National Comprehensive Cancer Network®

NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines®)

Genetic/Familial High-Risk Assessment: Breast, Ovarian, and Pancreatic

Version 1.2025 — September 11, 2024

NCCN.org

NCCN recognizes the importance of clinical trials and encourages participation when applicable and available. Trials should be designed to maximize inclusiveness and broad representative enrollment.

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¶ Breast surgical oncology
₪ Clinical genetics
Δ Genetic counseling
¤ Gastroenterology
Ω Gynecologic oncology/ Gynecology
‡ Hematology/ Hematology oncology
Þ Internal medicine
† Medical oncology
§ Radiation oncology
¥ Patient advocacy
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NCCN Categories of Evidence and Consensus: All recommendations are category 2A unless otherwise indicated.

See NCCN Categories of Evidence and Consensus.

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Updates in Version 1.2025 of the NCCN Guidelines for Genetic/Familial High-Risk Assessment: Breast, Ovarian, and Pancreatic from Version 3.2024 include:

Global Updates

- References updated throughout the guideline.

EVAL-A (1 of 11)

- 2nd bullet, 1st sub-bullet added: For principles of genetic testing for patients with cancer (active diagnoses and previous history) when testing is performed outside of specialty genetics setting, see EVAL-A 10 of 11.

EVAL-A (2 of 11)

- Prior to genetic testing, the following should be taken into consideration:
  - 4th bullet revised from "Testing for unaffected family members when no affected member is available should be considered. Significant limitations of interpreting test results should be discussed." to "While testing an affected family member is most informative, it is also appropriate to test unaffected family members who meet testing criteria. Limitations of interpreting negative test results in unaffected individuals should be discussed."

EVAL-A (3 of 11)

- Choice of multigene testing
  - 4th bullet revised by adding: For individuals of Ashkenazi Jewish descent, complete gene panel analysis including specific AJ founder mutations should be considered based on family history; testing limited to AJ founder testing may be appropriate for families segregating known mutations, or in population screening in which a negative test is followed by more complete testing depending on personal and/or family history.

EVAL-A (5 of 11)

- 2nd bullet, 4th sub-bullet revised by adding: For these reasons, ctDNA should not be used, outside of the clinical trial setting, to replace well-established methods of cancer screening (eg, mammography).

EVAL-A (10 of 11)

- New page added: Principles of genetic testing for patients with cancer (active diagnoses and previous history) when testing is performed outside of specialty genetics setting

CRIT-2

- Testing Criteria for High-Penetrance Breast Cancer Susceptibility Genes
  - Header revised: ~~Specifically~~ *Genes such as...* (Also for CRIT-4, CRIT-5)
  - Personal history of breast cancer.. bullet revised: Lobular breast cancer with personal or family history of diffuse gastric cancer ~~(NCCN Guidelines for Gastric Cancer~~ NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal. Endometrial, and Gastric)
  - Family history section revised:
    - ◊ Family history ~~of cancer~~ *criteria: unaffected; or affected but does not meet above criteria*
      - ~~Individuals affected with breast cancer (not meeting testing criteria listed above) or~~
      - Individual ~~unaffected with breast cancer with~~ a first- or second-degree blood relative meeting any of the criteria listed above (except unaffected individuals whose relatives meet criteria only for systemic therapy decision-making).
      - Individuals ~~affected or unaffected with breast cancer~~ who ~~otherwise do not meet the criteria above but~~ have a probability >5% of a BRCA1/2 P/LP variant based on prior probability models (eg, Tyrer-Cuzick, BRCAPro, CanRisk)

CRIT-2A

- Footnote n revised: Consideration of the limitations of unknown or limited family structure is indicated in those aged ≥51 years. *See EVAL-A*.

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Updates in Version 1.2025 of the NCCN Guidelines for Genetic/Familial High-Risk Assessment: Breast, Ovarian, and Pancreatic from Version 3.2024 include:

CRIT-3
- Testing Criteria for High-Penetrance Breast Cancer Susceptibility Genes
  - Testing may be considered in the following scenarios
    - 1st bullet revised: Personal history of breast cancer ~~<60 y~~ ≤*65* y not meeting any of the above criteria ~~may approach a 2.5% probability of having a P/LP variant, based on recent data~~.
      - Footnote s revised: ~~Kurian A, et al. JAMA 2020;323:995-997~~ *Bedrosian I, et. al. J Clin Oncol 2024;42:584-604*.
      - Corresponding footnote t added: Testing includes breast cancer genes plus other inherited cancer genes consistent with family phenotype.
    - 3rd bullet clarified from, "Individuals affected or unaffected with breast cancer who otherwise do not meet any of the above criteria (CRIT-2) but with a 2.5%–5% probability of BRCA1/2 P/LP variant based on prior probability models..." to "Individuals (unaffected; or affected but does not meet above criteria [CRIT-2]) with a 2.5%-5% probability of BRCA1/2 P/LP variant based on prior probability models..."
    - 4th bullet added: Personal history of malignant phyllodes tumors. Corresponding footnote u added: See Discussion.
  - There is a low probability...1st bullet revised: Female diagnosed with breast cancer at age ~~>60 y~~ *>65 y,...*

CRIT-4
- Testing Criteria for Ovarian Cancer Susceptibility Genes
  - Footnote x, last sentence revised: Examples include an association between sex-cord tumors with annular tubules and PJS or Sertoli-Leydig tumors, DICER1-related disorders, *and small cell carcinoma of the ovary and hypercalcemic type with SMARCA4*.

CRIT-6
- Testing Criteria for Prostate Cancer Susceptibility Genes
  - Header revised: ~~Specifically~~ *Genes such as...* and *TP53*)
  - Family history section revised:
    - Family history ~~of cancer~~ *criteria: unaffected; or affected but does not meet criteria above*
      - ~~An affected (not meeting testing criteria listed above) or unaffected~~ Individual with a first-degree blood relative meeting any of the criteria listed above (except unaffected individuals whose relatives meet criteria only for systemic therapy decision-making)

CRIT-8A
- ~~Testing~~ *Diagnostic* Criteria for Cowden Syndrome (CS)/PTEN Hamartoma Tumor Syndrome (PHTS)
  - Major and Minor Criteria clarified as diagnostic criteria and updated to be consistent with Pilarski R, et al. J Natl Cancer Inst 2013;105:1607-1616.
  - Footnote * revised from, "Other cancers associated with PTEN but not in the testing criteria include: colorectal, kidney cancer, and melanoma" to "Melanoma is also associated with PTEN but is not included in the testing criteria."

GENE-1
- Genetic Testing, No known familial P/LP variant revised: Germline multigene panel testing ~~or if unaffected, attempt, if possible, to test family member with highest likelihood of a P/ LP variant before testing an unaffected family member~~ *While testing an affected family member is most informative, it is also appropriate to test unaffected family members who meet testing criteria.*

GENE-A (1 of 11)
- ATM
  - Primary Breast Cancer
    - Absolute risk revised from 20%–30% to 21%–24%
  - Other Cancer Risks: Colorectal cancer added.
  - Comments section revised: ...~~See Discussion for information regarding the c.7271T>G variant, which is associated with greater risk of breast cancer~~. *ATM missense c.7271T>G variant is a higher penetrance allele (60% by age 80 y;* Goldgar DE, et al. Breast Cancer Res 2011;13:R73) (Hall MJ, et al. Cancer Prev Res (Phila). 2021;14:433-440; Southey MC, et al. J Med Genet 2016;53:800-811).

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Updates in Version 1.2025 of the NCCN Guidelines for Genetic/Familial High-Risk Assessment: Breast, Ovarian, and Pancreatic from Version 3.2024 include:

GENE-A (2 of 11)
- BRCA1
  - Primary Breast Cancer
    - ◊ Absolute risk revised from >60% to 60%–72%
  - Comments section revised by adding: The risk for breast cancer appears to be lower for the BRCA1 R1699Q variant (24% by age 70 y) (Spurdle AB, et al. J Med Genet 2012;49:525-532). Screening should be individualized based on personal and family history.
- BRCA2
  - Primary Breast Cancer
    - ◊ Absolute risk revised from >60% to 55%–69%

GENE-A (3 of 11)
- CDH1
  - Primary Breast Cancer
    - ◊ Absolute risk revised from 41%–60% to 37%–55%
  - Comments section revised by removing: There is controversy over how to manage gastric cancer risk in individuals with CDH1 P/LP variants in the absence of a family history of gastric cancer. However, one small study found that >50% of such individuals had gastric cancer identified at the time of risk-reducing total gastrectomy (Jacobs MF, et al. Gastroenterology 2019;157:87-96), and penetrance for lifetime risk is increased with a positive family history of HDGC (Roberts ME, et al. JAMA Oncol 2019;5:1325-1331).

GENE-A (4 of 11)
- CDKN2A
  - Comments section, 1st sentence revised: Comprehensive skin examination by a dermatologist, supplemented with total body photography and dermoscopy is recommended ~~biannually~~ *every 6 mo* for individuals
- CHEK2
  - Primary Breast Cancer
    - ◊ Absolute risk revised from 20%–49% to 23%–27%
  - Other Cancer Risks
    - ◊ Colorectal cancer removed.
  - Comment revised: ... ~~The risks for most missense variants are unclear but for some P/LP variants, such as Ile157Thr, the risk for breast cancer appears to be lower. Additional cancer risk management based on this variant (Ile157Thr) is not recommended.~~ *There is emerging evidence that not all missense P/LP variants are low penetrance. For some P/LP variants, such as Ile157Thr and Ser428Phe, the risk for breast cancer appears to be lower. Additional cancer risk management based on these variants* ~~(Ile157Thr)~~ *is not recommended*. Management should be based on best estimates of cancer risk for the specific P/LP variant and family history. *There are some data to indicate females with biallelic CHEK2 P/LP variants have a higher risk for invasive breast cancer, are more likely to be diagnosed at ≤50 years, and are more likely to have multiple primary breast cancers. However, lifetime risk estimates are difficult to quantify due to small study sizes. Therefore taking personal and family history into account to advise on cancer risk management is appropriate.*

GENE-A (6 of 11)
- PALB2
  - Primary Breast Cancer
    - ◊ Absolute risk revised from 41%–60% to 32%–53%

GENE-A (7 of 11)
- RAD51C and RAD51D
  - Primary Breast Cancer
    - ◊ Absolute risk revised from 17%–30% to ~20%
    - ◊ Management, added sub-bullet: Risk reduction: Evidence insufficient for risk-reducingmastectomy (RRM); manage based on family history

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GENE-A (9 of 11)
- Footnote b revised: Screening and risk-reduction management for *breast and ovarian cancer* is extrapolated from BRCA1/2 data based on risk levels.
- Footnote f added: Breast awareness starting at age 18 years. Clinical breast exam, every 6–12 months, starting at age 25 years or 5–10 years before the earliest known breast cancer in the family (whichever comes first). Age >75 years, management should be considered on an individual basis.

GENE-B
- Bullet added above table: Biallelic P/LP variants in some genes, included on gene panels, may be associated with rare autosomal recessive conditions, such as FA or CMMRD. For these genes, consideration should be given to carrier testing the partner for P/LP variants in the same gene if it would inform reproductive decision-making and/or risk assessment and management.

***BRCA* Pathogenic/Likely Pathogenic Variant-Positive Management**

BRCA-A (2 of 5)
- Ovarian/Fallopian Tube/Peritoneal/Uterine Cancers
  - Surgical risk reduction with bilateral salpingo-oophorectomy, 4th bullet added: If serous tubal intraepithelial carcinoma (STIC lesion) is found, further consultation with a gynecologist oncologist is recommended.

Pancreatic Cancer Screening

PANC-A (1 of 2)
- 1st bullet, #2 revised: A family history of exocrine pancreatic cancer in ≥1 first-degree and ≥1 second-degree relatives from the same side of the family, even in the absence of a known P/LP germline variant ~~(many centers would enroll individuals with one affected first-degree relative and one second-degree relative)~~
- Screening table revised:
  - Consider pancreatic cancer screening *(preferably in the setting of a longitudinal study) for the following*:
  - 3rd bullet added: Individuals with P/LP germline variants in ATM or BRCA2 - Beginning at age 50 years (or 10 years younger than the earliest exocrine pancreatic cancer diagnosis in the family, whichever is earlier).
  - 4th bullet: ATM and BRCA2 removed from first column and added to second column.

Li-Fraumeni syndrome

LIFR-A (3 of 6)
- Table 1: Workup and Management Depending on Etiology of TP53 Mutation Found on Genetic Testing extensively revised.

LIFR-A (4 of 6)
- Other cancer risks
  - 7th bullet added: For pancreatic cancer screening recommendations, see PANC-A.

Breast, Ovary, Uterine, and Prostate Cancer Risk Reduction Strategies for Transgender, Non-Binary and Gender Diverse People with Hereditary Cancer Syndromes

TNBGD-2
- Uterine cancer, 1st bullet revised: There are several PVs associated with an increased risk for uterine cancer, including ~~BRCA1 (serous endometrioid type)~~, PTEN and LS genes.

Summary of Genes and/or Syndromes Included/Mentioned in Other NCCN Guidelines

SUMM
- Revisions made throughout.

PRINCIPLES OF CANCER RISK ASSESSMENT AND COUNSELING

- **Risk assessment and discussion of genetic testing involves three related stages:**
  1) **Pre-test counseling done prior to ordering testing**
  2) **Consideration of the most appropriate tests to order**
  3) **Post-test counseling done when results are disclosed[1-6]**
- **It is recommended that a genetic counselor, clinical geneticist, oncologist, surgeon, oncology nurse, or other health professional with expertise and experience in cancer genetics be involved at each stage whenever possible.**
  - **For principles of genetic testing for patients with cancer (active diagnoses and previous history) when testing is performed outside of specialty genetics setting, see EVAL-A 10 of 11.**
- **Testing should be considered in appropriate individuals where it is likely to impact the risk management and/or treatment of the tested individuals and/or their family members who also have increased risk.**

Pre-test counseling includes the following elements:

- **Evaluate patient's needs and concerns regarding:**
  - **Knowledge of genetic testing for cancer risk, including benefits, risks, and limitations**
  - **Variant-specific cancer risks**
  - **Goals for cancer family risk assessment**
- **Detailed family history including:**
  - **Collection of a comprehensive family history**
    - ◊ **Assessment of family history; close blood relatives include first-, second-, and third-degree relatives on each side of the family, particularly around individuals with a diagnosis of cancer (EVAL-B)**
    - ◊ **Types of cancer, bilaterality, age at diagnosis, subtype, and pathology report confirmation**
    - ◊ **Ethnicity (specifically Ashkenazi Jewish ancestry)**
- **Detailed medical and surgical history including:**
  - **Documentation of prior genetic testing results for patients and their family members**
  - **Personal cancer history (eg, age, histology, laterality)**
  - **Pathology reports of primary cancers and/or benign lesions (eg, breast biopsies)**
  - **Carcinogen exposure (eg, history of radiation therapy [RT])**
  - **Reproductive history**
  - **Hormone or oral contraceptive use**
  - **History of risk-reducing surgeries**
  - **Smoking, alcohol, or other exposures related to cancer risk**
- **Focused physical exam (conducted by qualified clinician) when indicated:**
  - **Cowden syndrome (CS)/*PTEN* hamartoma tumor syndrome (PHTS) specific: dermatologic,[a] including oral mucosa, head circumference, and thyroid (enlarged or nodular on palpation)**
- **Generate a differential diagnosis and educate the patient on inheritance patterns, penetrance, variable expressivity, and the possibility of genetic heterogeneity.**

Pre-test counseling continued

[a] For CS/PHTS dermatologic manifestations, see CRIT-8 and for Peutz-Jeghers syndrome (PJS) dermatologic manifestations, see NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric.

