International Society of Gynecological Pathologists (ISGyP) Endometrial Cancer Project: Guidelines From the Special Techniques and Ancillary Studies Group

Kathleen R. Cho, M.D., Kumarasen Cooper, M.B.Ch.B., D.Phil., F.R.C.Path., Sabrina Croce, M.D., Bojana Dзоревиќ, M.D., F.R.C.P.C., Simon Herrington, M.D., F.R.C.Path., Brooke Howitt, M.D., Pei Hui, Ph.D., M.D., Philip Ip, M.B.Ch.B., F.R.C.Path., Martin Koebel, M.D., Sigurd Lax, M.D., Bradley J. Quade, M.D., Patricia Shaw, M.D., August Vidal, M.D., Anna Yemelyanova, M.D., Blaise Clarke, M.B.B.Ch., Lora Hedrick Ellenson, M.D., Teri A. Longacre, M.D., Ie-Ming Shih, Ph.D., M.D., W. Glenn McCluggage, M.D., M.R.C.Path., Anaïs Malpica, M.D., Esther Oliva, M.D., Vinita Parkash, M.B.B.S., and Xavier Matias-Guiu, M.D., Ph.D.

Summary: The aim of this article is to propose guidelines and recommendations in problematic areas in pathologic reporting of endometrial carcinoma (EC) regarding special techniques and ancillary studies. An organizing committee designed a comprehensive survey with different questions related to pathologic features, diagnosis, and prognosis of EC that was sent to all members of the International Society of Gynecological Pathologists. The special techniques/ancillary studies group received 4 different questions to be addressed. Five members of the group reviewed the literature and came up with recommendations and an accompanying text which were discussed and agreed upon by all members of the group. Twelve different recommendations are made. They address the value of immunohistochemistry, ploidy, and molecular analysis for assessing prognosis in EC, the value of steroid hormone receptor analysis to predict response to hormone therapy, and parameters regarding applying immunohistochemistry and molecular tests for assessing mismatch deficiency in EC. Key Words: Endometrial carcinoma—Guidelines—ISGyP—Molecular pathology.

From the MD Anderson Cancer Center, Houston, Texas (R.B., A.Y., A.M.); University of Michigan Medical School, Ann Arbor, Michigan (K.R.C.); Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania (K.C.); Bergonie Institute, Bordeaux, France (S.C.); The Ottawa Hospital, University of Ottawa, Ottawa (B.D.); Toronto General Hospital, Toronto (P.S., B.C.), Ontario; Department of Pathology, University of Calgary, Calgary, Alberta (M.K.), Canada; Edinburgh Cancer Research Centre, Edinburgh (S.H.); Belfast Health and Social Care Trust, Belfast (W.G.M.), UK; Brigham and Women’s Hospital (B.H., B.J.Q.); Massachusetts General Hospital, Harvard University (E.O.), Boston, Massachusetts; Yale New Haven Hospital, New Haven, Connecticut (P.H., V.P.); Department of Pathology, University of Hong Kong, Hong Kong, China (P.I.); Department of Pathology, Medical University of Graz, Graz, Austria (S.L.); Bellvitge University Hospital, IDIBELL, Barcelona (A.V., X.M.G.); Hospital Universitari Arnau de Vilanova, University of Lleida, IRBLLEIDA, Lleida (X.M.G.), CIBERONC, Spain; Weill Cornell Medical College, New York, New York (L.H.E.); Stanford University Medical Center, Stanford, California (T.A.L.); and Johns Hopkins University School of Medicine, Baltimore, Maryland (I.M.S.).

The authors declare no conflict of interest. Address correspondence and reprint requests to Xavier Matias-Guiu, MD, PhD, Hospital Universitari Arnau de Vilanova, Av Rovira Roure, 80, Lleida 25198, Spain. E-mail: fimatiasguiu lleida.ics@ct.cat.

This is an open access article distributed under the Creative Commons Attribution License 4.0 (CCBY), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

DOI: 10.1097/PGP.0000000000000496
In the western world, endometrial carcinoma (EC) is the fourth most common cancer among women, with an estimated incidence of 10 to 20 per 100,000 women. Although the prognosis is favorable for patients with low-grade tumors and early-stage disease, the outcomes for patients with high-grade and/or advanced stage tumors remains relatively poor. Following surgery (which is the usual treatment), patients with tumors with a high risk of recurrence often receive adjuvant radiotherapy, chemotherapy, and/or hormone therapy. However, traditional chemotherapeutic regimes are less effective in comparison with cancers of other organs, which emphasize the importance of identifying new molecular targets. Several biomarkers have been proposed to better assess the prognosis and prediction of response to therapy and to identify patients carrying germline mutations associated with an increased risk of EC (1). However, there is no consensus regarding the application of these biomarkers in clinical practice.

