Pictorial Review

MRI appearances of pure epithelial papillary serous borderline ovarian tumours

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Borderline epithelial ovarian tumours (BOT) represent 15–20% of all non-benign ovarian epithelial neoplasms. Compared to malignant ovarian tumours, they usually present at a younger age and carry a far superior prognosis. Fertility-conserving surgery is an important treatment option for patients with BOT. Ultrasound and CT are both widely available and play roles in the initial investigation and staging of BOT, respectively. However, lack of soft-tissue contrast limits their ability to characterize BOT. MRI can facilitate recognition of pure epithelial serous BOT (SBOT), including the cystic papillary and surface papillary subtypes. An abundance of hyperintense papillary projections with low signal internal branching and ovarian stroma preservation with a hypointense ovarian capsular margin on T2-weighted imaging are features strongly suggestive of SBOT. In this review we will discuss the general morphological features of SBOT, the benefits and drawbacks of ultrasound and CT in the initial work-up, and the principal MRI features enabling recognition of surface papillary and cystic papillary SBOT.

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Introduction

Borderline ovarian tumours (BOT) represent an intermediate grade of neoplasm between benign and malignant ovarian tumours. They comprise 15–20% of all non-benign ovarian epithelial neoplasms and are most commonly serious or mucinous. At histology, BOT are characterized by atypical epithelial cell proliferation greater than in benign tumours but without any destructive stromal invasion.

Compared to malignant ovarian tumours, BOT present in younger patients; typically between 40–50 years of age. Patients commonly report abdominal distension or pain or may even be asymptomatic and serum CA-125 is raised in roughly half of patients. Fertility-sparing surgery is sometimes offered to younger patients with early-stage disease over the more established treatment of bilateral salpingo-oophorectomy, hysterectomy, and omentectomy commonly offered to older patients or those who have completed their family.

The prognosis of serous BOT is far superior to malignant tumours as disease is usually confined to the ovary, with stage 1 disease having a >95% 10 year survival rate. However, 30% of serous BOT are associated with peritoneal implants, which may be invasive or non-invasive, with survival rates falling considerably in those with invasive implants. Adjuvant chemotherapy is offered to these patients but no firm evidence for any survival benefit exists.

In this review we will describe the MRI appearances of pure epithelial serous BOT (SBOT), which include surface...
papillary and cystic papillary subtypes.2 Previously only two publications have specifically addressed MRI appearances of surface papillary SBOT.13,14 SBOT are an important disease entity to recognize given the different prognosis and treatment options compared to benign and malignant tumours.

Firstly, we will describe the general morphology of SBOT and the salient ultrasound and CT appearances, as well as the limitations of these techniques, before reviewing the MRI features. Our description is based on five cases of SBOT observed within our regional cancer network (Table 1).

Gross morphological features

Cystic papillary SBOT is characterized by the presence of a cystic component that may demonstrate endophytic, in addition to exophytic papillary projections. Whereas surface papillary SBOT appears as an encapsulating solid “mass”, with numerous exophytic projections but no cystic component or endophytic projections.12,13 The ovarian stroma is preserved in both cystic and surface SBOT and identified separately.

SBOT have a greater association with bilaterality, papillary projections, and peritoneal implantation, and are less frequently multicellular, compared to mucinous BOT (MBOT).1,5,15 However, SBOT appearances exhibit significant overlap with both benign and malignant neoplasms, making their identification particularly difficult.16

The abundance of papillary projections with a smaller or absent solid component can help distinguish SBOT from malignant serous tumours.17,18 Smaller and few papillary projections associated with a thin-walled cystic structure suggests benignity. Whereas papillary projections with a more dominant solid ovarian mass is suggestive of malignancy.11,18,19

Imaging features

Ultrasound

Ultrasound is usually the first-line investigation for suspicion of adnexal pathology. Surface papillary SBOT may appear as a solid soft-tissue mass encasing the ovaries (Figs 1 and 2). This can lead to confusion with a malignant neoplasm due to the significant solid component. However, a smaller proportion of solid tissue, unilocularity, lack of thickened septa, and lack of ascites are helpful features that reduce the likelihood of invasive malignancy.20–23 Cystic papillary SBOT may demonstrate a hypoechoic cystic mass, with absent or low-level internal echogenicity, with echogenic internal foci representing endophytic projections (Figs 3 and 4).24 In general, ultrasound has low sensitivity for BOT diagnosis with BOT more likely to be characterized as benign.25

Burkholz et al.17 described a case of cystic SBOT on ultrasound, which appeared as a solid adnexal mass with multi-cystic areas containing central intermediate echogenicity, likely representing endophytic projections. Van Vierzen et al.24 also described ultrasound findings in a cohort that included three SBOT. The appearances of cystic SBOT with endocystic vegetations described by these authors are remarkably similar to the appearances described in Figs 3 and 4.