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Note: All recommendations are category 2A unless otherwise indicated.

PRINCIPLES OF CANCER RISK ASSESSMENT AND COUNSELING

Pre-test counseling includes the following elements (con't):

- Prepare for the possible outcomes of testing, including positive (pathogenic/likely pathogenic [P/LP]) (person is a carrier of an alteration in a known cancer-predisposing gene), true negative (person is not a carrier of a known cancer-predisposing gene that has been positively identified in another family member), uninformative negative (person is not a carrier of a known cancer-predisposing gene, and the carrier status of other family members is either also negative or unknown), uncertain variants (person is a carrier of an alteration in a gene that currently has no known significance), and mosaic results (occurrence of 2 or more cell lines with different genetic or chromosomal makeup, within a single individual or tissue).
- Obtain written informed consent, and document the informed consent in the patient's medical record.
- Discuss plan for results disclosure when appropriate, including the possibility of the patient consenting to Release of Information of test results to a close relative or spouse when results are released in case patient is deceased or incapacitated.
- Discuss possible management options if a P/LP variant is identified (enhanced surveillance, risk-reducing agents, and risk-reducing surgery).
- Discuss that their results may be important to therapeutic decision-making as directed by a qualified health care provider (eg, oncologist).
- Advise about possible inherited cancer risk to relatives, and options for risk assessment, testing, and management.
- Discuss cost of genetic testing.
- Provide overview of current legislation regarding genetic discrimination and the privacy of genetic information.[b]

Prior to genetic testing, the following should be taken into consideration:

- The probability of P/LP variant detection associated with these criteria will vary based on family structure, which includes size of the family, age of the family members, early death, adoption, and number of male and female relatives. Individuals with unknown or limited family history/structure, such as fewer than 2 female first- or second-degree relatives having lived beyond age 45 in either lineage, may have an underestimated probability of familial P/LP variant detection. The estimated likelihood of P/LP variant detection may be low in families with a large number of unaffected and/or male relatives.
- Patients who have received an allogeneic bone marrow transplant or with active or recent hematologic malignancies should not have molecular genetic testing via blood, saliva, or buccal samples (due to unreliable test results from contamination or due to somatic pathogenic variants [PVs] associated with the hematologic malignancy) until other technologies are available. If available, DNA should be extracted from a fibroblast culture. If this source of DNA is not possible, buccal samples can be considered, subject to the risk of donor DNA contamination or malignant cells from the hematologic malignancy.
- If more than one family member is affected with cancers highly associated with a particular inherited cancer susceptibility syndrome, consider initial testing of a family member with youngest age at diagnosis, bilateral disease, multiple primary cancers, or other cancers associated with the syndrome, or most closely related to the proband/patient. If there are no available family members with cancer that is a cardinal feature of the syndrome in question, consider testing first- or second-degree family members affected with other cancers thought to be related to the gene in question (eg, prostate or pancreas with *BRCA1/2*).
- While testing an affected family member is most informative, it is also appropriate to test unaffected family members who meet testing criteria. Limitations of interpreting negative test results in unaffected individuals should be discussed.
- In children <18 years, genetic testing is generally not recommended when results would not impact medical management.[7]
- LP variants are usually clinically managed similarly to PVs, while patients with variants of uncertain significance (VUS) and likely benign variants should be cared for based on the cancers present in the family.
- For choice of multigene testing, see EVAL-A 3 of 10.

Continued

[b] Genetic Information Nondiscrimination Act of 2008 (GINA). Vol. Public Law No.110-233. Available at: https://www.eeoc.gov/laws/statutes/gina.cfm

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Note: All recommendations are category 2A unless otherwise indicated.

PRINCIPLES OF CANCER RISK ASSESSMENT AND COUNSELING

Choice of Multigene Testing

- **The introduction of multigene testing for hereditary forms of cancer has rapidly altered the clinical approach to hereditary cancer testing of patients at increased risk of inherited susceptibility to cancer and their families. Based on next-generation sequencing (NGS) technology, these tests simultaneously analyze a set of genes that are associated with a specific family cancer phenotype or multiple phenotypes.**
- **An individual's personal and/or family history may be explained by more than one inherited cancer syndrome; thus, phenotype-directed testing based on personal and family history through a tailored[c] multigene panel test is often more efficient and cost-effective and increases the yield of detecting a P/LP variant in a gene that will impact medical management for the individual or their family members with increased risk.**
- **There may also be a role for multigene testing in individuals who have tested negative for a single syndrome, but whose personal or family history remains suggestive of an inherited susceptibility.**
- **Some individuals may carry P/LP germline variants in more than one cancer susceptibility gene; thus, consideration of a multigene panel for individuals already known to carry a single P/LP germline variant from phenotype-directed testing may be considered on a case-by-case basis, based on the degree of suspicion for there being additional variants. For individuals of Ashkenazi Jewish descent, complete gene panel analysis including specific AJ founder mutations should be considered based on family history; testing limited to AJ founder testing may be appropriate for families segregating known mutations, or in population screening in which a negative test is followed by more complete testing depending on personal and/or family history.**
- **Because commercially available tests differ in the specific genes analyzed, variant classification, and other factors (eg, methods of DNA/RNA analysis or option to reflex from a narrow to a larger panel; provision of financial assistance for cascade testing of relatives), it is important to consider the indication for testing and expertise of the laboratory when choosing the specific laboratory and test panel.**
- **Multigene testing can include "intermediate" penetrant (moderate-risk) genes.[d] For many of these genes, there are limited data on the degree of cancer risk, and there may currently be no clear guidelines on risk management for carriers of P/LP variants. Not all genes included on available multigene tests will change risk management compared to that based on other risk factors such as family history.**
- **It may be possible to refine risks associated with both moderate and high-penetrance genes, taking into account the influence of gene/gene or gene/environment interactions. In addition, certain P/LP variants in a gene may pose higher or lower risk than other P/LP variants in that same gene. This information should be taken into consideration when assigning risks and management recommendations for individuals and their relatives who also have increased risk.**
- **P/LP variants in many breast, ovarian, pancreatic, and prostate cancer susceptibility genes involved in DNA repair may be associated with rare autosomal recessive conditions, thus posing risks to offspring if the partner is also a carrier.**
- **As more genes are tested, there is an increased likelihood of finding VUS, mosaicism, and clonal hematopoiesis of indeterminate potential (CHIP).**
- **When a P/LP variant with clinical implications for the patient and/or their family members is found on tumor genomic testing, germline confirmatory testing should be recommended.**
- **There are significant limitations in interpretation of polygenic risk scores (PRS). PRS should not be used for clinical management at this time and use is recommended in the context of a clinical trial, ideally including diverse populations. See Discussion.**

[c] Tailored is defined as a disease-focused multigene panel of clinically actionable cancer susceptibility genes, in contrast to large multigene panels of uncertain or unknown clinical relevance.

[d] Research is evolving, and individuals with P/LP variants in cancer susceptibility genes should be encouraged to participate in clinical trials or genetic registries. Individuals with P/LP variants are also encouraged to recontact their genetics providers every few years for updates.

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Note: All recommendations are category 2A unless otherwise indicated.

PRINCIPLES OF CANCER RISK ASSESSMENT AND COUNSELING

Evaluating the Source of Genetic Testing Information

- **Prior to using any germline findings for medical management, it is important to establish whether the reported findings were obtained from a laboratory that is certified by the College of American Pathologists (CAP) and Clinical Laboratory Improvement Amendments (CLIA) to issue a report of germline findings directly to ordering health care providers. Some states (eg, New York) may have additional reporting requirements.**

- **Confirmatory germline testing through an appropriately certified laboratory is clinically indicated when a potential P/LP variant is identified through various data sources as noted below:**
  - **Commercial entities providing ancestry (and sometimes health) information typically do so through microarray-based single nucleotide polymorphism (SNP) testing that has not been validated for clinical use. Third-party software applications can be used by consumers to obtain an interpretation of the raw data provided by these companies. Raw data and third-party software are not able to provide information that is appropriate for medical management, as these services are not subject to quality-control processes and recent research suggests that the error rate (40%) is substantial.[8] In addition, the current tests only provide limited founder PV results without the benefit of family history. More comprehensive genetic counseling and testing for PVs in other inherited cancer risk genes may be appropriate at the time of confirmation testing.**
  - **Commercial laboratories utilizing consumer-initiated or direct-to-consumer (DTC) marketing of DNA sequence-based cancer predisposition tests vary substantially in providing information necessary to make informed decisions regarding results and may vary in accuracy in their variant interpretation.[9,10]**
  - **Research: Patients may have participated in research studies that included germline genomic analysis.[11] In such cases, it is clinically indicated to review the patient's findings with a genetics professional and/or the reporting laboratory to establish whether the original report was generated by an appropriately certified laboratory, or whether confirmatory testing is clinically indicated.**

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Note: All recommendations are category 2A unless otherwise indicated.

PRINCIPLES OF CANCER RISK ASSESSMENT AND COUNSELING

Tumor Genomic Testing: Potential Implications for Germline Testing

- **Testing may provide information suggesting a potential germline finding. P/LP variants reported in the tumor may be of somatic or germline origin.**
  - **Because tumor genomic testing is designed to address treatment actionability, not germline status, a variant that may be considered as P/LP in the germline may not be reported at all, or reported as normal in the tumor if it lacks clinical implications.**
  - **The filtering of raw sequencing data may differ between tumor and germline testing labs so that variants reported out with one analysis may not be reported with the other.**
  - **Somatic P/LP variants seen in tumor specimens are common in some genes with germline implications (eg, *TP53, STK11, PTEN*) and may not indicate the need for germline testing unless the clinical/family history is consistent with a P/LP variant in the germline.**
  - **Tumor-only sequencing may not detect about 10% of clinically actionable P/LP germline variants (eg, deletion, duplication, and splicing variants).[12]**
  - **The fraction of PVs in cancer susceptibility genes identified through tumor-only testing, and also present in the germline, is highly variable between genes.[13,14]**
- **Regardless of findings in the tumor, when germline testing is clinically indicated, it should be performed in a CLIA-approved lab with established experience in germline testing because:**
  - **The germline panel performed by some labs offering paired tumor and germline testing may have incomplete coverage and analyze only a subset of those genes of interest to the clinician.**
  - **The sensitivity of most tumor genomic testing is lower (particularly for intermediate-sized deletions and duplications) than germline testing.**
  - **Similarly, circulating tumor DNA (ctDNA) has the potential to identify both somatic and germline variants with germline treatment implications. Some ctDNA assays, but not all, will alert providers that the particular gene variant identified has a high enough variant allele frequency (VAF) that it is suspicious for germline origin. However, most commercially available assays specializing in somatic ctDNA detection are neither intended nor validated for the reporting or interpretation of germline variants. Thus, variants detected by ctDNA that are suspected to be present in the germline should be evaluated via a CLIA-approved assay specializing in detection and interpretation of germline variants.**
  - **ctDNA, detected by mutation profile, copy number changes, altered methylation patterns, fragmentation, size alterations, or other approaches, has application for disease monitoring as well as early detection. For individuals at increased hereditary risk for cancer, use of pre-symptomatic ctDNA cancer detection assays should only be offered in the setting of prospective clinical trials, because the sensitivity, false-positive rates, and positive predictive value of ctDNA tests for early-stage disease, which are needed to derive clinical utility and determine clinical validity, are not fully defined.[15-18] The psychological impact of ctDNA testing remains unknown. For these reasons, ctDNA should not be used, outside of the clinical trial setting, to replace well-established methods of cancer screening (eg, mammography).**

Continued
References on EVAL-A 11 of 11

Note: All recommendations are category 2A unless otherwise indicated.

PRINCIPLES OF CANCER RISK ASSESSMENT AND COUNSELING

Post-Test Counseling

- **When the testing provider/facility does not include pre-test counseling or have all of the resources or expertise for facilitating follow-up testing, management, or family testing, referral to a genetics provider is recommended. In particular, referral to a genetics provider is recommended for the following test results:**
  - **P/LP variant identified**
  - **Negative results but tumor profiling, personal history, or family history remain suggestive of inherited condition**
  - **Any VUS result that warrants further evaluation or for which a patient or provider considers using to guide management (EVAL-A 9 of 11)**
  - **A mosaic/possibly mosaic result or clonal hematopoiesis**
  - **Discrepant interpretation of variants, including discordant results across laboratories**
  - **Interpretation of PRS, if they are being considered for use in clinical management, recognizing that the clinical value of PRS has not yet been established**
  - **Interpretation of P/LP variants for patients tested through DTC or consumer-initiated models**

- **Post-test counseling includes the following elements:**
  - **Discussion of results and associated medical risks**
  - **Interpretation of results in context of personal and family history of cancer**
  - **Discussion of recommended medical management options including discussion of therapeutic implications by a qualified health care provider if positive**
  - **Discussion of the importance of notifying family members and offering materials/resources for informing and testing family members who also have increased risk**
  - **Discussion of available resources such as high-risk clinics, disease-specific support groups, and research studies**

Continued
References on EVAL-A 11 of 11

Note: All recommendations are category 2A unless otherwise indicated.