In this article, we provide guidelines, which have been produced after a thorough literature search, and discussed among a group of members of the International Society of Gynecological Pathologists (ISGyP), selected because of their expertise in the immunohistochemistry (IHC) and molecular pathology of EC.

**METHODS**

An organizing committee composed of 5 of the authors (W.G.M., V.P., A.M., E.O., and X.M.G.) was chosen by the Executive Committee of ISGyP. The committee designed a survey (see paper on survey) with many different questions, related to the pathologic features, diagnosis, and prognosis of EC, which was sent to all members of ISGyP. After analysis of the responses, the organizing committee selected several problematic areas that would be addressed, to achieve consensus and provide recommendations. The organizing committee created 3 different groups: (1) diagnosis, (2) processing/sampling/staging/prognosis, and (3) special techniques/ancillary studies. Several questions were sent to each group.

The special techniques/ancillary studies group addressed 4 different questions. Five members of the group (T.A.L., B.C., I.M.S., L.H.E., and X.M.G.) reviewed the literature and came up with recommendations and accompanying text which were discussed and agreed by all members of the group. Levels of evidence and strength of the recommendations were established according to criteria established in Table 1.

**TABLE 1. Level of evidence and strength of recommendation adapted from ESMO 2014 endometrial cancer consensus conference**

| Level of evidence | Strength of recommendation |
|-------------------|----------------------------|
| I. Evidence from at least 1 large randomized control trial of good methodological quality (low potential for bias) or metaanalyses of well-conducted RCTs without heterogeneity | Strong evidence for efficacy or for adverse outcome, generally recommended |
| II. Small RCTs or large RCTs with a suspicion of bias (lower methodological quality) or metaanalyses of such trials or of trials with demonstrated heterogeneity | Moderate evidence against efficacy or for adverse outcome, generally not recommended |
| III. Prospective cohort studies | Strong evidence against efficacy but with a limited clinical benefit, generally recommended |
| IV. Retrospective cohort studies or case-control studies | Insufficient evidence for efficacy or benefit does not outweigh the risk or the disadvantages (adverse events, costs, etc.) optional |
| IV. Studies without control group, case reports, experts opinions | Moderate evidence against efficacy or for adverse outcome, generally not recommended |
| V. Observational studies | Strong evidence against efficacy or for adverse outcome, never recommended |

**Question 1. Should IHC and Ploidy Analysis be Performed for Assessing Prognosis in EC?**

A preliminary comment is necessary to emphasize that IHC is important in histologic typing, and this is relevant for prognosis. This is particularly important for high-grade EC, including high-grade endometrioid carcinoma (EEC), serous carcinoma (SC), and clear cell carcinoma, since there is poor interobserver agreement in diagnosing this subset of tumors (2). These issues will be addressed by the diagnosis group.

Other than markers which are useful in diagnosis, there are few specific studies that provide definitive evidence for the routine use of IHC or ploidy analysis in determining the prognosis of EC.

There has been considerable literature on the association between prognosis and the IHC analysis of estrogen receptor (ER), progesterone receptor (PR), Ki67, and p53 in EC (3). It is well established that there is an association between the expression of these markers and prognosis and there is a significant literature regarding this (4–7), but there are a lack of large prospective studies to determine their prognostic utility.

Hormone receptor status has been suggested to be a relevant prognostic marker, and the presence of steroid receptors correlates with low tumor grade, as well as favorable outcome in some studies. However, there is no absolute evidence that steroid hormone receptor analysis should be incorporated into clinical practice.

Similar comments pertain to ploidy analysis. There is some literature on the association of ploidy with
prognosis, with promising results (8,9), but there is a lack of definitive studies to determine its true prognostic impact (10).

There are a number of additional potential biomarkers reported for EC, but none of them are validated for use as robust prognostic indicators. New prognostic markers such as L1CAM (11,12) or Annexin A-2 (13) are promising, but require prospective validation studies before bringing them into clinical practice. Additional potentially useful markers are intratumoral lymphocytes (CD8+), tumor-associated macrophages, loss of ASRGL1, or hyaluronidase 1 (14,15). There is particular interest regarding L1CAM and several studies have validated this marker in multicentric analysis (16,17).

One of the important issues with implementing these markers in the routine clinical setting is the lack of uniformity regarding the methodology used, both technical and interpretive. Clearly, large prospective, well defined, uniform studies are needed to determine the possible role of IHC for specific biomarkers and ploidy analysis in the clinical setting.

