Modern Pathology (2005) 18, 1411–1416

www.modernpathology.org

Expression of CD117 (c-kit) receptor in dysgerminoma of the ovary: diagnostic and therapeutic implications

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The proto-oncogene *c-kit* encodes a tyrosine kinase receptor, c-kit (CD117), which has been implicated in the development of a number of human malignancies. While the preferential expression of this protein has been well documented in testicular seminomas, there is little data concerning its expression in dysgerminomas of the ovary. We examined the expression of c-kit in 30 cases of ovarian dysgerminomas using immunohistohemical staining with a polyclonal anti-CD117 antibody. Staining was graded in a semiquantitative manner as follows: negative (no staining), 1+ (1–10% staining), 2+ (10–29% staining), 3+ (30–50% staining), or 4+ (>50% staining). Of the 30 cases examined, 26 (87%) demonstrated immunoreactivity for CD117. In total, 10 (33%) demonstrated 4+ staining; 9 (30%) demonstrated 3+ staining; 3 (10%) demonstrated 2+ staining; 4 (13%) demonstrated 1+ staining; and 4 (13%) demonstrated no staining. In conclusion, CD117 immunoreactivity was detected in 87% of ovarian dysgerminomas, a finding that correlates with previously reported frequencies of CD117 expression in seminomas (78–100%). Thus, antibodies to c-kit may be a useful diagnostic marker for ovarian dysgerminoma. Although the prognosis of patients with dysgerminoma is generally good, this receptor could potentially serve as a target for site-specific immunotherapy as an alternative and/or complement to conventional treatment options.
Modern Pathology (2005) **18,** 1411–1416. doi:10.1038/modpathol.3800463; published online 22 July 2005

Keywords: ovary; germ cell tumors; c-kit (CD117); differential diagnosis; OCT4; dysgerminoma

The proto-oncogene *c-kit* encodes a 145–160 kDa, type III transmembrane tyrosine kinase receptor known as c-kit or CD117,[1,2] which belongs to the same family of receptors as platelet-derived growth factor and colony-stimulating factor-1.[3] The binding of stem cell factor, the ligand for this receptor, leads to the dimerization of c-kit proteins, thus initiating a signaling cascade that ultimately induces cell growth.[1] Expression of c-kit is essential in the development of some cell types, including melanocytes, germ cells, mast cells, erythrocytes, and interstitial cells of Cajal.[1,4–6] In addition, expression of this receptor may be seen in other histologically normal cell types, such as breast epithelial cells, renal tubule cells, astrocytes, Purkinje cells, parotid acini, and endometrial cells.[6–8] Aberrant expression of this receptor, however, has been implicated in the development of a number of human cancers, including malignancies of the lung, skin, breast, uterus, endometrium, urinary bladder, and ovary, as well as in certain types of leukemia, Ewing tumor, gastrointestinal stromal tumors (GISTs), and germ cell tumors.[8–28] The advent of therapies targeted to c-kit have proven highly effective in treating some cancers that overexpress this receptor, such as chronic myeloid leukemia and GISTs.[29–32]

Dysgerminoma is an uncommon primitive germ cell tumor of the ovary, comprising 0.5–5% of all ovarian malignancies.[33–37] This tumor is histologically and biologically similar to testicular seminoma. Accurate diagnosis of dysgerminoma is important as its treatment and prognosis differ significantly from those of other ovarian tumors.[36,38–41] Thus, an immunohistochemical marker

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Received 28 December 2004; revised 31 May 2005; accepted 1 June 2005; published online 22 July 2005

sensitive for this type of tumor could serve as a useful diagnostic tool. While current therapeutic regimens consisting of chemotherapy and radiation are highly effective in eradicating the disease,[41,42] reproductive compromise is a common side effect of treatment and is a major concern given the young age at which this tumor typically presents. The identification of cellular proteins, such as c-kit, that may be overexpressed in this tumor could potentially lead to targeted therapies with less devastating side effects. While aberrant expression of c-kit has been well documented in testicular seminoma,[2,5,11,13,14,43–46] little data concerning its expression in ovarian dysgerminoma are available. Therefore, we analyzed the immunohistochemical expression of c-kit in 30 cases of dysgerminoma of the ovary.

Materials and methods

In all, 30 cases of dysgerminoma of the ovary accessioned from 1982 to 2002 were retrieved from the surgical pathology files of three institutions: Indiana University Medical Center (Indianapolis, IN, USA), University Hospitals of Cleveland (Cleveland, OH, USA), and Yale University (New Haven, CT, USA). Medical records for the cases were reviewed. Formalin-fixed paraffin-embedded tissue specimens were available for all cases. Sections (4 μm thick) were cut from paraffin blocks and stained with hematoxylin and eosin for microscopic examination. Pathologic staging was performed according to the FIGO staging system for ovarian neoplasms.[47] This research was approved by the Institutional Review Boards in accordance with the Institutional Committee for the Protection of Human Subjects (Figure 1).