PRINCIPLES OF CANCER RISK ASSESSMENT AND COUNSELING

- **Positive results:**
  - Some medical centers include services that are specialized in cancer screening, risk reduction, and treatment for individuals with a P/LP variant associated with increased risk for cancer. Where available, consider referring patients to these services, either on a consultative basis or for coordination of ongoing care.
  - In patients being treated for cancer, identification of a P/LP variant may affect options and recommendations for treatment of their disease. A P/LP variant in certain genes is also a component of eligibility for some clinical trials. Specific circumstances are addressed in the NCCN Treatment Guidelines for breast, ovarian, and other cancers.
  - Many patients who have been diagnosed with cancer and have a P/LP variant are at increased risk for additional primary cancers in the future. Management of those risks may be appropriate after treatment of the current cancer or may be combined with treatment for a current cancer.
  - Multiple sources, including these NCCN Guidelines, provide estimated lifetime risks of cancer associated with specific P/LP variants. A discussion of risk should include:
    - ◊ Presenting risk estimates as a range rather than a single number (ie, 30%–40%)
    - ◊ Presenting absolute risk and minimizing use of relative risk terminology (ie, odds ratios or hazard ratios)
    - ◊ Acknowledging that risk estimates always have a margin of error[e]
    - ◊ Identifying that these risk estimates change over time (ie, older patients will have lower remaining lifetime risk)
  - Individuals with a P/LP variant should be informed of the importance of this information for their blood relatives. Knowledge of the P/LP variant may affect risk assessment and recommendations for genetic testing, early detection, and/or cancer risk reduction in those relatives. Where relationships allow, individuals should be encouraged to communicate this information to their blood relatives. A medical provider can assist by providing patients with information for relatives written in simple language and a copy of their genetic test results.
  - Over time, patients with a P/LP variant benefit from re-consultation with a medical provider who is familiar with inherited risk for cancer. This re-consultation is important for:
    - ◊ Increasing adherence with screening guidelines, which is known to decrease over time
    - ◊ Re-evaluating personal choices about risk-reducing surgeries, based on changing life stage and circumstances
    - ◊ Ensuring patients are following up-to-date guidelines
    - ◊ Discussing additional genetic testing options
    - ◊ Reviewing improved risk models as appropriate
  - The frequency of follow-up depends on many factors, such as age, reproductive planning, comorbidities, risk-reducing surgeries, and other risk factors.
  - For patients of reproductive age, advise about options for prenatal diagnosis and assisted reproduction, including pre-implantation genetic testing and donor gametes. Discussion should include known risks, limitations, and benefits of these technologies. See Discussion for details.
  - Biallelic P/LP variants in some genes, included on gene panels, may be associated with rare autosomal recessive conditions, such as Fanconi anemia (FA) or constitutional mismatch repair (MMR) deficiency (CMMRD) (GENE-B). Thus, for these genes, consideration should be given to carrier testing the partner for P/LP variants in the same gene if it would inform reproductive decision-making and/or risk assessment and management.[19]
  - Some P/LP variants found in blood, saliva, or buccal samples, most notably in *TP53*, warrant consideration of testing of non-blood samples to try to distinguish between germline, constitutional mosaicism, and somatic findings.

[e] Risk estimates are influenced by the numbers of individuals with these mutations: the more individuals, the more precise the estimates are (ie, the confidence interval is narrower).

Note: All recommendations are category 2A unless otherwise indicated.

Continued
References on EVAL-A 11 of 11

PRINCIPLES OF CANCER RISK ASSESSMENT AND COUNSELING

- **Negative results:**
  - These results reduce concern for cancer risk. However, the individual may still have increased cancer risk based on personal and family history. Also, other family members may have a P/LP variant that the tested individual did not inherit.
  - Although negative results of genetic testing are generally reassuring, other reasons that a patient can test negative include:
    1) A gene P/LP variant may exist in the gene that was not recognized due to limitations in technology.
    2) P/LP variants exist in genes that were not evaluated by this testing.
    3) Family members may harbor a P/LP variant that the patient may not have inherited.
  - Other family members may be appropriate candidates for testing, both to assess their own cancer risk as well as to clarify the overall contribution of known P/LP variants to the family history. If another family member tests positive for a P/LP variant, this might lower concern for the individuals who tested negative. The determination of a “true negative” result depends on the specific family history of cancer, the specific P/LP variant found, and the relationship to the family member(s) who tested positive.
  - When an individual has tested negative, it may still be appropriate to consider increased screening and risk reduction measures for cancer based on family history. See appropriate screening based on family history in the guidelines as outlined in Summary of Genes and/or Syndromes Included/Mentioned in Other NCCN Guidelines (SUMM-1). Some medical centers include specialized high-risk clinics to offer this type of family history-based screening.
  - Over time an individual who tested negative may be a candidate for additional genetic testing due to additional family history, as new genes are identified to be associated with cancer risk or technology advances.

Continued
References on EVAL-A 11 of 11

Note: All recommendations are category 2A unless otherwise indicated.

PRINCIPLES OF CANCER RISK ASSESSMENT AND COUNSELING

- **Variants of uncertain significance (VUS)**
  - **VUS are alterations in the genetic code for which the impact on protein function is uncertain.**
  - **VUS are common, particularly with the use of large multigene panels. The more genes that are included on a genetic testing panel, the more likely a VUS will be identified.[20]**
  - **VUS are more commonly found during genetic testing of Asian and Black individuals compared with non-Hispanic white individuals.[20]**
  - **In VUS that are reclassified, approximately 80%–90% are reclassified as likely benign or benign and 10%–20% as P/LP.[21,22]**
  - **There are discordant variant interpretations across labs,[23] requiring careful counseling and skilled interpretation. Resources are available to review the available data supporting pathogenic consequences of specific variants and identify discrepant results (eg, https://www.ncbi.nlm.nih.gov/clinvar/; https://brcaexchange.org/about/app; cangene-canvaruk.org/canvig-uk).**
  - **VUS should not be used to alter medical management. In the event additional discussion is needed for classification and management, additional genetic expertise is recommended. Screening and risk reduction strategies should be recommended on the basis of personal and family history.**
  - **RNA studies (when appropriate) may be a consideration to further define functional impact of variants. Testing family members for a VUS should not be done for clinical purposes, unless there are data to support discrepancy in interpretation of results. Consider a referral to research studies that aim to define the functional impact of variants such as variant reclassification programs through clinical labs or registries.**

Continued
References on EVAL-A 11 of 11

Note: All recommendations are category 2A unless otherwise indicated.

PRINCIPLES OF CANCER RISK ASSESSMENT AND COUNSELING

Principles of genetic testing for patients with cancer (active diagnoses and previous history) when testing is performed outside of specialty genetics setting (often referred to as "point of care" testing)

There are clinical situations in which germline genetic testing is critical to therapeutic decision-making but comprehensive risk assessment and genetic counseling are not feasible. In these situations, the treating clinician (eg, oncologist, surgeon) may order germline genetic testing. They should be aware that there may be feasibility and cost limits on the type and number of genetic tests ordered for each individual patient. To maximize the value of the testing experience they should ensure that they include in their discussion with the patient the following points:

- **Pre-test**
  - **Documentation**
    - ◊ **Family history collection of both maternal and paternal relatives who have been diagnosed with cancer of any type, ideally from three generations**
    - ◊ **Pertinent medical and surgical history**
    - ◊ **Informed consent for genetic testing**
  - **Understanding of the germline genetic test ordered and preparedness to counsel patients about any possible result outcomes, including future cancer risks**
    - ◊ **There are many testing options and the choice of which multigene panel test to order can be complicated, eg, when the personal and/or family history may suggest more than one cancer syndrome (EVAL-A 3 of 11)**
    - ◊ **Result outcomes: positive (EVAL-A 7 of 11), negative (EVAL-A 8 of 11), uncertain variant (EVAL-A 9 of 11), possible mosaic, and/or clonal hematopoiesis of indeterminate potential (LIFR-A 3 of 6)**
- **Post-test**
  - **Discussion of result including interpretation of result in the context of the patient's diagnosis, impact on future cancer risk and management if applicable, impact on reproductive plans if applicable, and impact on family members if applicable**
  - **Referral to clinical genetics services should be offered in the following situations:**
    - ◊ **for a P/LP variant result or one for which clinical management is uncertain. Local clinical genetics providers and those that provide telehealth services nationally can be located at https://findageneticcounselor.nsgc.org. Some genetic testing laboratories also offer this service.**
    - ◊ **when a patient has complex personal and/or family history suggestive of inherited risk, or has a result that may be difficult to interpret (EVAL-A 6 of 11)**
  - **Patients should be given a physical and/or electronic copy of their germline genetic test results, as this is often not available to patients through electronic medical record (EMR) portals, if the testing was sent to an outside laboratory. This document is an important reference for the patient and their relatives in the future.**
  - **For patients who test positive or need other genetics follow-up, consider revisiting this information over time, such as when initial treatment is completed and patient is entering a phase of maintenance or surveillance. This is a time when patients may have more ability to follow up on long-term implications of their genetic testing, such as increased screening for other cancers and informing family members.**
  - **It is expected for the ordering clinician to communicate a change in the status of a VUS to the patient, especially if it is an upgrade to pathogenic.**

Note: All recommendations are category 2A unless otherwise indicated.

References on EVAL-A 11 of 11

PRINCIPLES OF CANCER RISK ASSESSMENT AND COUNSELING
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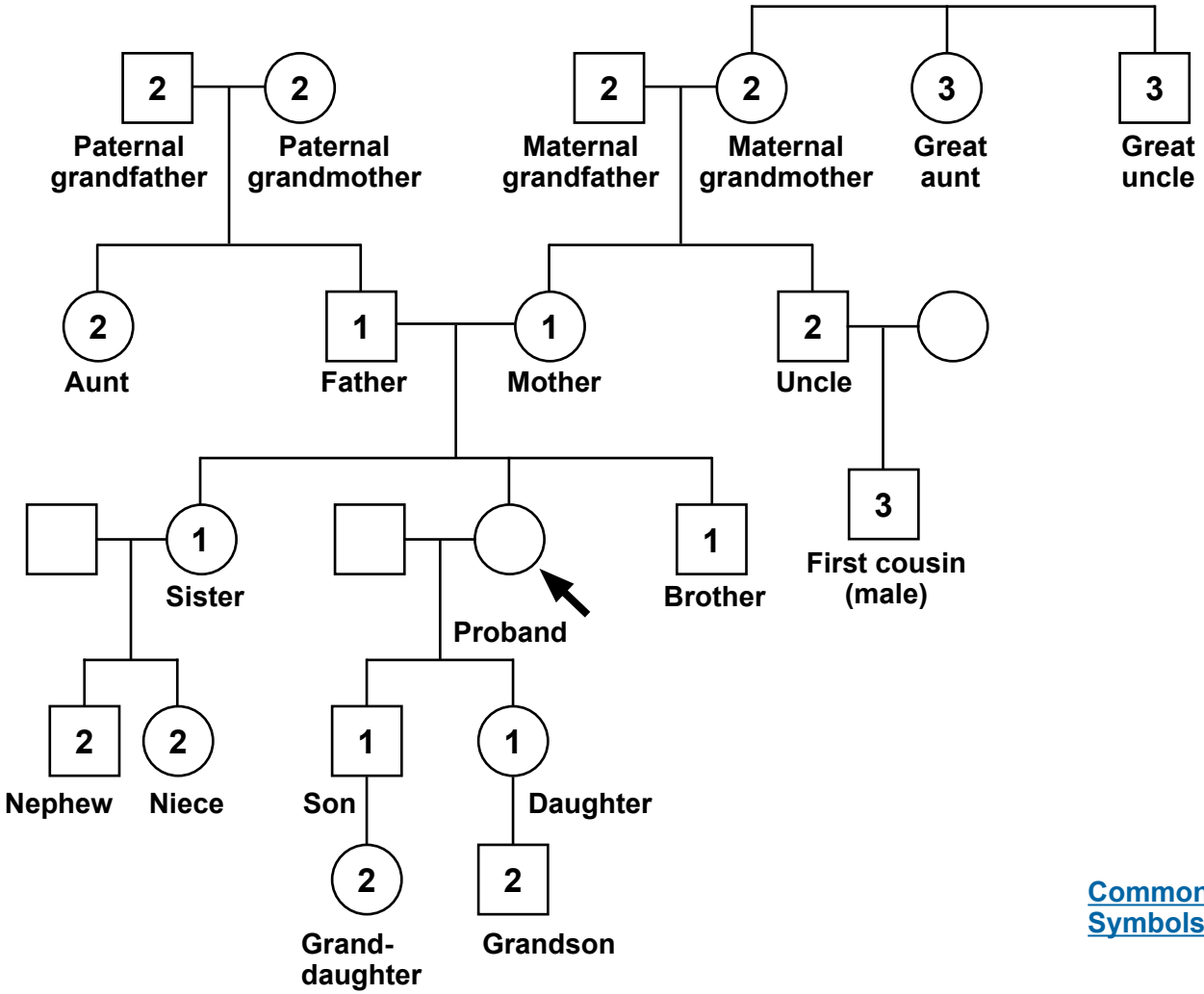
Note: All recommendations are category 2A unless otherwise indicated.

PEDIGREE: FIRST-, SECOND-, AND THIRD-DEGREE RELATIVES OF PROBAND[a]

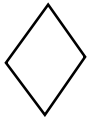
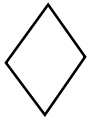
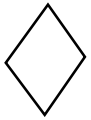


Common Pedigree Symbols (EVAL-B 2 of 3)

[a] First-degree relatives: parents, siblings, and children;
second-degree relatives: grandparents, aunts, uncles, nieces, nephews, grandchildren, and half-siblings;
third-degree relatives: great-grandparents, great-aunts, great-uncles, great-grandchildren, first cousins, and half aunts and uncles.

Note: All recommendations are category 2A unless otherwise indicated.

COMMON PEDIGREE SYMBOLS[b]

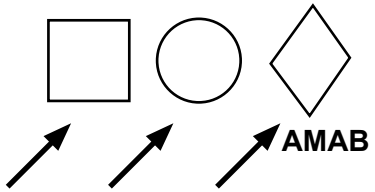
Gender	Sex		
	Male	Female	Unassigned at Birth
Man/Boy		 AFAB (assigned female at birth)	 UAAB (unassigned at birth)
Woman/Girl	 AMAB (assigned male at birth)		 UAAB (unassigned at birth)
Non-binary/ Gender diverse	 AMAB (assigned male at birth)	 AFAB (assigned female at birth)	 UAAB (unassigned at birth)

Continued

[b] Bennett R, French KS, Resta R, Austin J. Practice resource-focused revision: Standardized pedigree nomenclature update centered on sex and gender inclusivity: A practice resource of the National Society of Genetic Counselors. J Genet Couns 2022 31:1238-1248.

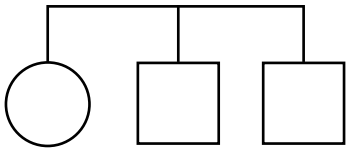
Note: All recommendations are category 2A unless otherwise indicated.

COMMON PEDIGREE SYMBOLS[b]

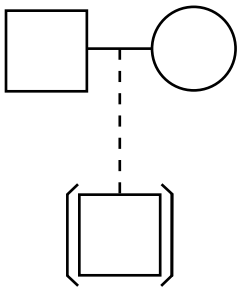


Consultand/ Proband (initiating genetic workup, shade if affected)

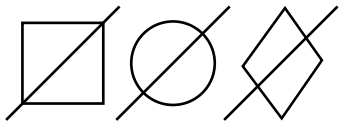
Relationship line



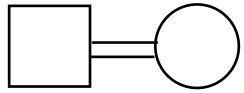
Sibship line



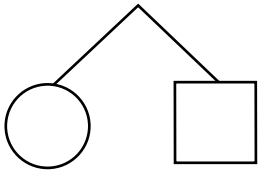
Adopted into a family



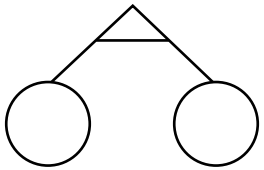
Deceased



Consanguinity



Dizygotic twins



Monozygotic twins

AMAB = assigned male at birth

[b] Bennett R, French KS, Resta R, Austin J. Practice resource-focused revision: Standardized pedigree nomenclature update centered on sex and gender inclusivity: A practice resource of the National Society of Genetic Counselors. J Genet Couns 2022 31:1238-1248.