**Question 2. Should ER IHC be Used to Predict Response to Hormone Therapy? Are There Any Other Predictive Markers of Response to Hormone Therapy?**

Hormone therapy is sometimes administered to patients with advanced or recurrent EC, particularly low-grade EEC (18). A wide range of hormonal agents have been used, including medroxyprogesterone acetate and synthetic progesterational agents, LHRH antagonists, tamoxifen, and new generations of selective estrogen receptor modulators (19).

Although receptor IHC estimation has not been universally accepted as the standard for prediction of hormone response, several international guidelines recommend determination of hormone receptor status before hormone therapy is initiated (18).

A recent systematic review of 5 randomized trials and 29 phase II studies, comprising a total of 2471 patients, concluded that hormone receptor assessments should be carried out in all patients entered into clinical trials, and may aid clinical management in selected patients (20). The report notes that receptor-negative status is not an absolute contraindication to hormone treatment. Response rates to various hormonal treatments for EC patients are higher for patients with low-grade EEC, and those with PR expression. However, the methodology for assessing and scoring hormone receptor expression in EC was variable in the reported series.

Furthermore, changes in ER, and particularly PR, expression occur during tumor progression, and expression is generally higher in primary in comparison with metastatic tumors. This suggests that assessment of ER status in the primary tumor may not reflect the status in the recurrent or metastatic tumor and that biopsies of recurrent or metastatic tumors with hormone receptor analysis on these may be helpful (21).

In summary, at the present time there is not enough data to support that the ER or PR status of tumors, as determined by IHC, is a reliable marker for predicting response to hormone therapy. There are studies that have concluded that positive staining does correlate with response, but other studies have indicated that there is no correlation. Large prospective studies using defined, uniform approaches need to be performed to determine whether ER and/or PR IHC is a robust marker to predict hormone therapy response.

**Question 3. Should Molecular Analysis be Performed to Diagnose and/or Classify Appropriately EC? When Should This be Used and Which Analysis is Recommended?**

Tests based on sets of genes that are differentially expressed in ECs compared with normal endometrium cells have been proposed as adjuncts to diagnosis on endometrial biopsies. They have been shown to be useful in women with suspicion of cancer and noninformative endometrial biopsies with insufficient material to allow a specific diagnosis.

Although promising, and assessed in prospective studies (22), their incorporation into clinical practice requires further validation.

There are different pathologic variants of EC. Single-gene approaches have shown that the molecular alterations involved in the development of EEC are different from those of SC, clear cell carcinoma, and carcinosarcoma. Many EECs exhibit microsatellite instability (MSI), as well as mutations in PTEN, KRAS, and CTNNB1 whereas SC exhibits alterations of TP53, widespread loss of heterozygosity, as reflected by chromosomal instability, as well as other molecular alterations (1).

The Cancer Genome Atlas (TCGA) Research Network performed an integrated genomic characterization of EC (23). The genes most frequently mutated in EEC were PTEN (77%), PIK3CA (53%), PIK3RI (37%), CTNNB1 (36%), ARID1A (35%), KRAS (24%), CTCF (20%), RPL22 (12%), TP53 (11%), FGFR2 (11%), and ARID5B (11%). The genes most frequently
mutated in SC were TP53 (90.7%), PIK3CA (41.9%), FBXW7 (30.2%), PPP2R1A (36.6%), CHD4 (16.3%), CSMD3 (11.6%), and COLA11 (11.6%) (1). Additional studies using exome-sequencing analysis have also shown mutations in TAF1 (30%), in SC (24).

In addition to the TCGA approach, several groups have assessed the usefulness of next-generation sequencing in differential diagnosis between different types of tumors, particularly EEC and SC (25). This may be particularly interesting in tumors with non-informative immunohistochemical results and ambiguous microscopic appearances. Further studies are required to investigate whether next-generation sequencing is more accurate, informative, clinically relevant, and cost-effective in comparison with IHC.

The TCGA exome sequence analysis revealed 4 groups of tumors with significant differences in prognosis. Group 1 comprised EEC with mutations in POLE (ultramutated), associated with good prognosis. Group 2 comprised EEC with MSI (hypermutated) and group 3 tumors comprised EEC with low copy number alterations; both groups 2 and 3 tumors showed similar and intermediate progression-free survival rates. Group 4 (serous-like) tumors show TP53 mutations, and a worse prognosis. They are composed mostly of SCs, but also include some EEC (many grade 3 but also some grades 1 and 2).