Additional paraffin sections of selected blocks were obtained for immunohistochemical studies, which were performed on an automated immunostainer. Immunohistochemical staining was performed with the avidin–biotin complex method of Hsu *et al*.[48,49] In brief, serial 4-μm-thick sections of formalin-fixed, paraffin-embedded tissue samples were used for the studies. Slides were deparaffinized twice in xylene for 5 min and rehydrated through graded ethanol solutions to distilled water. Antigen retrieval was performed by heating sections in citrate buffer (DAKO Target Retrieval Solution S1699, DAKO corporation, Carpinteria, CA, USA) for 15 min. Inactivation of endogenous peroxidase activity was achieved by incubation in 3% H_2O_2 for 15 min. Nonspecific binding sites were bound using Protein Block (DAKO) for 20 min. Tissue sections were then incubated with the purified rabbit polyclonal antibody against the C-terminus of the p145 human c-kit protein (IgG, 1:50 dilution; Oncogene, Boston, MA, USA) for 30 min at room temperature. This was followed by biotinylated secondary antibody (DAKO) and peroxidase-labeled streptavidin.

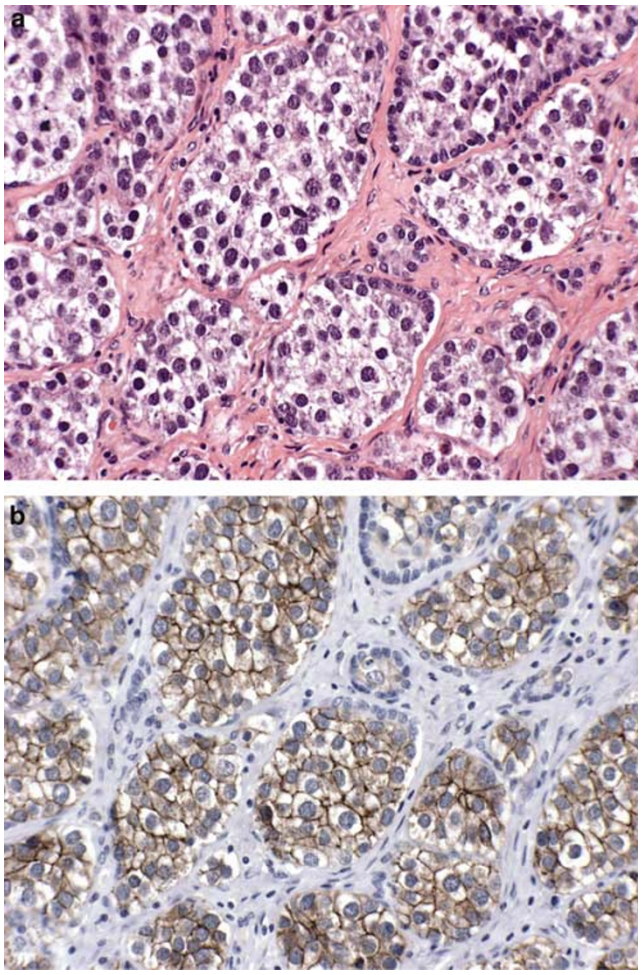

Figure 1 Dysgerminoma of the ovary (**a**). Positive membranous c-kit immunostaining was noted (**b**).

The chromogen 3,3-diaminobenzidine was used in the presence of hydrogen peroxide. Sections from GISTs were used as positive controls. Negative controls were performed using blocking serum in place of primary antibody. Positive and negative controls were run in parallel with each batch, and appropriate results were obtained.

The expression of c-kit was evaluated in a semiquantitative manner as follows: no staining (0), 1–10% staining (1+), 11–29% (2+), 30–50% (3+), and greater than 50% (4+). Given that c-kit is a membrane-bound tyrosine kinase receptor, only membranous staining pattern was considered positive.[50]

Results

The 30 patients examined had a mean age of 22 years (range of 6–50 years). In all, 21 of the patients (70%) presented with stage Ia or Ib disease; two (7%) presented with stage IIa disease; and seven (23%) presented with more advanced disease (stage

IIIb or IIIc). Five of the patients (17%) were found to have lymph node metastasis at presentation. Tumor sizes ranged from 2.5 to 21 cm in greatest dimension. Of 30 cases, 26 (87%) demonstrated positive staining with antibodies to c-kit. In all, 10 (33%) showed diffuse staining (>50%), while nine (30%) demonstrated 30–50% staining. Three cases (10%) showed 11–29% staining and four cases (13%) showed 1–10% staining. Only four of 30 cases (13%) were immunohistochemically negative for c-kit. There was no statistically significant correlation between c-kit staining and pathologic stage or tumor size, as summarized in Table 1. Two lymph nodes from two patients with metastatic disease demonstrated strong c-kit reactivity.

