Comparison of CT or MRI and ¹⁸F-FDG PET/CT for the Preoperative Staging Accuracy of Ovarian Cancer

Guk Won Jung, M.D., Young Joon Lee, M.D., Soon Nam Oh, M.D., Sung Eun Rha, M.D., Jae Young Byun, M.D., Je Ryung Yoo, M.D., Sung Hoon Kim, M.D., Soo Kyo Chung, M.D.

Purpose: To compare the diagnostic accuracy of CT or MRI with ¹⁸F-FDG PET/CT for the preoperative staging of ovarian cancer.

Materials and Methods: Twenty-eight patients (15–67 years; mean 46 years) with 38 surgically confirmed ovarian cancer lesions (4–30 cm, mean 11.2 cm) underwent CT or MR (CT on 20; MR on 10) and ¹⁸F-FDG PET/CT to compare each imaging modality in accordance to the FIGO stage.

Results: The FIGO staging results revealed stage I disease in 11 patients, stage III disease in 14 patients, and stage IV disease in three patients. In total, six of the 38 tumors (16%) showed no evidence of abnormal uptake on the ¹⁸F-FDG PET/CT, while one of the 38 tumors (3%) showed no evidence of enhancing on the solid portion for either CT or MRI. The lack of typical advanced stage characteristics of the aforementioned tumors resulted in their stage I disease classification. The CT or MRI staging was correlated with FIGO staging in 21 of the 28 patients (75%), whereas the ¹⁸F-FDG PET/CT staging was similarly correlated in 23 of the 28 patients (82%). We found no significant difference in the diagnostic accuracy of CT or MRI versus the ¹⁸F-FDG PET/CT in the preoperative staging of ovarian cancer.

Conclusion: Besides CT or MRI, additional ¹⁸F-FDG PET/CT imaging is not mandatory for the preoperative staging of ovarian cancer.

Index words: Ovarian neoplasms
Neoplasm staging
Tomography, X-ray computed
Magnetic resonance imaging
Positron emission tomography
the staging of ovarian cancer has been reported to range between 70 to 90% (2). Moreover, CT and MRI have been reported to be equivalent in its diagnostic capabilities, such that either modality can be used to stage ovarian cancer (3-6). 18F-FDG PET/CT is a unique imaging modality in which the patient undergoes a PET and CT in one session. 18F-FDG PET/CT images constitute the fusion of functional and anatomical images. Recently, several reports have shown that the addition of 18F-FDG PET to conventional imaging methods, such as CT, improve the accuracy for the staging of ovarian cancer (7). 18F-FDG PET/CT has been reported to be a successful modality in the detection of recurrent ovarian cancer (8-11). However, to our knowledge, there are few reports comparing the diagnostic accuracy of CT or MRI and 18F-FDG PET/CT for the preoperative staging of ovarian cancer.

The purpose of this article is to compare the diagnostic accuracy of CT or MRI versus the 18F-FDG PET/CT for the preoperative staging of ovarian cancer.

Materials and Methods

Patients

Twenty-eight patients [mean age, 46 years; range, 15-67 years], who were surgically confirmed to have a malignant ovarian tumor between January 2004 and June 2006 at our institution, were recruited. These patients underwent CT or MRI of their abdomen and pelvis (CT on 20 patients; MR on 10 patients), in addition to 18F-FDG PET/CT within 2 weeks before surgery. Two patients underwent both the CT and MRI. The time intervals between CT, MR, and 18F-FDG PET/CT and surgery ranged from 5-20 days (mean, 10 days), 1-21 days (mean, 9.5 days), and 1-12 days (mean, 5.0 days), respectively. The surgeries constituted a dual adnexectomy with lymph node dissection in 20 patients, a unilateral adnexectomy with pelvic lymph node dissection in 2 patients, a unilateral adnexectomy with a unilateral pelvic lymph node dissection in 2 patients, a unilateral adnexectomy in 3 patients, and both adnexectomies in 1 patient. Bilateral ovarian cancers were identified in 10 patients, while 18 patients were diagnosed with unilateral ovarian cancer. Therefore, a total of 38 primary malignant ovarian tumors were included in this study [mean size, 11.2 cm; range 4-30 cm]. The types of tumors included 24 epithelial cell tumors (serous adenocarcinoma, n=15; mucinous adenocarcinoma, n=5; endometrioid adenocarcinomas, n=2; clear cell carcinosomas, n=2), two germ cell tumors (dysgerminoma and immature teratoma), and two sex cord-stromal tumors (juvenile granulosa cell tumor and sertoli-leydig cell tumor). The value of the CA-125 tumor marker study ranged from 9 to 970 U/ml [mean, 608 U/ml]. This retrospective study received institutional review board approval and informed consent was not required.