CT

Due to the relatively poor soft-tissue contrast, which limits visibility of the papillae and normal ovarian stroma, CT is unable to characterize SBOT as well as MRI (see Fig 5a).14 In a series of six SBOTs, Tanaka et al.13 concluded that a specific diagnosis of SBOT could not be reached during CT as the tumour was “poorly demarcated”. However, CT can identify peritoneal implants (see Fig 5), which are of prognostic importance in SBOT.10,14,17 Therefore, CT is mainly a staging and monitoring tool rather than a characterization technique.13,26,27

MRI

The superior soft-tissue contrast of MRI, relative to CT and ultrasound, can reveal the complex architecture of SBOT and enable classification into cystic and surface subtypes.13,14,23 We have identified a few MRI features that enable recognition of cystic and papillary SBOT (Table 2). We describe them under the headings that follow. All MRI images were acquired using a 1.5 T MRI machine and imaging parameters are provided in the figure legends.

Papillary projections

The presence of abundant papillary projections is associated with serous as opposed to mucinous tumours and borderline as opposed to benign or malignant tumours.3,15,19,28 In borderline tumours, papillary projections are larger, greater in number compared to benign tumours, and dominate over the presence of any solid component.17,18,28 In one study papillary projections were noted in 67% of BOT compared with 38% of malignant and 13% of benign neoplasms at CT or MRI.28 MBOT infrequently demonstrate papillary projections; they are more likely to demonstrate irregularly thickened plaque-like septa.15,29

Papillary projections are best identified on T2-weighted imaging (T2WI). They appear as intermediate- to high-signal structures with low signal internal branching as illustrated in Figs 6–10. They are inconspicuous on T1WI as demonstrated in Fig 6b.

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**Table 1**

Patient details of five histologically confirmed cases of serous borderline ovarian tumours.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (years)</th>
<th>CA-125 (units/ml)</th>
<th>Bilateral Imaging</th>
<th>Morphological subtypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>38</td>
<td>10</td>
<td>Yes</td>
<td>TVUS, MRI</td>
</tr>
<tr>
<td>2</td>
<td>38</td>
<td>176</td>
<td>Yes</td>
<td>TVUS, MRI</td>
</tr>
<tr>
<td>3</td>
<td>42</td>
<td>318</td>
<td>Yes</td>
<td>TAUS, MRI, CT</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
<td>185</td>
<td>No</td>
<td>TAUS, MRI</td>
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<tr>
<td>5</td>
<td>73</td>
<td>52</td>
<td>Yes</td>
<td>TVUS, MRI</td>
</tr>
</tbody>
</table>

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Where the high signal papillary projections are related to the surface of the ovary without any cystic component, it suggests a diagnosis of surface SBOT (Fig 7a). In the case of cystic SBOT, the papillary projections may also occur within the cystic component as endophytic projections (Fig 7b).

Tanaka et al.\textsuperscript{13} have described the appearance of papillary projections in surface SBOT on T2WI as hyper-intense with internal low signal branching. They likened it to the appearance of a sea anemone and deemed it a “hallmark” feature of surface BOT. Other authors simply refer to papillary projections as having low or intermediate signal on T2WI.\textsuperscript{15,16,29} To be precise, the T2 low signal represents the fibrous internal architecture of the papillary projections and the hyperintense regions represent oedematous papillae.\textsuperscript{28}

Papillary projections may restrict on diffusion-weighted imaging (DWI) and enhance post-contrast.\textsuperscript{16} However, the degree of diffusion restriction of papillary projections in BOT is characteristically lower than in malignant ovarian

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**Figure 1** Patient 1. A 38-year-old woman with bilateral surface papillary SBOT. Transvaginal ultrasound demonstrates the preserved ovaries (arrowheads) encapsulated by the echogenic tumour mass (arrows) in transverse (a) and longitudinal right ovary (b).

**Figure 2** Patient 2. A 38-year-old woman with a surface papillary SBOT. Transvaginal ultrasound demonstrates the preserved right ovary (arrowheads) encapsulated by the echogenic tumour mass (arrows).

**Figure 3** Patient 5. A 73-year-old woman with cystic SBOT. Transvaginal ultrasound demonstrates a large cyst (arrow heads) with numerous endophytic papillary projections (arrow) in the left adnexa.