Note: All recommendations are category 2A unless otherwise indicated.

GENERAL TESTING CRITERIA[a]

Testing is clinically indicated in the following scenarios:

- Individuals with any blood relative with a known P/LP variant in a cancer susceptibility gene
- Individuals meeting the criteria below but who tested negative with previous limited testing (eg, single gene and/or absent deletion duplication analysis) and are interested in pursuing multigene testing
- A P/LP variant identified on tumor genomic testing that has clinical implications if also identified in the germline
- To aid in systemic therapy and surgical decision-making[b]
- Individual who meets Li-Fraumeni syndrome (LFS) testing criteria (CRIT-7) or CS/PHTS testing criteria (CRIT-8) or Lynch syndrome (LS) NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric
- For personal or family history of
  - Breast cancer — Testing Criteria for High-Penetrance Breast Cancer Susceptibility Genes (CRIT-2)
  - Ovarian cancer — Testing Criteria for Ovarian Cancer Susceptibility Genes (CRIT-4)
  - Pancreatic cancer — Testing Criteria for Pancreatic Cancer Susceptibility Genes (CRIT-5)
  - Prostate cancer — Testing Criteria for Prostate Cancer Susceptibility Genes (CRIT-6)
  - Colorectal cancer — NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric

Testing *may be* considered in the following scenario (with appropriate pre-test education and access to post-test management):

- An individual of Ashkenazi Jewish ancestry[c] without additional risk factors[d]
- Personal history of serous endometrial cancer[e]

For a list of NCCN Guidelines that include content focused on inherited cancer conditions, including criteria for testing and/or cancer risk management based on a genetic test result, see Summary of Genes and/or Syndromes Included/Mentioned in Other NCCN Guidelines (SUMM-1).

Footnotes on CRIT-1A

Note: All recommendations are category 2A unless otherwise indicated.

FOOTNOTES FOR CRIT-1

[a] For further details regarding the nuances of genetic counseling and testing, see EVAL-A.

[b] Eg, PARP inhibitors for ovarian cancer, prostate cancer, pancreatic cancer, and metastatic HER2-negative breast cancer; platinum therapy for prostate cancer and pancreatic cancer; and risk-reducing surgery. See the relevant NCCN Treatment Guidelines for further details.

[c] Testing for three founder P/LP variants of *BRCA1/2* may be offered to individuals as early as age 18–25 years, who have one grandparent identified as of Ashkenazi Jewish ancestry, irrespective of cancer history in the family, as part of longitudinal studies. For those without access to longitudinal research studies, testing may be provided if there is access to pre-test education along with post-test counseling, additional genetic testing if indicated, and high-risk management. Testing should not be offered outside of a medical framework or clinical trial.

[d] In addition to the *BRCA1* and *BRCA2* PV in those of Ashkenazi ancestry, there are other ancestries that demonstrate "Founder mutations." In these circumstances, the decision to test will depend on the prevalence of the PV in the local population, family history, clinical features, and age of cancer diagnosis. Some additional examples where ancestry may, along with personal and/or family history, contribute to decisions about genetic testing include the following associations: *BRCA1* PV in those of Polish ancestry; *BRCA2* PV in those of Icelandic ancestry; *BRCA1* and *BRCA2* PV in those of French Canadian ancestry; numerous *BRCA1* and *BRCA2* PV in those of Spanish, Mexican, and Central and South American ancestry; *BRCA1* and *BRCA2* PV in those of Bahamian ancestry; and *BRCA1* and *BRCA2* PV in those of Hungarian ancestry. The *TP53* PV c.1010G>A (p.Arg337His) is seen in a subset of those of Brazilian ancestry, and *CDKN2A* founder c.225_243del (p.Ala76fs) in those of Dutch ancestry. While emerging data derived from populations of Asian, African, and Middle Eastern origin have documented recurring mutations in *BRCA1* and *BRCA2* and other genes, population allele frequency data are not yet available to inform testing individuals based solely on ancestry in the absence of personal and/or family history. The same is true for founder mutations in lower penetrance genes (eg, *CHEK2* c.1100delC in those of northern European ancestry), where family and personal history inform decisions for testing. See Discussion.

[e] This is a rare subtype of uterine cancer for which there is evolving evidence of an association with *BRCA1* P/LP variants.

Note: All recommendations are category 2A unless otherwise indicated.

TESTING CRITERIA FOR HIGH-PENETRANCE BREAST CANCER SUSCEPTIBILITY GENES
(Genes such as *BRCA1, BRCA2, CDH1, PALB2, PTEN, STK11,* and *TP53*. See GENE-A)[a,f,g,h,i]

Testing is clinically indicated in the following scenarios:

- **See General Testing Criteria on CRIT-1.**
- **Personal history of breast cancer with specific features:**
  - **≤50 y**
  - **Any age:**
    - ◊ **Treatment indications**
      - – **To aid in systemic treatment decisions using PARP inhibitors for breast cancer in the metastatic setting[j,k] (NCCN Guidelines for Breast Cancer)**
      - – **To aid in adjuvant treatment decisions with olaparib for high-risk,[l] HER2-negative breast cancer[j]**
    - ◊ **Pathology/histology**
      - – **Triple-negative breast cancer**
      - – **Multiple primary breast cancers (synchronous or metachronous)[m]**
      - – **Lobular breast cancer with personal or family history of diffuse gastric cancer (NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric)**
    - ◊ **Male breast cancer**
    - ◊ **Ancestry: Ashkenazi Jewish ancestry**
  - **Any age (continued):**
    - ◊ **Family history[n]**
      - – **≥1 close blood relative[o] with ANY:**
        - ▪ **breast cancer at age ≤50 y**
        - ▪ **male breast cancer**
        - ▪ **ovarian cancer**
        - ▪ **pancreatic cancer**
        - ▪ **prostate cancer with metastatic,[p] or high- or very-high-risk group (Initial Risk Stratification and Staging Workup in NCCN Guidelines for Prostate Cancer)**
      - – **≥3 diagnoses of breast and/or prostate cancer (any grade) on the same side of the family including the patient with breast cancer**
- **Family history criteria: unaffected; or affected but does not meet above criteria**
  - **Individual with a first- or second-degree blood relative meeting any of the criteria listed above (except unaffected individuals whose relatives meet criteria only for systemic therapy decision-making).[q]**
  - **Individuals who have a probability >5% of a *BRCA1/2* P/LP variant based on prior probability models (eg, Tyrer-Cuzick, BRCAPro, CanRisk).[r]**

Criteria met → **GENE-1**

If testing criteria not met, consider testing criteria for other hereditary syndromes → **If criteria for other hereditary syndromes not met, then cancer screening as per NCCN Screening Guidelines**

Continued on CRIT-3

Footnotes on CRIT-2A

Note: All recommendations are category 2A unless otherwise indicated.

TESTING CRITERIA FOR HIGH-PENETRANCE BREAST CANCER SUSCEPTIBILITY GENES

[a] For further details regarding the nuances of genetic counseling and testing, see EVAL-A.
[f] Testing for PVs in other genes should take into consideration factors such as patient preferences, turnaround time, and insurance restrictions to particular labs (and thus particular panels). The prevalence of VUS increases with testing of additional genes. Individuals should have pre-test education on the challenges in managing PVs in genes associated with specific syndromes (eg, *CDH1* and *TP53* given their expanding clinical phenotypes) in the absence of a family history typical of such syndromes (does not apply for de novo PVs). Patients should also have pre-test education regarding the uncertain clinical utility of identifying certain PVs (eg, monoallelic *MUTYH*).
[g] Meeting one or more of these criteria warrants further personalized risk assessment, genetic counseling, and often genetic testing and management.
[h] For the purposes of these guidelines, invasive and ductal carcinoma in situ breast cancers should be included.
[i] For personal or family history of ovarian cancer, see CRIT-4; for pancreatic cancer, see CRIT-5; for prostate cancer, see CRIT-6.
[j] Robson M, et al. N Engl J Med 2017;377:523-533; Litton JK, et al. N Engl J Med 2018;379:753-763.
[k] As indicated in the criteria, testing is recommended for all triple-negative breast cancers, and these indications are specifically for PARP inhibitor eligibility.
[l] The definition of high-risk disease is that used in the phase III OlympiA trial, which compared adjuvant olaparib to placebo among *BRCA1/BRCA2* carriers with high-risk disease (Tutt ANJ, et al. Engl J Med 2021;384:2394-2405). The definition includes:
- Triple-negative breast cancer treated with either:
  -- adjuvant chemotherapy with axillary node-positive disease or an invasive primary tumor ≥2 cm on pathology analysis, or
  -- neoadjuvant chemotherapy with residual invasive breast cancer in the breast or resected lymph nodes.
- Hormone receptor-positive disease treated with either:
  -- adjuvant chemotherapy with ≥4 positive pathologically confirmed lymph nodes, or
  -- neoadjuvant chemotherapy that did not have a complete pathologic response, with a CPS + EG score of ≥3.
- The CPS + EG scoring system is based on a combination of clinical and pathologic stage, estrogen receptor status, and histologic grade. See Neoadjuvant Therapy Outcomes Calculator (Jeruss JS, et al. J Clin Oncol 2008;26:246-252; Mittendorf EA, et al. J Clin Oncol 2011;29:1956-1962). See NCCN Guidelines for Breast Cancer for further details.

[m] Weitzel JN, et al. Breast Cancer Res Treat 2021;188:759-768.
[n] Consideration of the limitations of unknown or limited family structure is indicated in those aged ≥51 years. See EVAL-A.
[o] Close blood relatives include first-, second-, and third-degree relatives on the same side of the family (EVAL-B).
[p] Metastatic prostate cancer is biopsy-proven and/or with radiographic evidence and includes distant metastasis and regional bed or nodes. It is not a biochemical recurrence only. Prostate cancer-specific mortality should be a surrogate for metastatic disease for family history purposes.
[q] This may be extended to an affected third-degree relative if related through two male relatives (eg, paternal grandfather's mother or sister). If the affected first-degree relative underwent genetic testing and is negative for detectable P/LP variants and there is no other family history of cancer, there is a low probability that any finding will have documented clinical utility.
[r] The approximate 5% threshold for probability of carrying *BRCA1/2* PVs is utilized because of availability of prior probability models; however, it is recognized that current model estimates vary substantially, and that different thresholds may be appropriate if other genes are included in the model utilized. If genes other than *BRCA1* and *BRCA2* are to be included in models evaluating the threshold for testing, the penetrance, clinical actionability, and phenotypic features of cancers associated with P/LP variants in these genes should be considered. The Panel encourages the development of validated models that include these parameters to determine eligibility and appropriateness for gene panel testing for inherited cancer risk. These models are only validated for *BRCA1/2*.

Note: All recommendations are category 2A unless otherwise indicated.

TESTING CRITERIA FOR HIGH-PENETRANCE BREAST CANCER SUSCEPTIBILITY GENES (continued)

Testing *may be* considered in the following scenarios (with appropriate pre-test education and access to post-test management):

- **Personal history of breast cancer ≤65 y not meeting any of the above criteria (CRIT-2).[s,t] It is cautioned that the majority of those PVs will be in moderate-penetrance genes, which are over-represented in older affected individuals. Access to an experienced genetic counseling team to discuss management options is particularly important in this setting.**
- **Personal history of breast cancer diagnosed at any age with ≥1 close blood relative[o] with intermediate-risk prostate cancer with intraductal/cribriform histology (see Initial Risk Stratification and Staging Workup in NCCN Guidelines for Prostate Cancer).**
- **Individuals (unaffected; or affected but does not meet above criteria [CRIT-2]) with a 2.5%-5% probability of BRCA1/2 P/LP variant based on prior probability models (eg, Tyrer-Cuzick, BRCAPro, CanRisk).[f]**
- **Personal history of malignant phyllodes tumors.[u]**

There is a low probability (<2.5%) that testing will have findings of documented high-penetrance genes in the following scenarios:

- **Female diagnosed with breast cancer at age >65 y, with no close relative[o] with breast, ovarian, pancreatic, or prostate cancer.**
- **Diagnosed with localized prostate cancer with Gleason Score <7 and no close relative[o] with breast, ovarian, pancreatic, or prostate cancer.**

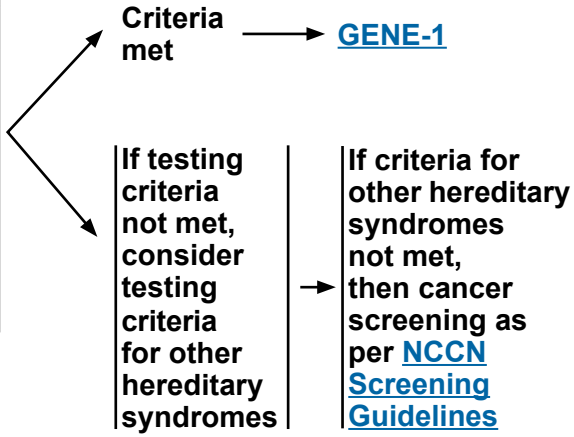
[f] Testing for PVs in other genes should take into consideration factors such as patient preferences, turnaround time, and insurance restrictions to particular labs (and thus particular panels). The prevalence of VUS increases with testing of additional genes. Individuals should have pre-test education on the challenges in managing PVs in genes associated with specific syndromes (eg, *CDH1* and *TP53* given their expanding clinical phenotypes) in the absence of a family history typical of such syndromes (does not apply for de novo PVs). Patients should also have pre-test education regarding the uncertain clinical utility of identifying certain PVs (eg, monoallelic *MUTYH*).
[o] Close blood relatives include first-, second-, and third-degree relatives on the same side of the family (EVAL-B).
[s] Bedrosian I, et. al. J Clin Oncol 2024;42:584-604.
[t] Testing includes breast cancer genes plus other inherited cancer genes consistent with family phenotype.
[u] See Discussion.

Note: All recommendations are category 2A unless otherwise indicated.