CT and MRI Protocol

Computed tomography data of the entire abdomen, including the pelvis, were acquired using a 4-channel multi-detector CT scanner [Somatom Volume Zoom, Siemens medical system, Forchheim, Germany], with a 7-mm slice thickness, 120 Kvp and 120 mAs. Intravenous non-ionic iodinated contrast medium [Ultravist 300, Schering, Berlin, Germany] was injected via a power injector (120 ml, 2-3 ml/s injection rate). Dynamic arterial and venous phase scans were obtained. Arterial phase scans began 45 seconds after starting the IV injection of contrast medium, followed by venous phase scans, which were obtained 35 seconds after the arterial phase scans. During the arterial phase, the scanning field included the iliac crest to the pubis symphysis. The scanning field during the venous phase extended from the upper end of the dome of the diaphragm to the pubis symphysis.

Magnetic resonance imaging was performed on a Siemens 1.5-T MR system [Magnetom Vision Plus, Siemens Medical System, Erlangen, Germany] and a GE 1.5T MR system [Signa Excite, GE Medical Systems, Milwaukee, WI, U.S.A.] using a pelvic-phased array coil. Following a sagittal localization, sagittal T2-weighted fast spin-echo imaging [repetition time (TR) range 4000-5000 ms/effective echo time (TE) range 100-130 ms with echo train length (ETL) 10-16; number of excitation (NEX) 2-3, field of view (FOV) 230×230, section thickness of 5 mm; intersection gap of 0-1 mm; matrices of 512×240, 384×256] was obtained. Axial T2-weighted fast spin-echo imaging [TR range 4000-5000 ms/TE range 100-130 ms with echo train length 10-16; NEX 2-3, FOV 230×230, section thickness 5 mm; intersection gap 0-2 mm; matrix 512×240, 256×192], axial T1-weighted spin-echo imaging [TR range 500-550 ms/TE, range 10-14 ms; section thickness 5 mm; intersection gap 0-2 mm; matrix 512×240, 256×192], as well as contrast enhanced, fat-suppressed, axial and sagittal T1-weighted images with gadopentetate dimeglumine (Magnevist; Schering, Germany) at a dose of 0.1 mmol/kg body weight using the same parameters as...
those for precontrast T1-weighted axial and sagittal images, were obtained. For the evaluation of the upper abdomen, contrast enhanced T1-weighted axial images with body coil were obtained from the upper end of the dome of the diaphragm, to the iliac crest (FOV 340 × 340, section thickness of 8–10 mm; intersection gap of 0–2 mm; matrix of 512 × 170, 256 × 190).

**18 F-FDG PET/CT Protocol**

All patients fasted for at least 6 hours before the 18F-PET/CT study. An average of 444 MBq of 18F-FDG (range of 370 to 555 MBq) was injected intravenously. Scanning began 60 min later after voiding. No patients had blood glucose levels exceeding 130 mg/dL before the injection, and no intravenous contrast agent was used for CT scan. A combined PET/CT in-line system (Biograph LSO; Siemens Medical Solutions, Knoxville, TN) was used to acquire all the data. Moreover, a full-ring PET scanner, integrated with a dual-section helical CT scanner (Somatom Emotion; Siemens), acquired the coregistration of the PET and CT images in one session. A total of 6–8 bed positions were available, and the acquisition time per bed position was 2 min. All patients were examined in the supine position with their arms raised. The CT began at the orbitomeatal line and progressed to the upper thigh (30 mAs; 130 kV; 5-mm slice thickness). The PET scan followed immediately after over the same body region aforementioned. The CT data were used for attenuation correction, whereas the images were reconstructed using a standard ordered-subset expectation maximization algorithm. The axial spatial resolution was 6.5 mm at the center of the field of view.