Following the TCGA study, sequencing of POLE has been proposed to identify the group of ultramutated tumors, which have been associated with an excellent prognosis in several case series (26,27). POLE sequencing seems to be particularly relevant in the subgroup of patients with high-grade EEC, particularly in those with some features mimicking SC (28), although SC may also show POLE mutations (29). Incorporation of POLE sequencing in the assessment of endometrial tumors may have an impact in tailoring treatment and possibly reducing the extent of surgery, in a subset of patients with high-grade ECs (30,31). Prospective studies are recommended to assess the benefits and cost-effectiveness of POLE sequencing. Development of molecular tests for POLE analysis is encouraged, particularly in pathology departments with experience in molecular pathology. Identification of possible IHC surrogates of POLE mutation in EC may also be of great interest.

Combining POLE mutational analysis with IHC analysis of p53 and mismatch repair (MMR) proteins (PMS-2 and MSH-6) has been proposed to classify ECs into the 4 TCGA groups. This is likely to be particularly useful for high-grade EEC and SC, as a surrogate assay that can replicate TCGA classification (30–32) (Table 2).

This topic will be also analyzed in another manuscript. However, it is worth mentioning that there are some aspects that should be taken into account. For example, not all POLE-mutated EC are hypermutated. Moreover, by performing MMR proteins IHC first, we will be missing some number of POLE-mutated cases. Interpretation of p53 immunostaining will be also discussed in a separate manuscript.

It is important to note that some tumors have intermediate features (double mutant), and the prognostic relevance of these unusual patterns will require further analysis. Application of TCGA surrogate classification to high-grade EC may also potentially help in deciding whether immunotherapy is useful (33). Emerging data have suggested that EECs exhibiting POLE mutations and MSI are hypersensitive to the immune checkpoint inhibitor, anti-PD-1, monotherapy because these tumors are characterized by a high mutation load which produces more neo-antigens. They also have a higher number of tumor infiltrating lymphocytes (34–36). There is a report of 2 cases of EC (1 POLE mutated, 1 MSH-6 mutated) both of whom were refractory to chemotherapy and radiation therapy, who both responded (sustained partial response by RECIST criteria) to nivolumab (37).

Addition of CTNNB1 (the gene coding for betacatenin) mutation analysis has also been proposed in EEC with low copy number alteration, as a prognostic biomarker in this subset of tumors (38).

Recent preclinical studies also demonstrate that tumors with ARID1A mutations are more sensitive to PARP1 inhibitors and EZH2 inhibitors (39,40). If the results of future clinical trials show clinical benefit, analyzing ARID1A expression status (loss of expression is a surrogate for ARID1A inactivating mutation) in EEC could be useful to stratify patients for ARID1A-based therapy.

| TABLE 2. Surrogate approach for applying TCGA scheme into pathology practice |
|---------------------------------------------------------------|
| POLE mutation pattern | POLE mutated EC (ultramutated) |
| p53 wild-type pattern, abnormal mismatch repair | EC with microsatellite instability (hypermutated) |
| p53 wild-type pattern, normal mismatch repair | EC with low copy number alterations |
| p53 abnormal expression and normal mismatch repair | Serous-like (high-copy number) EC |

EC indicates endometrial carcinoma; TCGA, The Cancer Genome Atlas.
Question 4. Should IHC and/or MSI (Including Methylation Analysis) be Performed Routinely in Apparently Sporadic ECs? All Cases? When?

Approximately 3% to 5% of ECs can be attributed to Lynch syndrome (LS) which is caused by germline mutations in DNA MMR genes (MLH1, MSH-2, MSH-6, PMS-2). Patients with LS have a 40% to 60% lifetime risk for endometrial and colon cancer (41–43). The identification of LS in women with EC can lead to the prevention of a second cancer in the patient and incident cancers in family members through risk-reducing strategies and heightened surveillance (44,45). Utilization of clinical criteria to identify patients with LS has less than optimal sensitivity and efficiency.

A Society of Gynecologic Oncologists Clinical Practice Statement in 2014 recommended all women diagnosed with EC undergo systematic clinical screening (review of personal and family history) and/or molecular or IHC screening for LS (46). In this statement IHC screening of EC for LS is stated to be the preferred screening strategy when resources are available for the following reasons.