**Figure 4** Patient 4. A 26-year-old woman with bilateral cystic SBOT. Transabdominal ultrasound demonstrates a left adnexal cystic lesion (arrowheads) with mural nodule (arrow).
tumours. In a study investigating DWI characteristics, Zhao et al. demonstrated that diffusion restriction was significantly lower, and the corresponding apparent diffusion coefficient (ADC) significantly higher in papillary projections in borderline tumours compared to solid elements in malignant tumours. However, given that ADC values are difficult to standardize universally across MRI machines, the ADC value proposed for differentiating borderline and malignant tumours has limited applicability at present. Van Vierzen et al. found that dynamic contrast-enhanced MRI was crucial for accurately differentiating papillary projections and solid elements from a cystic component. Furthermore, when papillary projections are small and endophytic use of contrast-enhanced T1WI can increase their conspicuity as they avidly enhance and their contrast against low signal intra-cystic fluid is increased. However, where papillary projections are larger, a hyperintense nodular outline with a low signal internal branching fibrous stalk on T2WI is characteristic and usually sufficient for the identification of papillary projections.

**Solid and cystic components**

On T2WI an intermediate to high signal intensity “mass” with a lobulate irregular contour, which lacks any cystic component, is seen as opposed to cystic SBOT (Fig 8). This appearance, which has been termed “sponge-like” by Shadbolt et al. is also a highly predictive feature for serous rather than mucinous BOT, with the high signal “mass” representing oedematous papillary projections. Internal low signal branching should also be identified in keeping with the central fibrous stroma of the papillary projections.

Cystic SBOT, on the other hand, is recognized as a spherical high signal cyst with internal low to intermediate signal endophytic papillary projections or mural nodules on T2WI (Fig 9). Intra-cystic fluid content is usually low signal on T1WI, but is high signal on T1WI in approximately 10% of SBOT. Cystic SBOT may also be multicellular, in which the internal papillary projections may involve the septa in addition to the cyst walls (Fig 9). Appearances of the papillary projections are inconspicuous on T1-WI (Fig 10), but may become more evident on T1-WI with contrast enhancement.

Thomassin-Naggara et al. identified that a solid component and septa were more frequent in malignant ovarian tumours, whereas papillary projections were more frequent in BOT. Papillary projections should therefore be distinguished from other solid components, which may suggest a diagnosis other than SBOT, such as irregular thickened septa and large mural nodules. The key discriminating feature is that septa and nodules are more homogeneous in signal intensity, whereas papillary

<table>
<thead>
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<th>Table 2</th>
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<tr>
<td><strong>A summary of the key MRI features of pure epithelial serous borderline ovarian tumours (SBOT).</strong></td>
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<th>Adnexal features suggestive of SBOT</th>
<th>Gross features associated with SBOT</th>
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<tbody>
<tr>
<td>1. An abundance of hyperintense papillary projections with low signal internal branching on T2-weighted imaging</td>
<td>1. Bilaterality (approx. 30%)</td>
</tr>
<tr>
<td>2. Cystic component with endophytic or exophytic papillary projections and/or encapsulating ovarian surface “mass” composed of papillary projections</td>
<td>2. Peritoneal implants (approx. 30%)</td>
</tr>
<tr>
<td>3. Preservation of the ovarian stroma with a low signal ovarian capsule margin on T2-weighted imaging</td>
<td>3. Ascites (more likely with exophytic projections)</td>
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</table>

Figure 5 Patient 3. A 42-year-old woman with cystic SBOT. (a) Coronal contrast-enhanced CT abdomen and pelvis demonstrates a soft-tissue mass involving bilateral adnexa (black arrows) and peri-hepatic ascites (arrowhead). However, neither the internal structure nor the exophytic papillary projections are identified in comparison using MRI (see Fig 11). (b) Axial contrast-enhanced CT demonstrates omental nodularity suspicious for metastatic disease (white arrows).
projections have an internal low signal branching structure with high signal nodular outline on T2WI. A brief overview of the signal and enhancement characteristics of these entities is provided in Table 3. It should be noted that where papillary projections are small they appear uniformly hypointense on T2WI and hence distinction between irregularly thickened septa cannot be made.19,31

Ovarian stromal preservation with or without distortion of the stromal contour
In surface SBOT, the tumour encapsulates preserved ovarian stroma.31 The ovarian shape and outline is virtually undistrupted, and on T2WI, a low signal rim can be delineated around the ovarian margin (Fig 11). Kim et al.14 described a case of surface BOT and elegantly described the clear preservation of the ovarian stroma with only mild distortion of the ovarian shape. They also stated that such features could not be distinguished using CT due to the limited soft-tissue contrast.