**Imaging Analysis**

The CT or MRI and 18F-FDG PET/CT were evaluated independently with the consensus of two radiologists and two nuclear physicians, respectively with a blind sample of FIGO staging and pathologic finding. The findings of the images were compared to the pathologic and operative findings.

We investigated the number of primary malignant ovarian tumors mimicking benign ovarian tumors on CT or MRI and 18F-FDG PET/CT.

When a contrast enhancing solid portion was present on enhanced CT or MR, we considered the ovarian tumor as malignant. A contrast enhancing lesion was diagnosed when there were different degrees of enhancing portions between the arterial and venous phase scans or the more increased nodular enhancement compared with surrounding tissues or muscular enhancement by visual assessment. We also analyzed presence of enlarged pelvic or para-aortic lymphadenopathies of more than 1 cm in size of short-axis diameter. When ascites, peritoneal enhancing nodules or plaque-like lesions and cake-like appearing omental enhancing soft tissue were present, carcinomatosis peritonei was diagnosed.

All 18F-PET/CT images were reviewed at a workstation with the aid of the fusion software (Syngo; Siemens), which provided multi-planar reformatted images and displayed PET images either before or after attenuation correction, CT images, and PET/CT fusion images. For PET/CT images, the presence of malignant ovarian cancer was diagnosed by visual assessment, when the FDG accumulation was moderate to markedly increase versus that of analogous, normal contralateral structures or surrounding tissues, excluding physiologic bowel and urinary activity.

We determined the preoperative staging using the FIGO criteria for CT or MRI and 18F-FDG PET/CT, respectively. Subcategorical FIGO staging was not considered in this study.

**Statistical Analysis**

The statistical analyses were performed using SPSS for Windows (version 13.0, SPSS Inc, Chicago, II, U.S.A.). The Mann Whitney-U test was used to compare the differences in the preoperative staging between the CT or MRI of the pelvis and PET/CT. A p-value less than 0.05 was considered to be statistical significant.

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**Table 1. Diagnostic Accuracy of CT or MRI Staging and 18F-FDG PET/CT Staging**

<table>
<thead>
<tr>
<th>FIGO Staging</th>
<th>CT or MRI Staging</th>
<th>PET/CT Staging</th>
<th>Patient Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>I I</td>
<td>I I</td>
<td>10</td>
<td></td>
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<tr>
<td>III III</td>
<td>III III</td>
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<td>IV IV</td>
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<td>IV III</td>
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Diagnostic Accuracy (21/28) 82%

FIGO, International Federation of Gynecology and Obstetrics

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Results

The FIGO stages of the 28 patients included 11 patients in stage I, 14 patients in stage III, and three patients in stage IV.

Six of the 38 tumors (16%) showed no abnormal uptake on 18F-FDG PET/CT, whereas one of the 38 tumors (3%) showed no evidence of an enhancing solid portion on CT (Fig. 1). The number of malignant ovarian tumors mimicking benign ovarian tumors was significantly different between CT or MRI and 18F-FDG PET/CT ($p = 0.049$). The preoperative staging of CT or MR and 18F-FDG PET/CT of all the six tumors, were determined to be in stage I, which concurred with the FIGO staging. Four of the tumors revealed borderline malignancy on histopathologic results.