Systematic clinical screening, including a focused personal and family history, will miss a significant fraction of women with LS who do not have a suggestive family history (47–51). Some studies indicate that up to 75% of LS patients are missed using the revised Bethesda guidelines. It has been proposed that the more sensitive strategy involves universal tumor testing for either all endometrial cancers or cancers diagnosed at age ≤60 (or 70), regardless of personal or family cancer history. Although EC can be screened for LS using IHC for the 4 MMR proteins (MLH1, MSH-2, MSH-6, PMS-2) and/or MSI analysis, with reflex MLH1 hypermethylation testing, IHC is the most cost-effective method and is widely available in almost all pathology laboratories. IHC testing of tumor tissue for lack of expression of MMR proteins has an overall reported sensitivity and specificity for LS of 83% and 89%, respectively. Additional advantages of IHC testing include (1) absence of expression of a specific mismatch protein can direct germline testing to that specific gene and (2) the relative increased prevalence of MSH-6 mutations in EC which may not exhibit MSI by molecular analysis. The specificity of both MSI and IHC testing in the detection of LS decreases with increasing age due to increased prevalence of somatic MLH1 hypermethylation (52–55).

As the majority of cases with MLH1 IHC loss are due to MLH1 hypermethylation, a sporadic cause of MLH1 loss, MLH1 hypermethylation analysis should be undertaken on tumors that show IHC loss of MLH1 to help triage appropriate cases for germline testing. It is well documented that MLH1 promoter hypermethylation analysis is an accurate, cost-effective, and superior prescreening method compared with BRAF mutation analysis in the diagnostic algorithm of LS for EC. MLH1 gene promoter hypermethylation can be undertaken at low costs in a routine molecular diagnostic setting, for example, by methylation-specific polymerase chain reaction or by methylation-specific multiplex ligation-dependent probe amplification. Given the inclusion of patient-derived normal DNA in the MLH1 promoter hypermethylation, the rare occurrence of germline MLH1 hypermethylation can also be detected. The most cost-effective approach involves screening with MSH-6 and PMS-2 IHC alone, with subsequent undertaking of MSH-2 and/or MLH1 IHC and reflex MLH1 hypermethylation when indicated.

The rationale behind universal testing is to reduce the morbidity and mortality of index patients as well as relatives of patients with LS. Universal testing for LS in colorectal cancer (CRC) has been endorsed by the National Comprehensive Cancer Network. Evaluation of a universal strategy by Ladabaum et al. (56) revealed that a systematic application of testing among patients with newly diagnosed CRC at ≤70 yr of age could provide substantial clinical benefits at acceptable costs. Other studies have also reported the cost-effectiveness of universal CRC testing (56). Ladabaum et al. (56) concluded that IHC testing of CRC for MMR proteins followed by reflex testing of the tumors when MLH1 protein expression is absent emerged as the most cost-effective approach. These data are not as robust for EC, but they appear to parallel that for CRC (56).

Approximately 50% of patients with EC with MMR deficiency (not due to MLH1 hypermethylation) do not harbor an apparent germline mutation. The cause of such discordance can be attributed to unidentified germline mutations, a false positive MMR deficiency test, or biallelic somatic inactivation of the MMR gene(s). Recent evidence based on next-generation sequencing suggests that almost 70% of these tumors harbor biallelic acquired somatic (tumor) mutations and/or loss of heterozygosity in MMR genes (57,58). Given the screening implications associated with a LS-suspected tumor, somatic mutational analysis and loss of heterozygosity should be considered in the diagnostic algorithm.

Although universal screening testing of EC for LS is suggested, development and implementation of
screening programs are complicated. These programs require cooperation and effective communication across multiple disciplines, ensuring that patients at risk for LS are identified, notified of abnormal results, and referred for genetic counseling and genetic testing. Moreover, the accuracy of IHC is operator dependent and varies according to the experience and skill of the laboratory performing the testing. Consequently, it may be that testing is optimally performed in laboratories with high volume and high-quality control measures.

Panel testing for germline mutations in >20 cancer-causing genes (which include the MMR and EPCAM genes) is now available commercially as a single test. Inevitably, advances in technology will decrease the cost of such analysis. In the future, germline testing, rather than tumor evaluation, may be the most cost-effective universal testing approach.

As per the recommendations of the Society of Gynecologic Oncologists, testing all patients with EC for LS is recommended. If utilizing this strategy, most experts would recommend routine tumor-based testing on ECs with IHC followed by methylation testing, if there is loss of expression of MLH1. Alternatively, the EC can be initially tested for MSI, but any abnormality would require the additional step of IHC and most experts agree that molecular testing by polymerase chain reaction misses many MSH-6 deficient tumors. Universal tumor testing is likely to become the future international standard of care and is already conducted in some hospitals in United States and elsewhere. However, this standard requires development of sufficient local and community infrastructure to appropriately handle genetic results before implementation, as discussed previously. Consequently, testing could be considered for all patients with EC 70 yr of age or younger (in corollary to the CRC recommendations) when appropriate infrastructure for testing exists. If tumor testing is performed for those aged 70 yr or younger only, a thorough family history is essential for those EC patients older than 70 yr; IHC testing should be performed for any individual whose personal and/or family history fulfill the Amsterdam or Bethesda guidelines or who have a ≥5% risk prediction based on the prediction models.

