calcifications. Imaging criteria predictive of malignancy were tumoral hypervascularization, a tumor larger than 12 cm and/or voluminous ascites. Ultrasound is the first-line test and MRI is essential and should be performed according to the “adult” protocol with analysis of contrast enhancement, although the value of dynamic imaging must be determined in children.
Table 5 Characteristics of the main ovarian tumors in children and adolescents according to the series in the literature.

<table>
<thead>
<tr>
<th>Tumors</th>
<th>Age</th>
<th>Biology</th>
<th>Imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germinal cell tumors</td>
<td>All ages</td>
<td>Non-specific</td>
<td>AFP/hCG (malignant)</td>
</tr>
<tr>
<td>Sex cord and stromal tumors</td>
<td>All ages</td>
<td>Granulosa Sertoli-Leydig Not specific</td>
<td>Inhibin B</td>
</tr>
<tr>
<td>Epithelial tumors</td>
<td>Post-pubescent</td>
<td></td>
<td>± CA 125</td>
</tr>
</tbody>
</table>

Disclosure of interest

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

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