TESTING CRITERIA FOR OVARIAN CANCER SUSCEPTIBILITY GENES[a,v]
(Genes such as *ATM*, *BRCA1, BRCA2*, *BRIP1*, LS genes [*MLH1, MSH2, MSH6, EPCAM*], *PALB2, RAD51C*, and *RAD51D*; see GENE-A)[w]

Testing is clinically indicated in the following scenarios:

- See General Testing Criteria on CRIT-1.
- Personal history of epithelial ovarian cancer[x] (including fallopian tube cancer or peritoneal cancer) at any age
- Family history of cancer only
  - An individual unaffected with ovarian cancer with a first- or second-degree blood relative with epithelial ovarian cancer,[x] (including fallopian tube cancer or peritoneal cancer) at any age[q]
  - An individual unaffected with ovarian cancer who otherwise does not meet the criteria above but has a probability >5% of a *BRCA1/2* P/LP variant based on prior probability models (eg, Tyrer-Cuzick, BRCAPro, CanRisk)[r]



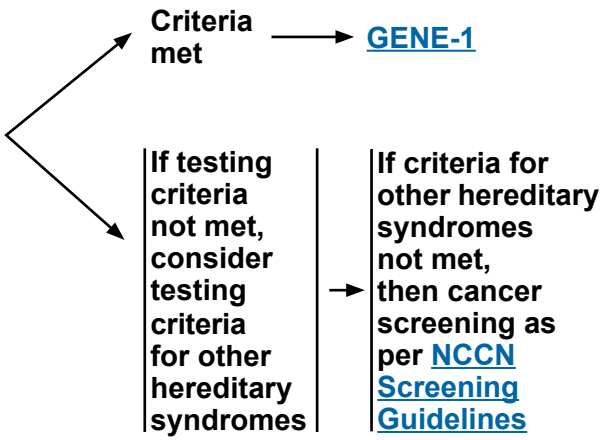
[a] For further details regarding the nuances of genetic counseling and testing, see EVAL-A.
[q] This may be extended to an affected third-degree relative if related through two male relatives (eg, paternal grandfather's mother or sister). If the affected first-degree relative underwent genetic testing and is negative for detectable P/LP variants and there is no other family history of cancer, there is a low probability that any finding will have documented clinical utility.
[r] The approximate 5% threshold for probability of carrying *BRCA1/2* PVs is utilized because of availability of prior probability models; however, it is recognized that current model estimates vary substantially, and that different thresholds may be appropriate if other genes are included in the model utilized. If genes other than *BRCA1* and *BRCA2* are to be included in models evaluating the threshold for testing, the penetrance, clinical actionability, and phenotypic features of cancers associated with P/LP variants in these genes should be considered. The Panel encourages the development of validated models that include these parameters to determine eligibility and appropriateness for gene panel testing for inherited cancer risk. These models are only validated for *BRCA1/2*.
[v] For personal or family history of breast cancer, see CRIT-2; for pancreatic cancer, see CRIT-5; for prostate cancer, see CRIT-6.
[w] The listed genes differ in their levels of risk. See GENE-A for specific risks.
[x] *BRCA*-related ovarian cancers are associated with epithelial, non-mucinous histology. LS can be associated with both non-mucinous and mucinous epithelial tumors. Be attentive for clinical evidence of LS (see NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric). Specific types of non-epithelial ovarian cancers and tumors can also be associated with other rare syndromes. Examples include an association between sex-cord tumors with annular tubules and PJS or Sertoli-Leydig tumors, *DICER1*-related disorders, and small cell carcinoma of the ovary and hypercalcemic type with *SMARCA4*.

Note: All recommendations are category 2A unless otherwise indicated.

TESTING CRITERIA FOR PANCREATIC CANCER SUSCEPTIBILITY GENES
(Genes such as *ATM, BRCA1, BRCA2, CDKN2A,* LS genes [*MLH1, MSH2, MSH6, EPCAM*], *PALB2, STK11, and TP53*) (GENE-A)[a,y]

Testing is clinically indicated in the following scenarios:

- See General Testing Criteria on CRIT-1.
- Exocrine pancreatic cancers
  - All individuals diagnosed with exocrine pancreatic cancer[z]
  - First-degree relatives of individuals diagnosed with exocrine pancreatic cancer[aa]
- Neuroendocrine pancreatic tumors - NCCN Guidelines for Neuroendocrine and Adrenal Tumors



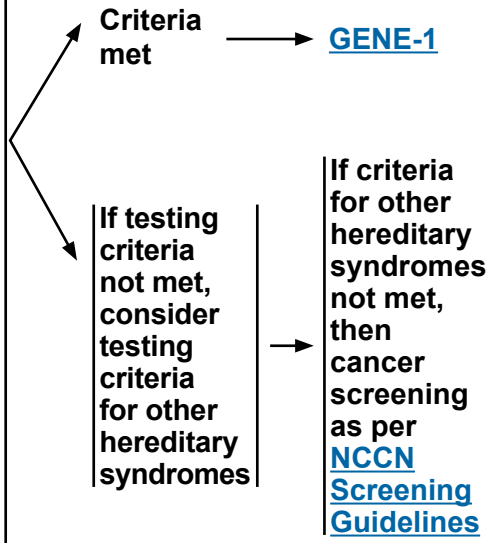
[a] For further details regarding the nuances of genetic counseling and testing, see EVAL-A.
[y] For personal or family history of breast cancer, see CRIT-2; for ovarian cancer, see CRIT-4; for prostate cancer, see CRIT-6.
[z] Pancreatic cancer risk is higher in individuals of Ashkenazi Jewish ancestry. Genetic testing of Ashkenazi Jewish patients with pancreatic cancer may have a higher yield of P/LP variants than of non-Ashkenazi Jewish patients. See Discussion.
[aa] Testing of first-degree relatives should only be done if it is impossible to test the individual who has pancreatic cancer. Some second-degree relatives may meet testing criteria based on additional family history. Approximately 2%–5% of unselected cases of pancreatic adenocarcinoma will have a *BRCA1/2* P/LP variant. However, the disease is highly aggressive and the option to test the affected relative may not be available in the future. Thus, there may be significant benefit to family members in testing these patients near the time of diagnosis. In addition, increasing evidence suggests that identification of a *BRCA1/2* P/LP variant may direct use of targeted therapies for patients with pancreatic cancer (see NCCN Guidelines for Pancreatic Adenocarcinoma). (Holter S, et al. J Clin Oncol 2015;33:3124-3129; Shindo K, et al. J Clin Oncol 2017;35:3382-3390; Golan T, et al. N Engl J Med 2019;381:317-327.) Family history of pancreatic cancer of unknown histology is often assumed to be an exocrine pancreatic cancer.

Note: All recommendations are category 2A unless otherwise indicated.

TESTING CRITERIA FOR PROSTATE CANCER SUSCEPTIBILITY GENES
(Genes such as *ATM, BRCA1, BRCA2, CHEK2, HOXB13,*[bb] and *TP53*) (GENE-A)[a,cc,dd]

Testing is clinically indicated in the following scenarios:

- See General Tumor Criteria on CRIT-1.
- Personal history of prostate cancer with specific features:
  - By tumor characteristics (any age)
    - ◊ Metastatic[p]
    - ◊ Histology
      - – high- or very-high-risk group (see Initial Risk Stratification and Staging Workup in NCCN Guidelines for Prostate Cancer)
  - By family history and ancestry
    - ◊ ≥1 close blood relative[o] with:
      - – breast cancer at age ≤50 y
      - – triple-negative breast cancer at any age
      - – male breast cancer at any age
      - – ovarian cancer at any age
      - – pancreatic cancer at any age
      - – metastatic,[p] high-, or very-high-risk group (see Initial Risk Stratification and Staging Workup in NCCN Guidelines for Prostate Cancer) at any age
    - ◊ ≥3 close blood relatives[o] with prostate cancer (any grade) and/or breast cancer on the same side of the family including the patient with prostate cancer
    - ◊ Ashkenazi Jewish ancestry
- Family history criteria: unaffected; or affected but does not meet criteria above
  - ◊ Individual with a first-degree blood relative meeting any of the criteria listed above (except unaffected individuals whose relatives meet criteria only for systemic therapy decision-making)[q]



Testing *may be* considered in the following scenario:

- Personal history of prostate cancer with intermediate-risk prostate cancer with intraductal/cribriform histology (see Initial Risk Stratification and Staging Workup in NCCN Guidelines for Prostate Cancer) at any age

Footnotes on CRIT-6A

Note: All recommendations are category 2A unless otherwise indicated.

FOOTNOTES FOR CRIT-6

[a] For further details regarding the nuances of genetic counseling and testing, see EVAL-A.
[o] Close blood relatives include first-, second-, and third-degree relatives on the same side of the family (EVAL-B).
[p] Metastatic prostate cancer is biopsy-proven and/or with radiographic evidence and includes distant metastasis and regional bed or nodes. It is not a biochemical recurrence only. Prostate cancer-specific mortality should be a surrogate for metastatic disease for family history purposes.
[q] This may be extended to an affected third-degree relative if related through two male relatives (eg, paternal grandfather's mother or sister). If the affected first-degree relative underwent genetic testing and is negative for detectable P/LP variants and there is no other family history of cancer, there is a low probability that any finding will have documented clinical utility.
[bb] NCCN Guidelines for Prostate Cancer.
[cc] For personal or family history of breast cancer, see CRIT-2; for ovarian cancer, see CRIT-4; for pancreatic cancer, see CRIT-5.
[dd] Level of risk for prostate cancer varies by gene. There is emerging evidence for potential risk and/or therapeutic relevance for prostate cancer for additional genes.

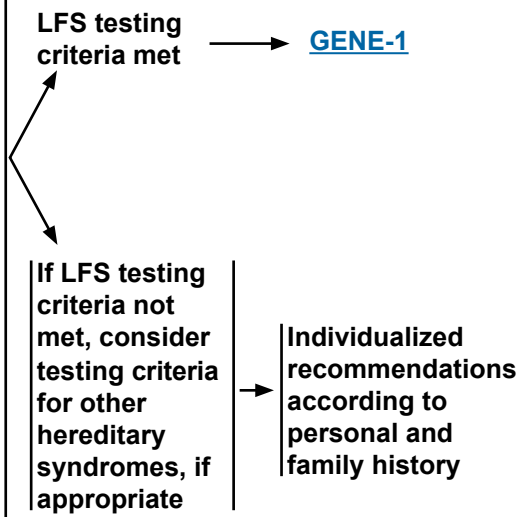
Note: All recommendations are category 2A unless otherwise indicated.

TESTING CRITERIA FOR LI-FRAUMENI SYNDROME[a]

Testing is clinically indicated in the following scenarios:*

- See General Testing Criteria on CRIT-1.

- Individual from a family with a known *TP53*[ee] P/LP variant
- Classic LFS criteria:[ff]
  - Combination of an individual diagnosed at age <45 years with a sarcoma[gg] ***AND***
    A first-degree relative diagnosed at age <45 years with cancer ***AND***
    An additional first- or second-degree relative in the same lineage with cancer diagnosed at age <45 years, or a sarcoma at any age
- Chompret criteria:[hh]
  - Individual with a tumor from LFS tumor spectrum (eg, soft tissue sarcoma, osteosarcoma, central nervous system [CNS] tumor, breast cancer, adrenocortical carcinoma [ACC]), diagnosed <46 years of age, AND at least one first- or second-degree relative diagnosed with any of the aforementioned cancers (other than breast cancer if the proband has breast cancer) at age <56 years or with multiple primaries at any age OR
  - Individual with multiple tumors (except multiple breast tumors), two of which belong to LFS tumor spectrum with the initial cancer occurring at age <46 years OR
  - Individual with ACC, or choroid plexus carcinoma or rhabdomyosarcoma of embryonal anaplastic subtype, at any age of onset, regardless of family history OR
  - Breast cancer diagnosed at age <31 years
- Personal or family history of pediatric hypodiploid acute lymphoblastic leukemia
- In individuals with cancer with a P/LP *TP53* variant identified on tumor-only genomic testing, germline testing should be considered for:[ii,jj,kk]
  1. Those meeting one or more of the other LFS testing criteria above after reevaluation of personal and family history
  2. Those diagnosed at age <30 years with any cancer
  3. Those with clinical scenario not meeting these criteria but warranting germline evaluation per clinician discretion



* Other cancers associated with LFS but not in the testing criteria include: melanoma, colorectal, gastric, and prostate.

[a] For further details regarding the nuances of genetic counseling and testing, see EVAL-A.
[ee] When this gene is included as part of a multigene panel, an individual does not need to meet these testing criteria if testing criteria on other testing criteria pages are met.
[ff] Li FP, et al. Cancer Res 1988;48:5358-5362.
[gg] In contrast to other types of sarcoma, germline *TP53* P/LP variants are rare in those with Ewing sarcoma, gastrointestinal stromal tumor (GIST), desmoid tumor, or angiosarcoma.
[hh] Chompret A, et al. J Med Genet 2001;38:43-47; Bougeard G, et al. J Clin Oncol 2015;33:2345-2352.
[ii] For testing in the pediatric setting, see Frebourg T, et al. Eur J Hum Genet 2020;28:1379-1386.
[jj] This should prompt a careful evaluation of personal and family history of the individual to determine the yield of germline sequencing. Somatic *TP53* P/LP variants are common in many tumor types in absence of a germline P/LP variant.
[kk] Mandelker D, et al. Ann Oncol 2019;30:1221-1231.

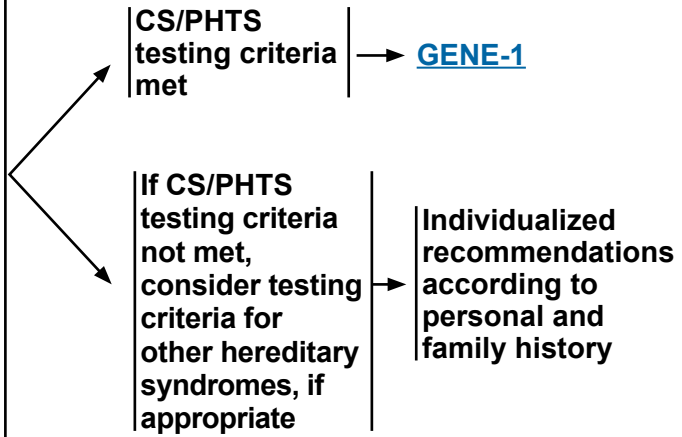
Note: All recommendations are category 2A unless otherwise indicated.

TESTING CRITERIA FOR COWDEN SYNDROME (CS)/*PTEN H*AMARTOMA TUMOR SYNDROME (PHTS)[a,ll,mm,nn]

Testing is clinically indicated in the following scenarios:

- See General Testing Criteria on CRIT-1.

- Individual from a family with a known *PTEN*[ee] P/LP variant
- Individual with a personal history of Bannayan-Riley-Ruvalcaba syndrome (BRRS)
- Individual meeting clinical diagnostic criteria[oo] for CS/PHTS
- Individual not meeting clinical diagnostic criteria[oo] for CS/PHTS with a personal history of:
  - Adult Lhermitte-Duclos disease (cerebellar tumors); or
  - Autism spectrum disorder and macrocephaly; or
  - Two or more biopsy-proven trichilemmomas; or
  - Two or more major criteria (one must be macrocephaly); or
  - Three major criteria, without macrocephaly; or
  - One major and ≥3 minor criteria;[pp] or
  - ≥4 minor criteria
- Individual with a relative with a clinical diagnosis of CS/PHTS or BRRS for whom testing has not been performed
  - Individual must have the following:
    - ◊ Any one major criterion or
    - ◊ Two minor criteria
- *PTEN* P/LP variant detected by tumor genomic testing on any tumor type in the absence of germline analysis[qq]



See major and minor criteria on CRIT-8A.