Independent of LS screening, the identification of the MSI (hypermutated)/MMR deficient phenotype in colorectal (and other) carcinomas has been recently exploited for targeted immune therapy with anti-PD-1, as has been mentioned previously. Potential applications for such targeted therapy in EC have not been as well investigated, but remain a viable possibility (59,60).

**SUMMARY OF RECOMMENDATIONS**

**Recommendation 1**
The prognostic value of IHC and DNA ploidy in EC is not clear. It is recommended to perform large prospective, multicenter studies with good methodological quality, to definitely prove the potential prognostic utility of these tests.

*Level of evidence: IV*  
*Strength of recommendation: C*

**Recommendation 2**
The predictive value of ER and PR IHC in response to hormone therapy in EC (particularly low-grade EEC) is not clear. It is recommended to perform large prospective, multicenter studies with good methodological quality, to definitely prove its potential predictive value. This should be done, by taking into account the following variables:

- Different drugs used.
- Differences between low-grade and high-grade tumors.
- Different methodological and scoring approaches.
- Best tissue type (primary vs. metastatic tumor).

*Level of evidence: II*  
*Strength of recommendation: C*

**Recommendation 3**
Validation of molecular tests for diagnosis of EC is encouraged as an adjunct to diagnosis in endometrial biopsies. This is particularly potentially interesting in women with a suspicion of EC and noninformative endometrial biopsies.

*Level of evidence: IV*  
*Strength of recommendation: B*

**Recommendation 4**
Investigational molecular studies are encouraged to assess the value of next-generation sequencing in differential diagnosis between different types of EC, by considering the potential benefits and cost-effectiveness in comparison with IHC and morphologic analyses.

*Level of evidence: IV*  
*Strength of recommendation: C*
Recommendation 5
Mutational analysis of POLE is considered optional for tailoring treatment in patients with high-grade EC.
Level of evidence: IV
Strength of recommendation: A

Recommendation 6
Combining POLE mutational analysis with IHC analysis of p53 and MMR proteins (PMS-2 and MSH-6) is considered optional as a surrogate to classify tumors into the 4 TCGA groups, particularly for high-grade EEC and SC.
Level of evidence: IV
Strength of recommendation: A

Recommendation 7
Development of simple molecular tests for POLE analysis or IHC surrogates of POLE mutation, is encouraged to allow POLE assessments in pathology departments with limited molecular pathology facilities.
Level of evidence: IV
Strength of recommendation: C

Recommendation 8
All women who are diagnosed with EC should undergo systematic clinical screening for LS (review of personal and family history) and/or IHC/molecular screening.
Level of evidence: III
Strength of recommendation: B

IHC screening of EC for LS is the preferred strategy when resources are available. The most cost-effective approach involves screening by MSH-6 and PMS-2 IHC alone, with subsequent MSH-2 or MLH1 IHC when indicated.
Level of evidence: III
Strength of recommendation: B

Recommendation 9
MLH1 hypermethylation analysis should be completed on tumors that show loss of MLH1 on IHC to help triage appropriate cases for germline testing.
Level of evidence: I
Strength of recommendation: A

Recommendation 10
Because of the occurrence of potential somatic mutations in MMR genes, somatic mutation analysis should be considered if germline testing in appropriately triaged patients is negative.
Level of evidence: IV
Strength of recommendation: B

Recommendation 11
Combining POLE mutational analysis with IHC analysis of p53 and MMR proteins (PMS-2 and MSH-6) is considered optional as a surrogate to classify tumors into the 4 TCGA groups, particularly for high-grade EEC and SC.
Level of evidence: IV
Strength of recommendation: A