On the other hand, in cystic SBOT, there is mass effect and the ovarian stroma although still preserved, is compressed against surrounding structures and loses its normal morphology (Fig 12). A low signal boundary on T2WI between the preserved ipsilateral ovarian stroma and tumour

Figure 6 Patient 1. A 38-year-old woman with bilateral surface SBOT. (a) Axial T2WI (5761.28 ms TR, 90 ms TE) demonstrates a hyperintense pelvic mass (arrowheads) posterior to the uterus with internal low signal branching (arrows). (b) Axial T1WI (745.13 ms TR, 6 ms TE) fails to demonstrate the internal branching, the tumour is of homogeneous low signal (arrowheads).

Figure 7 Patients 1 and 4. (a) A 38-year-old woman with bilateral surface SBOT. Sagittal T2WI (5429.27 ms TR, 90 ms TE). (b) A 26-year-old woman with bilateral cystic SBOT. Coronal T2WI (6960 ms TR, 104 ms TE). The contrasting appearances of exophytic surface papillary projections (a) in surface SBOT and endophytic internal cystic papillary projections (b) in cystic SBOT are demonstrated. The papillary projections are appreciated as intermediate signal intensity (arrowheads) with internal branching as low signal intensity (arrows). Note the lack of cystic component in surface SBOT (a).
is maintained. In a series of 76 BOT, Shadbolt et al.\textsuperscript{16} demonstrated that the ipsilateral ovarian stroma was preserved in 93\% of cases. In the images they provided, similar compression and distortion of the ovarian stroma was identified as we have illustrated in Fig 12.

**Peritoneal implants and ascites**

Peritoneal implants may be identified on T2WI as low signal foci within the peritoneal structures (Fig 13). However, some authors have faced difficulty in identifying peritoneal implants using MRI, which were subsequently identified at surgery.\textsuperscript{14,25} CT is deemed a more suitable staging tool for identifying distant metastasis and should be recommended if there is any suspicion of peritoneal disease.\textsuperscript{13,26,27}

Peritoneal implants are more likely in SBOTs with exophytic projections and in SBOTs in general when compared to mucinous BOT.\textsuperscript{1,12} Interestingly, it has been proposed that, given the extent and frequency of peritoneal spread in surface BOT and relative preservation of the ovarian stroma, surface SBOT and surface peritoneal tumours may be a spectrum of the same disease entity.\textsuperscript{14,33} The prognostic implications of peritoneal implants depend upon the invasiveness of the implants,\textsuperscript{1,33} which cannot be accurately determined using MRI, but only after surgical resection.

Although several authors describe the presence of large amounts of ascites with SBOT,\textsuperscript{13,14,17} ascites is an unreliable indicator for predicting the presence of BOT, as ascites is found equally, if not more frequently, in patients with malignant ovarian tumours.\textsuperscript{23}

**A comparison with previous morphological classifications of serous BOT**

In a review of 26 patients with BOT, including 20 serous and 11 mucinous tumours, Bent et al.\textsuperscript{29} described four morphological subtypes of BOT including (1) uni-locular with endophytic projections, (2) minimally septate with endophytic projections, (3) markedly septate with plaque-like excrescences, and (4) predominantly solid with exophytic excrescences. Although they did not differentiate between cystic and surface SBOT, our descriptions of cystic BOT match their types 1 and 2, and surface BOT with their type 4. It should be noted that appearances between serous and mucinous tumours did overlap; but in fact, the majority of their types 1, 2, and 4 were serous rather than mucinous BOT. Their type 4 morphology, solid with exophytic projections, was in all cases a serous BOT. It was also not

![Figure 8](image-url) Patient 1. A 38-year-old woman with bilateral surface SBOT. Axial T2WI (5761.28 ms TR, 90 ms TE) demonstrates intermediate to high signal intensity mass with a lobulate irregular contour (arrowheads), low signal internal branching, and preservation of the ovarian stroma with a low signal boundary (white arrows).

![Figure 9](image-url) Patient 5. A 73-year-old woman with cystic SBOT. Axial and sagittal T2WI (6960 ms TR, 104 ms TE). A left adnexal cyst (arrowheads) with internal low signal branching (arrow) structures adjacent to the septa and cyst wall. These appearances are in keeping with a multi-locular cystic SBOT with endophytic papillary projections.
unusual for the ovarian stroma to be preserved; this was observed in nearly 20% of their cases of SBOT.