[a] For further details regarding the nuances of genetic counseling and testing, see EVAL-A.
[ee] When this gene is included as part of a multigene panel, an individual does not need to meet these testing criteria if testing criteria on other testing criteria pages are met.
[ll] These are testing criteria; clinical diagnostic criteria can be found on CRIT-8A.
[mm] If two criteria involve the same structure/organ/tissue, both may be included as criteria.
[nn] Current evidence does not support testing for succinate dehydrogenase (*SDH*) gene P/LP variants in patients with PHTS (Bayley J-P. Am J Hum Genet 2011;88:674-675).
[oo] Pilarski R, et al. J Natl Cancer Inst 2013;105:1607-1616. See COWD-A.
[pp] If an individual has two or more major criteria, such as breast cancer and nonmedullary thyroid cancer, but does not have macrocephaly, one of the major criteria may be included as one of the three minor criteria to meet testing criteria.
[qq] This should prompt a careful evaluation of personal and family history of the individual to determine the yield of germline sequencing. Somatic *PTEN* P/LP variants are common in many tumor types in absence of germline P/LP variant.

Note: All recommendations are category 2A unless otherwise indicated.

DIAGNOSTIC CRITERIA FOR COWDEN SYNDROME (CS)/*PTEN* HAMARTOMA TUMOR SYNDROME (PHTS)[a,*]

Major criteria:
- Breast cancer
- Endometrial cancer (epithelial)
- Follicular thyroid cancer
- ≥3 GI hamartomas or ganglioneuromas[rr]
- Lhermitte-Duclos disease (adult)
- Macrocephaly (megalocephaly) (ie, ≥97%, 58 cm in adult female, 60 cm in adult male)[ss]
- Macular pigmentation of glans penis
- Mucocutaneous lesions[tt]
  - Trichilemmoma (≥3, at least 1 biopsy-proven)
  - ≥3 palmoplantar keratotic pits and/or acral hyperkeratotic papules)
  - ≥3 mucocutaneous neuromas
  - Oral papillomas (particularly on tongue and gingiva) (≥3 or 1 biopsy-proven or dermatologist diagnosed)

Minor criteria:[uu]
- Autism spectrum disorder
- Colon cancer
- ≥3 esophageal glycogenic acanthoses
- ≥3 lipomas
- Intellectual disability (ie, IQ ≤75)
- Renal cell carcinoma
- Testicular lipomatosis
- Papillary or follicular variant of papillary thyroid cancer
- Thyroid structural lesions (eg, adenoma, nodule[s], goiter)
- Single GI hamartoma or ganglioneuroma
- Vascular anomalies (including multiple intracranial developmental venous anomalies)

[*] Melanoma is also associated with PTEN but is not included in the testing criteria.

REVISED CLINICAL DIAGNOSTIC CRITERIA FOR *PTEN* HAMARTOMA TUMOR SYNDROME[oo]

Operational diagnosis in an individual (either of the following):
1. Three or more major criteria, but one must include macrocephaly, Lhermitte-Duclos disease, or GI hamartomas; or
2. Two major and three minor criteria.

Operational diagnosis in a family where one individual meets revised *PTEN* hamartoma tumor syndrome clinical diagnostic criteria or has a *PTEN* P/LP variant:
1. Any two major criteria with or without minor criteria; or
2. One major and two minor criteria; or
3. Three minor criteria.

[a] For further details regarding the nuances of genetic counseling and testing, see EVAL-A.
[oo] Pilarski R, et al. J Natl Cancer Inst 2013;105:1607-1616. See COWD-A.
[rr] Multiple polyp types are often seen in patients with PHTS, and less commonly may include adenomas, hyperplastic polyps, and other histologies.
[ss] Roche AF, et al. Pediatrics 1987;79:706-712.
[tt] The literature available on mucocutaneous lesions is not adequate to accurately specify the number or extent of mucocutaneous lesions required to be a major criterion for CS/PHTS. Clinical judgment should be used.
[uu] Insufficient evidence exists in the literature to include fibrocystic disease of the breast, fibromas, and uterine fibroids as diagnostic criteria.

Note: All recommendations are category 2A unless otherwise indicated.

National Comprehensive Cancer Network®

NCCN Guidelines Version 1.2025
Gene Summary: Risks and Management

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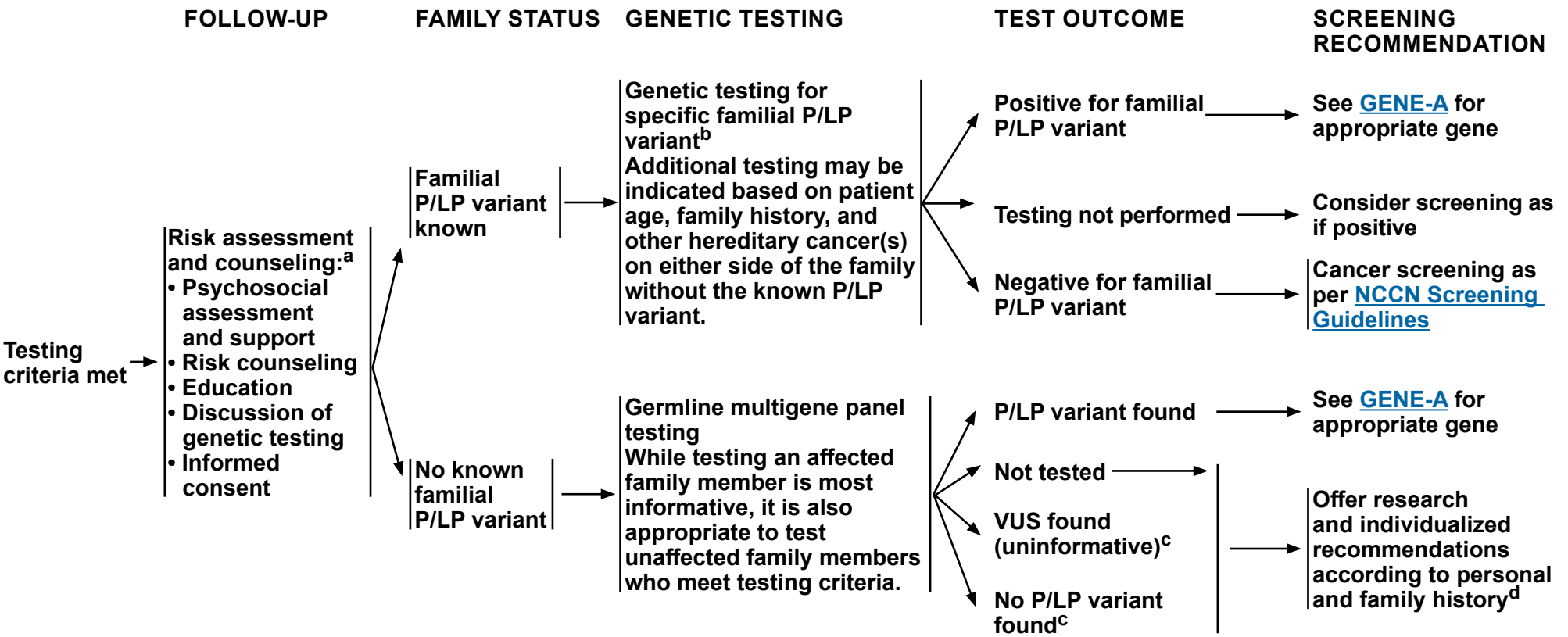

[a] For further details regarding the nuances of genetic counseling and testing, see EVAL-A.
[b] If of Ashkenazi Jewish ancestry, in addition to the specific familial P/LP variant, test for all three founder P/LP variants.
[c] If no P/LP variant is found, consider testing another family member with next highest likelihood of having a P/LP variant.
[d] Patients meeting CS/PHTS clinical diagnostic criteria (COWD-A 1 of 2) should be cared for as P/LP variant carriers.

Note: All recommendations are category 2A unless otherwise indicated.

CANCER RISK MANAGEMENT BASED ON GENETIC TEST RESULTS[a,1,2]

The inclusion of a gene in this table below does not imply the endorsement either for or against multigene testing for moderate-penetrance genes.

Gene	Breast Cancer[b]	Epithelial Ovarian Cancer[b]	Pancreatic Cancer[11-20] and Other Cancer Risks
ATM	Primary breast cancer • Absolute risk: 21%–24%[3,4] • Management: ▸ Screening: Annual mammogram at age 40 y and consider breast MRI with and without contrast starting at age 30–35 y[c,d,e,f] ▸ Risk reduction: Evidence insufficient for risk-reducing mastectomy (RRM); manage based on family history • Strength of evidence of association with cancer: Strong Contralateral breast cancer • 10-year cumulative risk: 4%[g,5] • Strength of evidence of association with cancer: Limited	• Absolute risk: 2%–3%[8-10] • Management: ▸ Risk reduction: Evidence insufficient for risk-reducing salpingo oophorectomy (RRSO); manage based on family history • Strength of evidence of association with cancer: Strong	Pancreatic cancer • Absolute risk: ~5%–10%[h,21] • Management: Screening, see PANC-A. • Strength of evidence of association with cancer: Strong Prostate cancer • Emerging evidence for association with increased risk.[22] Consider prostate cancer screening starting at age 40 (NCCN Guidelines for Prostate Cancer Early Detection) Colorectal cancer • NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric
	Comments: Heterozygous *ATM* P/LP variants should not lead to a recommendation to avoid RT at this time. *ATM* missense c.7271T>G variant is a higher penetrance allele (60% by age 80 y; Goldgar DE, et al. Breast Cancer Res 2011;13:R73; Hall MJ, et al. Cancer Prev Res (Phila) 2021;14:433-440; Southey MC, et al. J Med Genet 2016;53:800-811). See GENE-B for reproductive implications/recessive disease.		
BARD1	Primary breast cancer • Absolute risk:17%–30%[4] • Management: ▸ Screening: Annual mammogram and consider breast MRI with and without contrast starting at age 40 y[c,d,e,f] ▸ Risk reduction: Evidence insufficient for RRM, manage based on family history • Strength of evidence of association with cancer: Strong[4-7]	Evidence of increased risk: No established association	Other cancers • Unknown or insufficient evidence

Footnotes on GENE-A 9 of 11
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Note: All recommendations are category 2A unless otherwise indicated.

CANCER RISK MANAGEMENT BASED ON GENETIC TEST RESULTS[a,1,2]

The inclusion of a gene in this table below does not imply the endorsement either for or against multigene testing for moderate-penetrance genes.

Gene	Breast Cancer[b]	Epithelial Ovarian Cancer[b]	Pancreatic Cancer[11-20] and Other Cancer Risks
BRCA1	Primary breast cancer • Absolute risk: 60%–72%[23,24] • Management: See *BRCA* Pathogenic Variant-Positive Management • Strength of evidence of association with cancer: Very strong Contralateral breast cancer[l,j] • 20-year cumulative risk: 30%–40%[5,25] • 15-year cumulative risk in premenopausal women: >20%[5,25] • Strength of evidence of association with cancer: Strong Male breast cancer • Absolute risk: 0.2%–1.2% by age 70 y[26,27] • Management: See *BRCA* Pathogenic Variant-Positive Management • Strength of evidence of association with cancer: Strong	• Absolute risk: 39%–58%[29] • Management: See *BRCA* Pathogenic Variant-Positive Management • Strength of evidence of association with cancer: Very strong	Pancreatic cancer • Absolute risk: ≤5%[27] • Management: Screen P/LP variant carriers with a family history of pancreatic cancer, see PANC-A. • Strength of evidence of association with cancer: Strong Prostate cancer • Absolute risk: 7%–26%[30] • Management: See *BRCA* Pathogenic Variant-Positive Management
	Comment: See GENE-B for reproductive implications/recessive disease. The risk for breast cancer appears to be lower for the *BRCA1* R1699Q variant (24% by age 70 y) (Spurdle AB, et al. J Med Genet 2012;49:525-532). Screening should be individualized based on personal and family history.		
BRCA2	Primary breast cancer • Absolute risk: 55%–69%[23,24] • Management: See *BRCA* Pathogenic Variant-Positive Management • Strength of evidence of association with cancer: Very strong Contralateral breast cancer[l,j] • 20-year cumulative risk: 25%[5,25] • 15-year cumulative risk in premenopausal women: >20%[5,25] • Strength of evidence of association with cancer: Strong Male breast cancer • Absolute risk: 1.8%–7.1% by age 70 y[26-28] • Management: See *BRCA* Pathogenic Variant-Positive Management • Strength of evidence of association with cancer: Strong	• Absolute risk: 13%–29%[29] • Management: See *BRCA* Pathogenic Variant-Positive Management • Strength of evidence of association with cancer: Very strong	Pancreatic cancer • Absolute risk: 5%–10%[27] • Management: Screening, see PANC-A. • Strength of evidence of association with cancer: Very strong Prostate cancer • Absolute risk: 19%–61%[30,31] • Management: See *BRCA* Pathogenic Variant-Positive Management Melanoma • See *BRCA* Pathogenic Variant-Positive Management
	Comment: See GENE-B for reproductive implications/ recessive disease.		

Footnotes on GENE-A 9 of 11
References on GENE-A 10 of 11 and GENE-A 11 of 11
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Note: All recommendations are category 2A unless otherwise indicated.

CANCER RISK MANAGEMENT BASED ON GENETIC TEST RESULTS[a,1,2]

The inclusion of a gene in this table below does not imply the endorsement either for or against multigene testing for moderate-penetrance genes.

Gene	Breast Cancer[b]	Epithelial Ovarian Cancer[b]	Pancreatic Cancer[11-20] and Other Cancer Risks
BRIP1	Primary breast cancer • Absolute risk: Insufficient data to define • Management: Insufficient data; managed based on family history • Strength of evidence of association with cancer: Limited; potential increase in female breast cancer[6]	• Absolute risk: 5%–15%[8-10,35] • Management: ▸ Risk reduction: Recommend RRSO starting at age 45–50 y[k] • Strength of evidence of association with cancer: Strong	Other cancers • Unknown or insufficient evidence
	Comments: Based on estimates from available studies, the lifetime risk of ovarian cancer in carriers of a *BRIP1* P/LP variant justifies RRSO. The current evidence is insufficient to make a firm recommendation as to the optimal age for this procedure. Based on the current, limited evidence base, a discussion about surgery should be held around age 45–50 y or earlier based on a specific family history of an earlier onset of ovarian cancer. See GENE-B for reproductive implications/recessive disease.		
CDH1	Primary breast cancer • Absolute risk: 37%–55%[32-34] • Management: ▸ Screening: Annual mammogram and consider breast MRI with and without contrast starting at age 30 y[c,d,f] ▸ Risk reduction: Discuss option of RRM • Strength of evidence of association with cancer: Strong	Evidence of increased risk: No established association	Hereditary diffuse gastric cancer (HDGC) • Strength of evidence of association with cancer: Strong • See NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric
	Comments: Cleft lip with or without cleft palate has been associated with *CDH1* P/LP variants (Frebourg T, et al. J Med Genet 2006;43:138-142).		