References
1. Yeramian A, Moreno-Bueno G, Dolcet X, et al. Endometrial carcinoma: molecular alterations involved in tumor development and progression. Oncogene 2013;32:403-13.
2. Gilks CB, Oliva E, Soslow RA. Poor interobserver reproducibility in the diagnosis of high-grade endometrial carcinoma. Am J Surg Pathol 2013;37:874-81.
3. Matias-Guiu X, Davidson B. Prognostic biomarkers in endometrial and ovarian carcinoma. Virchows Arch 2014;464:315-31.
4. Trovik J, Wik E, Werner HM, et al. Hormone receptor loss in endometrial carcinoma curettage predicts lymph node metastasis and poor outcome in prospective multicentre trial. Eur J Cancer 2013;49:3431-41.
5. Jongen VH, Briët JM, de Jong RA, et al. Aromatase, cyclooxygenase 2, HER-2/neu, and p53 as prognostic factors in endometrioid endometrial cancer. Int J Gynecol Cancer 2009;19:670-6.
6. Gassel AM, Backe J, Krebs S, et al. Endometrial carcinoma: immunohistochemically detected proliferation index is a prognosticator of long-term outcome. J Clin Pathol 1998;51:25-29.
7. Garg K, Leitao MM Jr, Wynveen CA, et al. p53 overexpression in morphologically ambiguous endometrial carcinomas correlates with adverse clinical outcomes. Mod Pathol 2010;23:80-92.
8. Susini T, Amunni G, Molino C, et al. Ten-year results of a prospective study on the prognostic role of ploidy in endometrial carcinoma: DNA aneuploidy identifies high-risk cases among the so-called ‘low-risk’ patients with well and moderately differentiated tumors. Cancer 2007;109:882-90.
9. Njølstad TS, Trovik J, Hveem TS, et al. ENITEC Network/MoMaTEC Study Group. DNA ploidy in curettage specimens identifies high-risk patients and lymph node metastasis in endometrial cancer. Br J Cancer 2015;112:1656-64.
10. Green RW, Engblom S, Balderorp B, et al. Cell proliferation, measured as flow cytometric S-phase fraction, is a strong prognostic indicator in FIGO stage I endometrioid endometrial carcinoma: a population-based study. Acta Obstet Gynecol Scand 2015;94:1064-73.
26. Church DN, Reimer D, Huszar M, et al. L1CAM in early-stage type I endometrial cancer: results of a large multicenter evaluation. *J Natl Cancer Inst* 2013;105:1142–50.

27. Bosse T, Nout RA, Stelloo E, et al. L1 cell adhesion molecule is a strong predictor for distant recurrence and overall survival in early stage endometrial cancer: pooled PORTEC trial results. *Eur J Cancer* 2014;50:2602–10.

28. Alonzo-Alconada L, Santacana M, Garcia-Sanz P, et al. Annexin-A2 as predictor biomarker of recurrent disease in endometrial cancer. *Int J Cancer* 2015;136:1863–73.

29. Zeimet AG, Reimer D, Huszar M, et al. L1CAM in early-stage endometrial cancer. *Ann Surg* 2011;254:1062–7.

30. Pallis E, Nout RA, Stelloo E, et al. Re-examination of the prognostic significance of Annexin-A2 in recurrent endometrial cancer. *Am J Surg Pathol* 2014;38:1501–9.

31. Stelloo E, Bosse T, Nout RA, et al. Refining prognosis and identifying targetable pathways for high-risk endometrial cancer; a TransPORTEC initiative. *Mod Pathol* 2015;28:836–44.

32. Talhouk A, McConkey MK, Leung S, et al. A clinically applicable molecular-based classification for endometrial cancers. *Br J Cancer* 2015;113:299–310.

33. Puleats JM, Matias-Guiu X. Immunotherapy in endometrial cancer: in the nick of time. *Clin Cancer Res* 2016;22:5625–3.

34. Howitt BE, Shulka SA, Sholl LM, et al. Association of polymerase ε-mutated and microsatellite-instable endometrial cancers with neoantigen load, number of tumor-infiltrating lymphocytes, and expression of PD-1 and PD-L1. *JAMA Oncol* 2015;21:1319–23.

35. Bellone S, Centritto F, Black J, et al. Polymersese epsilon (POLE) ultra-mutated tumors induce robust tumor-specific CD4+ T cell responses in endometrial cancer patients. *Gynecol Oncol* 2015;138:11–7.

36. van Goor IC, Eggink FA, Freeman-Mills L, et al. POLE proofreading mutations elicit an antitumor immune response in endometrial cancer. *Clin Cancer Res* 2015;21:3347–55.

37. Santin AD, Bellone S, Buza N, et al. Regression of chemotherapy-resistant polymerase ε (POLE) ultra-mutated and MSH6 hyper-mutated endometrial tumors with nivolumab. *Clin Cancer Res* 2016;22:5682–7.

38. Liu Y, Patel L, Mills GB, et al. Clinical significance of CTNNB1 mutations and Wnt pathway activation in endometrioid endometrial carcinoma. *J Natl Cancer Inst* 2014;106:9.

39. Shen J, Peng Y, Wei L, et al. ARID1A deficiency impairs the DNA damage checkpoint and sensitizes cells to PARP inhibitors. *Cancer Discov* 2015;5:752–67.