The accuracy of preoperative staging by CT or MRI was at 75% (21/28), whereas the 18F-FDG PET/CT was at 82% (23/28) (Table 1). The diagnostic accuracy of stage I and stage III was equal between CT or MR and 18F-FDG PET/CT. The primary difference between modalities occurred in stage IV patients. Two patients of FIGO stage IV showed left supraclavicular metastatic lymphadenopathies on 18F-FDG PET/CT. One of them showed splenic metastasis on CT, indicating accurate preoperative staging. However, the other case with multiple para-aortic lymphadenopathies on CT was misdiag-

Table 2. The Diagnostic Accuracy of CT or MRI and 18F-FDG PET/CT for Metastatic Site Staging on a Patient by Patient Basis

<table>
<thead>
<tr>
<th>Site of Metastasis</th>
<th>TP</th>
<th>FP</th>
<th>TN</th>
<th>FN</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
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<tbody>
<tr>
<td>Pelvic lymph node</td>
<td></td>
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<td></td>
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<tr>
<td>CT or MR</td>
<td>2</td>
<td>3</td>
<td>17</td>
<td>6</td>
<td>25</td>
<td>85</td>
<td>68</td>
</tr>
<tr>
<td>PET/CT</td>
<td>3</td>
<td>1</td>
<td>19</td>
<td>5</td>
<td>38</td>
<td>95</td>
<td>79</td>
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<tr>
<td>Paraaortic lymph node</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT or MR</td>
<td>2</td>
<td>2</td>
<td>23</td>
<td>1</td>
<td>67</td>
<td>92</td>
<td>89</td>
</tr>
<tr>
<td>PET/CT</td>
<td>2</td>
<td>2</td>
<td>23</td>
<td>1</td>
<td>67</td>
<td>92</td>
<td>89</td>
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<tr>
<td>Distant metastasis</td>
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</tr>
<tr>
<td>CT or MR</td>
<td>1</td>
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<td>24</td>
<td>2</td>
<td>33</td>
<td>95</td>
<td>87</td>
</tr>
<tr>
<td>PET/CT</td>
<td>3</td>
<td>1</td>
<td>24</td>
<td>0</td>
<td>100</td>
<td>96</td>
<td>96</td>
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<tr>
<td>Carcinomatosis</td>
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<tr>
<td>CT or MR</td>
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<td>9</td>
<td>5</td>
<td>71</td>
<td>82</td>
<td>75</td>
</tr>
<tr>
<td>PET/CT</td>
<td>11</td>
<td>2</td>
<td>9</td>
<td>6</td>
<td>65</td>
<td>82</td>
<td>71</td>
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TP, true positive; FP, false positive; TN, true negative; FN, false negative

Fig. 1. A Stage I serous borderline malignant tumor in a 33-year-old woman. No FDG uptake was noted on the 18F-FDG PET/CT. A. The contrast enhanced T1-weighted axial scan shows a septated cystic right ovarian tumor with papillary enhancing solid portion (arrow). B. There is a photon defect cystic lesion (arrow) in the right pelvic cavity upon 18F-FDG PET/CT.
nosed as stage III (Fig. 2). The accuracy of preoperative staging by $^{18}$F-FDG PET/CT was mildly high, however the difference was not statistically significant.

Table 2 highlights the diagnostic accuracy of CT or MRI, as well as $^{18}$F-FDG PET/CT for pelvic lymph node metastasis, paraaortic lymph node metastasis, distant metastasis, and carcinomatosis peritonei. The sensitivity and accuracy of pelvic lymph node metastases were low in either CT or MRI (25% and 68%, respectively), as well as $^{18}$F-FDG PET/CT (38% and 79%). In one patient, $^{18}$F-FDG PET/CT showed a 1-cm right external iliac metastatic FDG uptaked lymphadenopathy, which was missed on MRI (Fig. 3). Only three patients with true para-aortic lymph node metastases occurred in our study and the diagnostic accuracy of para-aortic lymph node metastases was the same for both modalities. The metastatic sites of three patients with distant metastases included the spleen, right pleura, and supraclavicular lymph nodes. One patient had both supraclavicular lymph node and splenic metastasis, in which, both were detected by $^{18}$F-FDG PET/CT, whereas the CT could only define a splenic metastasis. Because the other patient with supraclavicular lymph node metastasis did not have intraabdominal metastasis, the patient was downstaged to stage III by CT, but correctly staged by $^{18}$F-FDG PET/CT. These two patients with supraclavicular lymph node metastasis also had multiple para-aortic lymph node metastases. CT could not define these supraclavicular lymph node metastases due to the limited scan field of the abdomen and pelvis. The right pleural metastasis was misdiagnosed as a perihilar seeding metastasis by CT but correctly diagnosed by $^{18}$F-FDG PET/CT. The sensitivity of distant metastases by $^{18}$F-FDG PET/CT was 100% accurate for the patients examined, as opposed to 33% by CT or MRI, but there was no statistically significant difference due to very small number of cases. The sensitivity and accuracy of diagnosing carcinomatoses was slightly higher for CT or