Footnotes on GENE-A 9 of 11
References on GENE-A 10 of 11 and GENE-A 11 of 11

Note: All recommendations are category 2A unless otherwise indicated.

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CANCER RISK MANAGEMENT BASED ON GENETIC TEST RESULTS[a,1,2]

The inclusion of a gene in this table below does not imply the endorsement either for or against multigene testing for moderate-penetrance genes.

Gene	Breast Cancer[b]	Epithelial Ovarian Cancer[b]	Pancreatic Cancer[11-20] and Other Cancer Risks
CDKN2A	Evidence of increased risk: No established association	Evidence of increased risk: No established association	Pancreatic cancer • Absolute risk: >15% • Management: Screening, see PANC-A. • Strength of evidence of association with cancer: Very strong Melanoma • Absolute risk: 28%–76% depending on other risk factors, including family history, geographic location, and other genetic modifiers[38,39] • Strength of evidence of association with cancer: Strong • Management: See comment Other cancers • See comment
	Comments: Comprehensive skin examination by a dermatologist, supplemented with total body photography and dermoscopy is recommended every 6 mo for individuals with P/LP variants affecting biologically relevant *CDKN2A* isoforms (ie, p16INK4A and p14ARF). Because P/LP variants that specifically disrupt the p14ARF protein cause a unique predisposition to nerve sheath tumors, sarcomas, melanoma, and other cancers, increased multidisciplinary cancer surveillance beyond pancreatic and dermatologic management has been recommended, which may include annual full-body and brain MRI based on the presentation in individuals/families (Sargen M, et al. Br J Dermatol 2016;175:785-789; Chan et al. Hered Cancer Clin Pract 2021;19:21).		
CHEK2	Primary breast cancer • Absolute risk: 23%–27%[3,4] • Management: ▸ Screening: Annual mammogram at age 40 y and consider breast MRI with and without contrast starting at age 30–35 y[c,d,e,f] ▸ Risk reduction: Evidence insufficient for RRM, manage based on family history • Strength of evidence of association with cancer: Strong[36] Contralateral breast cancer[i,j,l] • 10-year cumulative risk: 6%–8%[7,37] • Strength of evidence of association with cancer: Limited	Evidence of increased risk: No established association	Prostate cancer • Emerging evidence for association with increased risk.[40] Consider prostate cancer screening starting at age 40 y (NCCN Guidelines for Prostate Cancer Early Detection)
	Comments: Risk data are based only on frameshift P/LP variants. There is emerging evidence that not all missense P/LP variants are low penetrance. For some P/LP variants, such as Ile157Thr and Ser428Phe, the risk for breast cancer appears to be lower. Additional cancer risk management based on these variants is not recommended. Management should be based on best estimates of cancer risk for the specific P/LP variant and family history. There are some data to indicate individuals with biallelic *CHEK2* P/LP variants have a higher risk for invasive breast cancer, are more likely to be diagnosed at ≤50 years of age, and are more likely to have multiple primary breast cancers. However, lifetime risk estimates are difficult to quantify due to small study sizes. Therefore, taking personal and family history into account to advise on cancer risk management is appropriate.		

Note: All recommendations are category 2A unless otherwise indicated.

Footnotes on GENE-A 9 of 11
References on GENE-A 10 of 11 and GENE-A 11 of 11
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CANCER RISK MANAGEMENT BASED ON GENETIC TEST RESULTS[a,1,2]

The inclusion of a gene in this table below does not imply the endorsement either for or against multigene testing for moderate-penetrance genes.

Gene	Breast Cancer[b]	Epithelial Ovarian Cancer[b]	Pancreatic Cancer[11-20] and Other Cancer Risks
MSH2, MLH1, MSH6, PMS2, EPCAM	Primary breast cancer *MLH1, MSH2, MSH6, PMS2,* and *EPCAM* • Absolute risk: <15%[41-43] • Management: Insufficient data; managed based on family history • Strength of evidence of association with cancer: Limited	*MLH1* • Absolute risk: 4%–20%[46,47] • Strength of evidence: Strong *MSH2/EPCAM* • Absolute risk: 8%–38%[46,47,49,50] • Strength of evidence: Strong *MSH6* • Absolute risk: ≤1%–13%[48,49] • Strength of evidence: Strong *PMS2* • Absolute risk: 1.3%–3%[50] • Strength of evidence: Limited • Management for all genes: NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric	Pancreatic cancer • Absolute risk: <5%–10% (excluding *PMS2*) • Management: Screen P/LP variant carriers with a family history of pancreatic cancer (insufficient evidence for *PMS2*), see PANC-A. • Strength of evidence of association with cancer: Strong Colorectal, uterine, others • NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric
	Comments: Counsel for biallelic risk of P/LP variants that lead to CMMRD. See NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric.		
NF1	Primary breast cancer • Absolute risk: 20%–40%[44,45] • Management: ▸ Screening: Annual mammogram starting at age 30 y and consider breast MRI with and without contrast from ages 30–50 y[c,d,f] ▸ Risk reduction: Evidence insufficient for RRM, manage based on family history • Strength of evidence of association with cancer: Strong	Evidence of increased risk: No established association	Malignant peripheral nerve sheath tumors, gastrointestinal stromal tumors (GIST), others • Recommend referral to *NF1* specialist for evaluation and management
	Comments: At this time, there are no data to suggest an increased breast cancer risk after age 50 y. Consider possibility of false-positive MRI results due to presence of breast neurofibromas.		

Footnotes on GENE-A 9 of 11
References on GENE-A 10 of 11 and GENE-A 11 of 11 Continued

Note: All recommendations are category 2A unless otherwise indicated.

CANCER RISK MANAGEMENT BASED ON GENETIC TEST RESULTS[a,1,2]

The inclusion of a gene in this table below does not imply the endorsement either for or against multigene testing for moderate-penetrance genes.

Gene	Breast Cancer[b]	Epithelial Ovarian Cancer[b]	Pancreatic Cancer[11-20] and Other Cancer Risks
PALB2	Primary breast cancer • Absolute risk: 32%–53%[3,4] • Management: ▸ Screening: Annual mammogram and breast MRI with and without contrast at 30 y[c,d,f] ▸ Risk reduction: Discuss option of RRM • Strength of evidence of association with cancer: Strong Contralateral breast cancer[i,j,m] • 10-year cumulative risk: 5%–8%[5,37] • Strength of evidence of association with cancer: Limited Male breast cancer • Absolute risk: 0.9% by age 70 y[20] • Management: See comment • Strength of evidence of association with cancer: Strong	• Absolute risk: 3%–5%[8-10,20,58,59] • Management: ▸ Risk reduction: Consider RRSO at age starting at 45–50 y[k,60,61] • Strength of evidence of association with cancer: Strong	Pancreatic cancer • Absolute risk: 2%–5% • Management: Screen P/LP variant carriers with a family history of pancreatic cancer, see PANC-A • Strength of evidence of association with cancer: Limited Other cancers • Unknown or insufficient evidence
	Comments: See GENE-B for reproductive implications/recessive disease. For males, it is reasonable to consider breast cancer screening similar to that for carriers of a *BRCA1* P/LP variant. See BRCA-A.		
PTEN	Primary breast cancer • Absolute risk: 40%–60% (historical cohort data), >60% (projected estimates)[51-55] • Management: See Cowden Syndrome Management • Strength of evidence of association with cancer: Strong[56,57]	Evidence of increased risk: No established association	Thyroid, colorectal, endometrial, and renal cancers • See Cowden Syndrome Management

Footnotes on GENE-A 9 of 11
References on GENE-A 10 of 11 and GENE-A 11 of 11

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Note: All recommendations are category 2A unless otherwise indicated.

CANCER RISK MANAGEMENT BASED ON GENETIC TEST RESULTS[a,1,2]

The inclusion of a gene in this table below does not imply the endorsement either for or against multigene testing for moderate-penetrance genes.

Gene	Breast Cancer[b]	Epithelial Ovarian Cancer[b]	Pancreatic Cancer[11-20] and Other Cancer Risks
RAD51C	Primary breast cancer • Absolute risk: ~20%[62] • Management: ▸ Screening: Annual mammogram and consider breast MRI with and without contrast starting at age 40 y[f] ▸ Risk reduction: Evidence insufficient for risk-reducing mastectomy (RRM); manage based on family history • Strength of evidence of association with cancer: Strong Contralateral breast cancer[j] • 10-year cumulative risk: same as sporadic breast cancer (<2%)[63] • Strength of evidence of association with cancer: Limited	• Absolute risk: 10%–15%[8-10,62,64] • Management: ▸ Risk reduction: Recommend RRSO starting at 45–50 y[k] • Strength of evidence of association with cancer: Strong	Other cancers • Unknown or insufficient evidence
	Comments: Based on estimates from available studies, the lifetime risk of ovarian cancer in carriers of a *RAD51C* P/LP variant justifies RRSO. The current evidence is insufficient to make a firm recommendation as to the optimal age for this procedure. Based on the current, limited evidence base, a discussion about surgery should be held around age 45–50 y or earlier based on a specific family history of an earlier onset ovarian cancer. See GENE-B for reproductive implications of recessive disease.		
RAD51D	Primary breast cancer • Absolute risk: ~20%[62] • Management: ▸ Screening: Annual mammogram and consider breast MRI with and without contrast starting at age 40 y[f] ▸ Risk reduction: Evidence insufficient for risk-reducing mastectomy (RRM); manage based on family history • Strength of evidence of association with cancer: Strong Contralateral breast cancer[j] • 10-year cumulative risk: same as sporadic breast cancer (<2%)[63] • Strength of evidence of association with cancer: Limited	• Absolute risk: 10%–20%[8-10,62,64] • Management: ▸ Risk reduction: Recommend RRSO at starting at 45–50 y[j] • Strength of evidence of association with cancer: Strong	Other cancers • Unknown or insufficient evidence
	Comments: Based on estimates from available studies, the lifetime risk of ovarian cancer in carriers of a *RAD51D* P/LP variant justifies RRSO. The current evidence is insufficient to make a firm recommendation as to the optimal age for this procedure. Based on the current, limited evidence base, a discussion about surgery should be held around age 45–50 y or earlier based on a specific family history of an earlier onset ovarian cancer.		

Footnotes on GENE-A 9 of 11
References on GENE-A 10 of 11 and GENE-A 11 of 11
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Note: All recommendations are category 2A unless otherwise indicated.

CANCER RISK MANAGEMENT BASED ON GENETIC TEST RESULTS[a,1,2]

The inclusion of a gene in this table below does not imply the endorsement either for or against multigene testing for moderate-penetrance genes.

Gene	Breast Cancer[b]	Epithelial Ovarian Cancer[b]	Pancreatic Cancer[11-20] and Other Cancer Risks
STK11	Primary breast cancer • Absolute risk: 32%–54%[65,66] • Management: ▸ Screening: Annual mammogram and breast MRI with and without contrast starting at age 30 y[f] NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric - Peutz-Jeghers syndrome (PJS) ▸ Risk reduction: Discuss option of RRM • Strength of evidence of association with cancer: Strong	Evidence of increased risk: No established association	Pancreatic cancer • Absolute risk: >15% • Management: Screening, see PANC-A • Strength of evidence of association with cancer: Strong Non-epithelial ovarian cancer (sex cord tumor with annular tubules) • Absolute risk: >10%[58] • Management: NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric - PJS • Strength of evidence of association with cancer: Strong Other cancers • NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric - PJS
	Comments: Case-control studies have consistently demonstrated germline *STK11* PVs to be associated with high lifetime risks of pancreatic cancer. However, these variants are rare, and the risk estimates have wide confidence intervals.		
TP53	Primary breast cancer • Absolute risk: >60%[3,67-69] • Management: Li-Fraumeni Syndrome Management • Strength of evidence of association with cancer: Very strong[70] Contralateral breast cancer[j] • 10-year cumulative risk: 18-49%[37,69,71] • Strength of evidence of association with cancer: Strong	Evidence of increased risk: No established association	Pancreatic cancer • Absolute risk: ~5%[68] • Management: Screen P/LP variant carriers with a family history of pancreatic cancer, see PANC-A. • Strength of evidence of association with cancer: Limited Other cancers[n] • Classical LFS spectrum cancers (in addition to breast): soft tissue sarcoma, osteosarcoma, CNS tumor, ACC • Many other cancers have been associated with LFS, especially melanoma, colorectal, gastric, and prostate. • Li-Fraumeni Syndrome Management
	Comment: See Discussion for information on hypomorphic variants.		

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Note: All recommendations are category 2A unless otherwise indicated.

FOOTNOTES FOR GENE TABLES

[a] The following genes and others are found on some of the panels, but there is insufficient evidence to make any recommendations for breast MRI, RRSO, or RRM for: *FANCC*, *MRE11*, *MUTYH* heterozygotes, *NBN*, *RAD50, RECQL*, *RINT1*, *SLX4*, *SMARCA4*, or *XRCC2*. There is emerging evidence of an increased risk for breast cancer for *NTHL1* biallelic P/LP variant carriers (Weatherill CB, et al. Clin Genet 2023;103:231-235; Grolleman JE, et al. Cancer Cell 2019;35:256-266; Salo-Mullen EE, et al. JCO Precis Oncol 2021;5; Beck SH, et al. Fam Cancer 2022;21:453-462); however, there are not yet enough data to support increased breast cancer surveillance. There is emerging evidence of an increased risk for breast cancer for *RAD51B* P/LP variant carriers (Setton J, et al. NPJ Breast Cancer 2021;7:135) and breast screening may be considered.

[b] Screening and risk-reduction management for breast and ovarian cancer is extrapolated from *BRCA1/2* data based on risk levels.

[c] May be modified based on family history (typically beginning screening 5–10 years earlier than the youngest diagnosis in the family but not later than stated in the table) or specific gene P/LP variant.

[d] For patients with P/LP variants who are treated for breast cancer and have not had bilateral mastectomy, screening should continue as described.

[e] The use of MRI in these patients depends on a number of risk factors, including family history, age, breast density, and patient preference.

[f] Breast awareness starting at age 18 years. Clinical breast exam, every 6–12 months, starting at age 25 years or 5–10 years before the earliest known breast cancer in the family (whichever comes first). Age >75 years, management should be considered on an individual basis.

[g] This estimate is based on <10 events, with wide confidence intervals; therefore, additional studies are needed to confirm and refine this estimate.

[h] The higher range of risk is reflective of a prospective study of pancreatic cancer kindreds (Hsu FC, et al. JAMA Oncol 2021;7:1664-1668).