40. Bitler BG, Aird KM, Garipov A, et al. Synthetic lethality by targeting EZH2 methyltransferase activity in ARID1A-mutated endometrial cancers. *Cancer Res* 2016;76:3412–20.

41. Stoffel E, Mukherjee B, Raymond VM, et al. Calculation of risk of colorectal and endometrial cancer among patients with Lynch syndrome. *Gastroenterology* 2009;137:1621–7.

42. Aarno M, Sankila R, Pukkala E, et al. Cancer risk in mutation carriers of DNA-mismatch-repair genes. *Int J Cancer* 1999;81:214–8.

43. Egoavil C, Alenda C, Castillejo A, et al. Prevalence of Lynch syndrome (hereditary nonpolyposis colorectal cancer) among unselected women with newly diagnosed endometrial cancer. *Eur J Cancer* 2012;48:2069–75.

44. Daniels MS, Urbauer DL, Zangeneh A, et al. Outcomes of screening endometrial cancer patients for Lynch syndrome by patient-administered checklist. *Gynecol Oncol* 2013;131:619–23.

45. Salvesen HB, MacDonald N, Ryan A, et al. Methylation of hMLH1 in a population-based series of endometrial carcinomas. *Clin Cancer Res* 2006;12:3067–13.

46. SGO Clinical Practice Statement: Screening for Lynch Syndrome in Endometrial Cancer. March 2014.

47. Giardiello FM, Allen JI, Axilbund JE, et al. Guidelines on genetic evaluation and management of Lynch Syndrome: a consensus statement by the US Multi-Society Task Force on Colorectal Cancer. *Am J Gastroenterol* 2014;109:1159–79.

48. Rampy H, Frankel W, Panescu J, et al. Screening for Lynch syndrome (hereditary nonpolyposis colorectal cancer) among endometrial cancer patients. *Cancer Res* 2006;66:7810–7.

49. Ferguson SE, Aronson M, Pollett A, et al. Performance characteristics of screening strategies for Lynch syndrome in unselected women with newly diagnosed endometrial cancer who have undergone universal germline mutation testing. *Cancer* 2014;120:3932–9.

50. Mills AM, Liou S, Ford JM, et al. Lynch syndrome screening should be considered for all patients with newly diagnosed endometrial cancer. *Am J Surg Pathol* 2014;38:1501–9.

51. Ryan P, Mulligan AM, Aronson M, et al. Comparison of clinical schemas and morphologic features in predicting Lynch syndrome in mutation-positive patients with endometrial cancer.
encountered in the context of familial gastrointestinal cancer registries. *Cancer* 2012;118:681–8.

52. Mojtahed A, Schrijver I, Ford JM, et al. A two-antibody mismatch repair protein immunohistochemistry screening approach for colorectal carcinomas, skin sebaceous tumors, and gynecologic tract carcinomas. *Mod Pathol* 2011;24:1004–14.

53. Shia J, Tang LH, Vakiani E, et al. Immunohistochemistry as first-line screening for detecting colorectal cancer patients at risk for hereditary nonpolyposis colorectal cancer syndrome: a 2-antibody panel may be as predictive as a 4-antibody panel. *Am J Surg Pathol* 2009;33:1639–45.

54. Zighelboim I, Goodfellow PJ, Gao F, et al. Microsatellite instability and epigenetic inactivation of MLH1 and outcome of patients with endometrial carcinomas of the endometrioid type. *J Clin Oncol* 2007;25:2042–8.

55. Frolova AI, Babb SA, Zantow E, et al. Impact of an immunohistochemistry-based universal screening protocol for Lynch syndrome in endometrial cancer on genetic counseling and testing. *Gynecol Oncol* 2015;137:7–13.

56. Ladabaum U, Wang G, Terdiman J, et al. Strategies to identify the Lynch syndrome among patients with colorectal cancer: a cost-effectiveness analysis. *Ann Intern Med* 2011;155:69–79.

57. Geurts-Giele WR, Leenen CH, Dubbink HJ, et al. Somatic aberrations of mismatch repair genes as a cause of microsatellite-unstable cancers. *J Pathol* 2014;234:548–59.

58. Haraldsdottir S, Hampel H, Tomsic J, et al. Colon and endometrial cancers with mismatch repair deficiency can arise from somatic, rather than germline, mutations. *Gastroenterology* 2014;147:1308–16.e1.

59. Diaz LA, Le DT. PD-1 blockade in tumors with mismatch-repair deficiency. *N Engl J Med* 2015;373:1979–81.

60. Le DT, Uram JN, Wang H, et al. PD-1 blockade in tumors with mismatch-repair deficiency. *N Engl J Med* 2015;373:2509–20.