Discussion

The expression of c-kit (CD117) has been demonstrated in a wide variety of human malignancies, including those of the lung, breast, endometrium, gastrointestinal tract, urinary bladder, and hematopoietic system.[1,2,4–15,17–28,43–46] In addition, c-kit has also been shown to be overexpressed in specific types of malignant germ cell tumors, such as seminoma.[2,5,11,13,14,43–46] Dysgerminoma of the ovary is a neoplasm that is histologically, biologically, and clinically similar to testicular seminoma. While, the immunohistochemical expression of the transmembrane receptor c-kit in seminoma has been well documented, its expression in dysgerminoma has not been extensively explored. In this study, we analyzed 30 cases of ovarian dysgerminoma with anti-c-kit antibodies and found that, like seminoma, these tumors frequently (87%) exhibit immunoreactivity for c-kit.

The accurate diagnosis of dysgerminoma is of critical importance as the therapy and prognosis for these patients is significantly different from that of other ovarian malignancies.[37] Dysgerminoma has a better prognosis than other malignant ovarian tumors, as it is highly sensitive to cisplatin- or carboplatin-based chemotherapy and to radiotherapy.[39,42,51,52] Cure rates approach 95% with treatment strategies employing adjuvant chemotherapy, even in advanced metastatic disease.[14,33–41]

Histologically, the differential diagnosis for dysgerminoma includes other germ cell tumors, most notably the solid variants of yolk sac tumor and embryonal carcinoma, as well as clear-cell adenocarcinoma, granulosa cell tumor, lymphoma, and metastatic tumors, such as melanoma. Immunohistochemical stains can often aid in discriminating between these morphologically similar lesions. Immunostaining for placental-like alkaline phosphatase in the ovary, although relatively specific for dysgerminoma, can show positivity in other types of primitive germ cell tumors, as well as in benign germ cells.[53] Cytokeratins can show focal staining in dysgerminoma.[54] OCT4 has recently been shown to be a sensitive and relatively specific biomarker for the detection of dysgerminoma, although focal staining in clear-cell adenocarcinoma has been noted.[55] Likewise, stains for c-kit may prove to be a useful diagnostic tool in histologically difficult cases of dysgerminoma.

Previous studies demonstrating expression of c-kit in ovarian tumors, let alone dysgerminoma in particular, have included only small numbers of cases. In a broad study of c-kit expression in numerous tumors, Went *et al* demonstrated that dysgerminoma (two cases) and gonadoblastoma (one case) both demonstrate c-kit expression. Additionally, Brenner tumor (33% staining), cervical adenocarcinoma (33% staining), and, less frequently, ovarian carcinoma, cervical squamous carcinoma, and vulvar carcinoma all demonstrate minimal c-kit expression.[50] Klein *et al*[56] demonstrated the lack of c-kit expression in ovarian mesenchymal tumors, including leiomyosarcoma, carcinosarcoma, endometrial stromal tumors and clear-cell ovarian sarcoma. Similarly, Raspollini *et al*[57] demonstrated that 51% of advanced ovarian serous carcinoma demonstrated c-kit expression. Schmandt *et al*[9] found that low-grade serous carcinoma of the ovary demonstrated no c-kit expression, and only 26% of high-grade serous tumors showed some reactivity. Ramalingam *et al*[58] recently reported that yolk sac tumors of the ovary, often included in the differential diagnosis of dysgerminoma, demonstrated no c-kit expression.

Natali *et al*[6] investigated c-kit expression in a number of benign and malignant neoplasms using immunohistochemistry, including a single case of dysgerminoma, which was found to be immunoreactive for c-kit. Tsuura *et al*[5] similarly investigated c-kit expression in 884 solid tumors and found c-kit positivity in three of four (75%) dysgerminomas. Sakuma *et al*[59] studied 16 intracranial germinomas and found membranous c-kit immunoreactivity in the majority of tumor cells from all cases.

Our study of 30 cases of ovarian dysgerminoma is, to our knowledge, the largest series of cases to be analyzed for c-kit expression. Our finding of c-kit positivity in 87% of dysgerminoma suggests that this marker may serve as a useful marker for dysgerminoma, especially when other germ cell tumors and clear-cell adenocarcinoma fall in the differential diagnosis.