Tanaka et al. adopted a slightly different classification in their six cases of SBOT; they described three morphological tumour types: (1) a solid mass with a papillary architecture and internal branching (PA&IB), (2) a PA & IB with cysts, and (3) cysts with mural nodules. They considered the first two categories as representing surface SBOT and the latter as cystic SBOT, which is similar to our descriptions. Interestingly, all six cases of their surface BOT

Table 3
MRI signal and enhancement characteristics of papillary projections, mural nodules and irregular septa.

<table>
<thead>
<tr>
<th>MRI Type</th>
<th>Papillary projections</th>
<th>Mural nodules</th>
<th>Irregular septa</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1-weighted MRI</td>
<td>Intermediate—low signal</td>
<td>Intermediate—low signal</td>
<td>Intermediate—low signal</td>
</tr>
<tr>
<td>T2-weighted MRI</td>
<td>Internal low signal stalk and outer high signal oedematous papillae. Early enhancement Endophytic or exophytic</td>
<td>Intermediate—low signal if solid nodule High signal if multi-cystic mural “nodule” Early enhancement</td>
<td>Intermediate—low signal</td>
</tr>
<tr>
<td>T1 + Gd-enhanced MRI</td>
<td>Internal branching pattern on T2-weighted imaging Nodular outline</td>
<td>Endophytic Solid or multi-cystic (cluster of daughter cysts)</td>
<td>Early enhancement Extend across the cyst giving rise to a multi-locular appearance Linear/curvilinear Plaque-like thickening</td>
</tr>
</tbody>
</table>

Figure 10 Patient 4. A 26-year-old woman with bilateral cystic SBOT. (a) Axial T1WI (517 ms TR, 18 ms TE) and (b) T2WI (6960 ms TR, 104 ms TE) MRI. The cystic component is clearly demonstrated on T2WI as a high signal spherical structure (arrowheads) compared with T1WI where there is an indeterminate intermediate signal mass (arrow).

Figure 11 Patient 2. A 38-year-old woman with bilateral surface papillary SBOT. Coronal and sagittal T2WI (5633.9 ms TR, 90 ms TE). The ovarian stroma is encapsulated by the tumour (arrowheads) and a low signal boundary (arrows) separates the tumour from the ovarian stroma.
occurred simultaneously with contralateral cystic types of BOT. This may indicate that surface and cystic BOT are simply gross morphological variants of the same pathological process.

More recently, Zhao et al.\textsuperscript{31} also described SBOT under three morphological classifications: (1) a predominantly cystic mass, (2) a solid mass, or (3) a mixed solid–cystic mass, with all three types containing papillary projections. Their first and second types match our descriptions of cystic and surface SBOT, respectively.

As BOT are frequently complex structures, with appearances overlapping with malignant tumours, de Souza et al.\textsuperscript{23} have described MRI features that may help discriminate BOT from low-grade malignant tumours. These include thinner septa and smaller solid components in BOT. Zhao et al.\textsuperscript{31} also commented that a distinct boundary between cystic and solid components and lack of haemorrhage, necrosis and surrounding infiltration are features that help differentiate SBOT from invasive malignancy. We have also noted, in agreement with other authors, that the relative abundance of papillary projections compared to a solid component is a key finding in SBOT.\textsuperscript{1,17,18,28}

**Implications on treatment**

A diagnosis of SBOT can provide patients with the option of unilateral salpingo-oophorectomy or cystectomy as fertility-preserving surgery.\textsuperscript{34} Preoperative MRI can support the intra-operative frozen section diagnosis of SBOT through the characteristic features described above, but also assist with surgical planning by determining the extent of disease.\textsuperscript{15} However, due to the overlapping features of SBOT with benign and malignant tumours, a definitive diagnosis should not be made on the basis of MRI alone.\textsuperscript{5} With both thorough histological sampling, to exclude invasive disease, and supportive MRI appearances the patient may be selected for fertility-preserving surgery.

Recent developments with diffusion-weighted imaging (DWI) have demonstrated that differentiation between BOT and malignant tumours may reach an accuracy of 96%.\textsuperscript{30} In future, with more widespread use of MRI and DWI in conjunction with thorough intra-operative sampling, we may see a greater proportion of patients offered fertility-preserving surgery where it is necessary.

**Conclusion**

Borderline ovarian tumours have a different prognosis and treatment to their malignant counterparts. Therefore, radiological suspicion can have important implications for the patient. Techniques such as dynamic contrast-enhanced MRI and DWI may offer the opportunity for better differentiation of borderline from benign and malignant ovarian tumours; however, morphological assessment using MRI is still an important first step.\textsuperscript{19} The presence of abundant papillary projections and preservation of the ovarian stroma are characteristic imaging features of SBOT, which are readily appreciated on T2WI.

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**References**