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Fig. 2. Stage IV serous adenocarcinoma of the right ovary in a 57-year-old woman with left supraclavicular metastatic lymphadenopahies.

A. There were multiple enlarged para-aortic metastatic lymphadenopathies [arrow] on contrast enhanced CT, suggesting stage III.
B, C. The axial $^{18}$F-FDG PET/CT scan shows the abnormal FDG-uptaken para-aortic lymphadenopathies [arrow] and abnormal FDG-uptaken left supraclavicular lymphadenopathies [arrow heads]
MRI, but the difference was not statistically significant. Hence, we found no significant difference in diagnostic accuracy between CT or MRI and 18F-FDG PET/CT for metastatic site by patient based.

**Discussion**

Accurate staging of patients with ovarian cancer before treatment is important to determine the appropriate therapy, because successful cytoreductive surgery as the primary treatment for ovarian cancer improves a patient’s chances for long-term survival [12, 13]. The accuracy of CT in the staging of ovarian cancer has been reported to range from 70% to 90% [2]. MRI have been reported as being equivalent to CT in staging ovarian cancer [3-6].

The CT and MRI techniques are excellent in the identification of lymph node metastases. The criteria for tumor involvement of these anatomical imaging modalities mainly include morphology, including the location, size, and shape of a lesion [14, 15]. In contrast to CT and MRI, 18F-FDG PET lymph node metastases determination was made based on physiological, rather than morphological characteristics (i.e., glucose turnover in a malignant cell). However, PET can also lead to false negative results for small-sized tumors [16].

The diagnostic accuracy of PET for small recurrent tumor was lower than that of CT or MR, because PET has a less accurate spatial assignment compared to CT and MRI [4, 17]. The aforementioned studies were comparisons of PET; not a combined PET/CT. Combined PET/CT is more advantageous in terms of spatial resolution than PET, due to a more precise anatomical localization by accompanying CT images. Several reports established the improvement of the diagnostic accuracy of metastatic lymphadenopathies in patients with primary or recurrent ovarian cancer [11, 18-21]. In our study, both the sensitivities of pelvic lymph node and paraaortic lymph node metastases were low for both CT or MRI and 18F-FDG PET/CT. The causes of these different results compared to the above mentioned reports suggest a difference in the imaging modalities, techniques, analysis and methods of pathologic correlation.

Recently, Yamamoto et al reported that the sensitivity and specificity of 18F-FDG PET/CT in the detection of malignant or borderline malignant pelvic tumors were 71.4% and 81.3%, respectively, and that 18F-FDG PET/CT had a low diagnostic value in differentiating between borderline malignant and benign tumors [22]. This result concurs with our results in that all four borderline malignant tumors were mimicking a benign ovarian tumor without FDG uptake on 18F-FDG PET/CT. This highlights a limitation in the characterization of borderline tumors for primary ovarian cancer with 18F-FDG PET/CT.