Those cases that failed to exhibit c-kit expression may actually represent heterologous expression of the receptor in each tumor or variance among individuals. Review of the hematoxylin and eosin-stained sections revealed no morphologic qualities that served as a predictor of c-kit status, although areas of necrosis did fail to highlight with the antibody. Technical inadequacy may also serve as a less likely explanation. The stage of disease at presentation, too, was not a statistically significant predictor of c-kit expression. Of the cases that failed to show c-kit reactivity, all demonstrated strong

OCT4 expression, as reported previously, which may serve as an alternative marker in those cases that fail to show c-kit reactivity.[55] We should emphasize that OCT4 is also positive in embryonal carcinoma and clear-cell adenocarcinoma of the ovary;[55,60–62] therefore, its utility in the differential diagnosis of these tumors is limited. Furthermore, embryonal carcinoma has been noted to rarely demonstrate c-kit expression.[44]

With the advent of c-kit-targeted therapy with imatinib mesylate (Gleevec; Novartis), and the proven success of this drug in the treatment of chronic myelogenous leukemia (CML) and GIST,[29–32] c-kit expression may no longer be merely of diagnostic relevance but may also have therapeutic significance. Anti-c-kit compounds have been shown in *in vitro* and *in vivo* studies to inhibit effectively receptor autophosphorylation and subsequent MAP kinase activity and Akt activation.[16] The responsiveness of tumors to imatinib mesylate has been shown to correlate with specific *c-kit* gene mutations rather than with immunohistochemical expression.[50,63] Therefore, c-kit positivity on immunostaining does not necessarily indicate that a patient's tumor will respond to therapy targeted against c-kit. A number of *c-kit* mutations have been identified in GISTs in exons 9, 11, 13, and 17, resulting in a protein product with constitutive kinase activity.[15,16,64,65] Tian *et al*[2] discovered a novel missense mutation (D816H) in the phosphotransferase domain of the *c-kit* gene in tumors of seminoma/dysgerminoma type, providing the first evidence that the c-kit signal transduction cascade may be important in the pathogenesis of these neoplasms as well. Subsequently, Przygodzki *et al*[66] and Sakuma *et al*[43] identified *c-kit* gene mutations in primary mediastinal seminomas and testicular seminomas, respectively. Kemmer *et al*[67] examined the frequency and spectrum of *c-kit* gene mutations in 54 testicular seminomas, one ovarian dysgerminoma, and 37 nonseminomatous germ cell tumors and found *c-kit* mutations in 26% of seminomas. Neither the single dysgerminoma nor any of the nonseminomatous germ cell tumors harbored a *c-kit* gene mutation. Given the histologic, biologic, and immunohistochemical similarities between seminoma and dysgerminoma, it is reasonable to speculate that some *c-kit* mutations would be discovered in dysgerminoma if more than one case were analyzed. In fact, Pauls and associates[68] studied the expression and mutational status of a pure dysgerminoma and found an exon 17 D816V mutation in the *c-kit* gene and strong immunohistochemical c-kit expression. Sakuma *et al*[59] analyzed 16 intracranial germinomas and found *c-kit* gene mutations in four cases (25%). While *c-kit* mutations have been found in dysgerminomas, it is not clear if these mutations make these tumors amenable to treatment with anti-c-kit-targeted therapies.

Dysgerminoma is highly radiosensitive, and cure rates approach 95% with adjuvant chemotherapy, even in advanced metastatic disease.[51] Reproductive difficulties following treatment are a common adverse side effect.[33] Therefore, current therapeutic development has focused on reduction in morbidity with fertility-sparing treatments.[33–41] This is often of great concern to patients with dysgerminoma given the young mean age at presentation. Given the successful treatment of CML and GIST with imatinib mesylate, anti-c-kit compounds could prove to be an additional treatment option in patients with dysgerminoma, allowing for conservative therapy with a potentially less-devastating impact on post-treatment fertility. It has been suggested, although not rigorously proven, that tumor resistance to carboplatin-based chemotherapy may result from exon 17 *c-kit* gene mutations.[68] Similarly, Raspollini *et al*[57] demonstrated that advanced ovarian carcinoma that expressed c-kit was resistant to current chemotherapeutic regimens.

Dysgerminoma is a relatively rare malignant germ cell tumor of the ovary seen in young adults. In this study, we demonstrate that 87% of these tumors exhibit immunohistochemical expression of the transmembrane tyrosine kinase receptor c-kit (CD117), much like its male counterpart, seminoma. Thus, immunostains for c-kit may be potentially useful in distinguishing between dysgerminoma and other ovarian neoplasms. With the advent and success of c-kit-directed therapies in chronic myeloid leukemia and GIST, c-kit expression in dysgerminoma may provide a new target for conservative, fertility-sparing therapy.

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