In the staging of ovarian cancer, Castellucci et al. re-
ported that the 18F-FDG PET/CT were more accurate than CT [23]. CT incorrectly down-staged four out of six stage IV patients by missing distant metastasis in the liver, pleura, mediastinum, and left supraclavicular lymph nodes [23]. Our results also reflect the incorrect downstaging in two out of three stage IV patients with CT or MRI, while we accurately staged all stage IV patients with 18F-FDG PET/CT. However, the right pleural metastasis which was misdiagnosed as perihepatic seeding metastasis by CT in our result was not due to a problem of CT modality but rather the reader’s misinterpretation. Although there was no statistical significant difference in accuracy of preoperative staging between CT or MR and 18F-FDG PET/CT in our results, an obvious advantage of 18F-FDG PET/CT over CT or MRI was to detect metastasis outside the abdomen such as supraclavicular lymph node metastasis. The two patients with supraclavicular lymph node metastases, in this study, also had multiple pelvic and para-aortic lymphadenopathies. We believe that 18F-FDG PET/CT was useful in the accurate preoperative staging of ovarian cancer patients with multiple abdominal lymphadenopathies.

The results of the current study come with several limitations. First, the study was retrospective with a small population. Also, as is typical of all retrospective studies, the potential for selection bias must be considered. Second, the 18F-FDG PET CT scan was a whole body scan, but the CT or MRI covered only the abdomen and pelvis for this study. Therefore, extra-abdominal metastases without intra-abdominal distant metastases could be defined only by 18F-FDG PET CT. Third, contrast enhanced CT and abdominal T1-weighted enhanced scans only, could render an incomplete evaluation of seeding metastases. Fourth, pathologic correlation could not be assessed by a lesion to lesion and visual assessment of the 18F-FDG PET/CT interpretation may be subject to inter-observer variability.

In conclusion, despite these limitations, there was no difference in diagnostic accuracy between CT or MRI and 18F-FDG PET/CT in preoperative staging of ovarian cancer. Therefore, additional 18F-FDG PET/CT besides CT or MRI for preoperative staging of ovarian cancer is not mandatory, but may be useful in the evaluation of distant lymph node metastases when the patient has had multiple abdominal metastatic lymphadenopathies.

References

11. Bristow RE, Giuntoli RL 2nd, Pannu HK, Schulick RD, Fishman EK, Wahl RL. Combined PET/CT for detecting recurrent ovarian cancer limited to retroperitoneal lymph nodes. Gynecol Oncol 2005;99:294-300


Guk Won Jung, et al: Comparison of CT or MRI and 18F-FDG PET/CT for the Preoperative Staging Accuracy of Ovarian Cancer

난소암의 수술전 병기결정시 CT 또는 MRI검사와 18F-FDG PET/CT 검사의 정확성 비교

1가톨릭대학교 의과대학 강남성모병원 영상의학과, 2핵의학과

정국원·이영준·오순남·나성은·변재영·유이령2·김성훈2·정수교2

목적: 수술 전 난소암의 병기결정에서 CT 또는 MRI와 18F-FDG PET/CT 진단의 정확도를 비교하고자 하였다.

대상과 방법: 수술 후 약으로 치료된 28명의 환자(15-67세, 평균 46세)와 38개의 난소종양(4-30 cm, 평균 11 cm)을 대상으로 하였다. 환자들은 최소한 수술 2주 전에 CT(20예) 또는 MRI(10예)와 18F-FDG PET/CT를 시행 받았다. 영상은 각각 후향적 그리고 독립적으로 분석하였다. CT 또는 MRI와 18F-FDG PET/CT 검사에 의한 수술 전 난소암 병기결정의 정확성을 FIGO 병기결정을 기준으로 서로 비교하였다.

결과: FIGO기준에 의한 병기에서 제 1 암 병기가 11예, 제 3 암 병기가 14예, 제 4 암 병기가 3예였다. 전체 난소 종양 38예 중 6예(16%)가 18F-FDG PET/CT에서 FDG 역학을 보이지 않았고, 1예(3%)에서만 CT 또는 MRI에서 고형부분을 포함하지 않았는데, 이 경우는 모두 제 1 암 병기였다. CT 또는 MRI와 18F-FDG PET/CT의 수술 전 난소암 병기결정의 진단 정확도는 각각 75%(21/28)와 82%(23/28)로 유의한 차이가 없었다.

결론: 수술 전 난소암 병기결정을 위해 CT나 MRI 이외에 추가적인 18F-FDG PET/CT 검사가 반드시 필요하지는 않다.