[i] The risk of metachronous CBC in women >65 years of age with pathogenic variants in *BRCA1/2, CHEK2*, and *PALB2* appears similar to non-carriers (Yadav S, et al. J Clin Oncol 2023;41:1703-1713).

[j] Risk varies depending on age at diagnosis of first breast cancer, ER status, and/or family history. See Discussion.

[k] Risks and benefits of premature surgical menopause versus risk of cancer and family history should all be carefully considered, and the Panel recommends patients seek expert care.

[l] For *CHEK2* carriers, the risk of CBC is higher if the primary breast cancer was ER-positive (Yadav S, et al. J Clin Oncol 2023;41:1703-1713; Hanson H, et al. Genet Med 2023;25:100870).

[m] For *PALB2* carriers, the risk of CBC is not significantly elevated except if the primary breast cancer was ER-negative (Yadav S, et al. J Clin Oncol 2023;41:1703-1713).

[n] For risk associated with other LFS-associated cancers, see de Andrade KC, et al. Lancet Oncol 2021;22:1787-1798.

Strength of Evidence of Association with Cancer	**Population risk (per SEER registry data)**
• **Very strong:** Prospective cohort studies in a population-based setting have demonstrated risk. • **Strong:** Traditional case-control studies or more than three case-control studies including those with cases ascertained by commercial laboratories or those without controls from the same population. Traditional case-control study: A retrospective study that compares patients with a disease or specific outcome (cases) with patients without the disease or outcome (controls). • **Limited:** Small sample size or case series • **None**	• **Breast cancer: 12%–13%** • **Ovarian cancer: 1%–2%** • **Pancreatic cancer: 1%–2%**

Note: All recommendations are category 2A unless otherwise indicated.

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Note: All recommendations are category 2A unless otherwise indicated.

AUTOSOMAL RECESSIVE RISK IN CANCER GENES – MULTIGENE PANEL TESTING

- **Biallelic P/LP variants in some genes, included on gene panels, may be associated with rare autosomal recessive conditions, such as FA or CMMRD. For these genes, consideration should be given to carrier testing the partner for P/LP variants in the same gene if it would inform reproductive decision-making and/or risk assessment and management.**

GENE and CONDITION	DESCRIPTION
ATM **–** Ataxia-Telangiectasia (AT)	**AT is characterized by progressive cerebellar ataxia, telangiectasias, immune defects, and a predisposition to malignancy. Cells of individuals with AT are abnormally sensitive to ionizing radiation and resistant to inhibition of DNA synthesis by ionizing radiation.**
BRCA1 **–** Fanconi anemia complementation group S (FANCS)	**There are rare reports of compound heterozygous or biallelic *BRCA1* P/LP variants causing FANCS. FANCS is characterized by developmental delay apparent from infancy, short stature, microcephaly, and coarse dysmorphic features. It is associated with defective DNA repair and increased chromosomal breakage.**
BRCA2 **–** Fanconi anemia complementation group D1	**FA is characterized by developmental abnormalities in major organ systems, early-onset bone marrow failure, and a high predisposition to cancer. Bone marrow failure with pancytopenia often presents in the first decade of life. Adults with biallelic *BRCA2* (one allele hypomorphic) are reported. Biallelic PVs in *BRCA2* are associated with early-onset acute leukemia and solid tumors.**
BRIP1 **–** Fanconi anemia complementation group J (FANCJ)	**FA is characterized by developmental abnormalities in major organ systems, early-onset bone marrow failure, and a high predisposition to cancer. Bone marrow failure with pancytopenia often presents in the first decade of life.**
MLH1**,** ***MSH2*****,** ***MSH6*****,** ***PMS2*****,** ***EPCAM*** **–** CMMRD	**CMMRD is a childhood cancer predisposition syndrome characterized by hematologic malignancies, brain/CNS tumors, colorectal tumors and multiple intestinal polyps, and other malignancies including embryonic tumors and rhabdomyosarcoma.**
PALB2 **–** Fanconi anemia complementation group N (FANCN)	**FA is characterized by developmental abnormalities in major organ systems, early-onset bone marrow failure, and an increased lifetime risk of cancer. Bone marrow failure with pancytopenia often presents in the first decade of life. Biallelic PVs in *PALB2* are associated with solid tumors, such as medulloblastomas and Wilms tumors.**
RAD51C **–** Fanconi anemia complementation group O	**FA is characterized by developmental abnormalities in major organ systems, early-onset bone marrow failure, and a high predisposition to cancer. Bone marrow failure with pancytopenia often presents in the first decade of life.**

Note: All recommendations are category 2A unless otherwise indicated.

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NCCN Guidelines Version 1.2025
BRCA-Pathogenic/Likely Pathogenic Variant - Positive Management

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Discussion

BRCA PATHOGENIC/LIKELY PATHOGENIC VARIANT-POSITIVE MANAGEMENT

Site	Screening/Surveillance Procedure and Interval
General	• Education regarding signs and symptoms of cancer(s), especially those associated with *BRCA* P/LP variants.
Breast cancer (female)	• Breast awareness[a] starting at age 18 years. • Clinical breast exam, every 6–12 months,[b] starting at age 25 years. • Breast screening[c,d] ▸ Age 25–29 years, annual breast MRI[e] screening with and without contrast[f] (or mammogram, only if MRI is unavailable) or individualized based on family history if a breast cancer diagnosis before age 30 is present. ▸ Age 30–75 years, annual mammogram and breast MRI[e] screening with and without contrast. ▸ Age >75 years, management should be considered on an individual basis. ▸ For individuals with a *BRCA* P/LP variant who are treated for breast cancer and have not had a bilateral mastectomy, screening with annual mammogram and breast MRI should continue as described above. ▸ Discuss option of RRM ◊ Counseling should include a discussion regarding degree of protection, reconstruction options, and risks. In addition, the family history and residual breast cancer risk with age and life expectancy should be considered during counseling. – Address psychosocial and quality-of-life aspects of undergoing RRM. • Consider risk reduction agents as options for breast cancer, including discussion of risks and benefits (see Discussion for details). (NCCN Guidelines for Breast Cancer Risk Reduction).
Breast cancer (male)	• Breast self-exam training and education starting at age 35 years. • Clinical breast exam, every 12 months, starting at age 35 years. • Consider annual mammogram, especially for those with *BRCA2* P/LP variants in whom the lifetime risk of breast cancer is up to 7%, starting at age 50 or 10 years before the earliest known male breast cancer in the family (whichever comes first).[g,h]

[a] Females should be familiar with their breasts and promptly report changes to their health care provider. Periodic, consistent breast self examination (BSE) may facilitate breast self awareness. Premenopausal individuals may find BSE most informative when performed at the end of menses.

[b] Randomized trials comparing clinical breast exam versus no screening have not been performed. Rationale for recommending clinical breast exam every 6–12 mo is the concern for interval breast cancers.

[c] The appropriateness of imaging modalities and scheduling is still under study. Lowry KP, et al. Cancer 2012;118:2021-2030.

[d] Lehman CD, et al. J Natl Cancer Inst 2016;108.

[e] The criteria for high-quality breast MRI include a dedicated breast coil, the ability to perform biopsy under MRI guidance, radiologists experienced in breast MRI, and regional availability. Breast MRI is preferably performed on days 7–15 of a menstrual cycle for premenopausal patients. FDA Drug Safety Communication: FDA identifies no harmful effects to date with brain retention of gadolinium-based contrast agents for MRIs; review to continue.

[f] Breast MRI is preferred due to the theoretical risk of radiation exposure in P/LP variant carriers.

[g] Because of lack of screening, males diagnosed with breast cancer have historically presented with advanced stage disease. There are limited data describing the performance of breast screening for males at inherited risk; however, recent studies suggest that the detection rate is similar or better than for females at population risk. Gao Y, et al. Radiology 2019;293:282-291; Li S, et al. J Clin Oncol 2022;40:1529-1541.

[h] In males, breast cancer risk in *BRCA1* carriers is lower than that in *BRCA2* carriers.

Note: All recommendations are category 2A unless otherwise indicated.

Continued

BRCA PATHOGENIC/LIKELY PATHOGENIC VARIANT-POSITIVE MANAGEMENT

Site		
Ovarian/ Fallopian Tube/ Peritoneal/ Uterine Cancers	• Counseling includes a discussion of reproductive options, extent of cancer risk balanced with cancer worry; degree of protection for breast, ovarian and uterine cancer; management of menopausal symptoms; hormone replacement therapy (HRT); and related medical or surgical history. • Considerations for salpingectomy with delayed oophorectomy, BSO, or non-surgical risk reduction strategies can apply to moderate-penetrance genes as well, with attention to age-related cancer risk of the known PV and family history.	
	Reproductive considerations in premenopausal women	• If desired, refer to fertility specialists for discussion of age-related fertility considerations, options for in vitro fertilization, egg- and embryo-cryopreservation, and consideration of preimplantation genetic testing, gestational carrier, and adoption. • If eggs/embryos are cryopreserved, pregnancy may be achieved with uterus in place, with or without fallopian tubes or ovaries. • Individuals with P/LP *BRCA1* variant may have earlier menopause and oocyte aging.[1,2]
	Non-surgical risk reduction	• Consultation with gynecologic oncologist or gynecologist with expertise/experience in genetic susceptibility to gynecologic cancer recommended. • Consideration of combination estrogen/progestin (E/P) contraception (such as oral contraceptive pills [OCP]) for ovulation suppression. Overall, studies in P/LP variant carriers support significant risk reduction benefits for ovarian cancer.[3,4,5] See Discussion for risk/benefits of OCP. • Levonorgestrel intrauterine device (LNG-IUD) has been shown to reduce risk for ovarian cancer in the average-risk population.[6,7]
	Surgical risk reduction with bilateral salpingo-oophorectomy	• Based on age-related risks of ovarian/fallopian tube cancer: ▸ *BRCA1*: Recommend RRSO between 35 and 40 years. ▸ *BRCA2*: Because ovarian cancer onset in patients with *BRCA2* P/LP variants is an average of 8–10 years later than in patients with *BRCA1* P/LP variants,[8] it is reasonable to delay RRSO for management of ovarian cancer risk until age 40–45 years in patients with *BRCA2* P/LP variants unless age at diagnosis in the family warrants earlier age for consideration of prophylactic surgery. • CA-125 and pelvic ultrasound are recommended for preoperative planning. • See Risk-Reducing Salpingo-Oophorectomy (RRSO) Protocol in NCCN Guidelines for Ovarian Cancer - Principles of Surgery. Appropriate surgical and pathologic expertise is strongly recommended. SEE-FIM (Sectioning and Extensively Examining the Fimbriated End) protocol for pathologic assessment and pelvic washings should be performed. • If serous tubal intraepithelial carcinoma (STIC lesion) is found, further consultation with a gynecologist oncologist is recommended. • In addition, in premenopausal individuals, oophorectomy likely reduces the risk of developing breast cancer but the magnitude is uncertain and may be gene-specific. • Address bone health, cardiovascular health, psychosocial health, neurologic health, sexual health, and generalized quality-of-life aspects of undergoing RRSO. Consider preoperative menopause management consultation if patient is still premenopausal at time of RRSO.[9,10] • HRT is generally not contraindicated and thus should be discussed with premenopausal patients who do not have a personal history of breast cancer.[11,12]

Note: All recommendations are category 2A unless otherwise indicated.

References on BRCA-A 5 of 5

Continued

BRCA PATHOGENIC/LIKELY PATHOGENIC VARIANT-POSITIVE MANAGEMENT

Site		
Ovarian/ Fallopian Tube/ Peritoneal/ Uterine Cancers	Salpingectomy	• Salpingectomy reduces the risk of ovarian cancer in the general population and is an option for premenopausal patients with hereditary cancer risk who are not yet ready for oophorectomy.[13,14,15,16] • Completion oophorectomy is recommended as per gene-specific guidelines. • SEE-FIM protocol for pathologic assessment and pelvic washings should be performed at salpingectomy or completion oophorectomy. • CA-125 and pelvic ultrasound are recommended for preoperative planning. • Clinical trials of interval salpingectomy and delayed oophorectomy are ongoing. Strong consideration of surgical choice study participation if available[i] • Consider continuation of combination OCP or hormonal IUD for continued ovarian cancer risk reduction while ovaries remain in place. • Salpingectomy is also an option for average or uncertain risk patients if they also desire surgical sterilization.
	Considerations for hysterectomy	• Limited data suggest that there may be a slightly increased risk of serous uterine cancer among individuals with a *BRCA1/2* P/LP variant. The clinical significance of these findings is unclear. Further evaluation of the risk of serous uterine cancer in the *BRCA* population is ongoing. The provider and patient should discuss the risks and benefits of concurrent hysterectomy at the time of RRSO for individuals with a *BRCA1/2* P/LP variant prior to surgery.[17] • Individuals who undergo hysterectomy at the time of RRSO are candidates for estrogen-alone HRT, which is associated with a decreased risk of breast cancer compared to combined estrogen and progesterone, which would be required when the uterus is left in situ[11,18,19] • Risk of pelvic floor dysfunction or urinary incontinence after hysterectomy is influenced by factors other than hysterectomy alone; if no preceding pelvic organ prolapse, long-term follow up studies indicate risks are <5%.[20,21]
	Hormone replacement options after risk-reducing surgery	• In conjunction with a gynecologist or other qualified health care professional with expertise in menopause management: ▸ HRT recommendations should be tailored depending on each patient's personal history of breast cancer and/or breast cancer risk reduction strategies. ▸ HRT is an important consideration for premenopausal patients who do not carry a diagnosis of breast cancer or do not have other contraindications for HRT. ▸ Premature menopause due to RRSO can cause detriments to bone health, cardiovascular health, psychosocial health, neurologic health, sexual health, and generalized quality-of-life. HRT can reduce these risks. • If uterus is left in place at time of RRSO, consider options for hormone replacement ▸ LNG-IUD for uterine protection with oral or transdermal estrogen. LNG-IUD may have benefits over combined HRT including potential decreased risk for breast cancer.[22] ▸ Combination E/P HRT with counseling regarding bleeding precautions and endometrial cancer risk/awareness. ▸ Combination estrogen with selective estrogen receptor modulator (such as bazedoxifene)[23] ▸ Combination OCPs which can be taken continuously without placebo week

[i] Clinical trials are in progress. See Discussion.

Note: All recommendations are category 2A unless otherwise indicated.

References on BRCA-A 5 of 5 Continued

BRCA PATHOGENIC/LIKELY PATHOGENIC VARIANT-POSITIVE MANAGEMENT

Site	Screening/Surveillance Procedure and Interval
Pancreatic cancer	• For pancreatic cancer screening recommendations, see PANC-A.
Prostate cancer	• Starting at age 40 years: (Guidelines for Prostate Cancer Early Detection) ▸ Recommend prostate cancer screening for *BRCA2* carriers. ▸ Consider prostate cancer screening for *BRCA1* carriers.
Melanoma	• No specific screening guidelines exist for melanoma, but general melanoma risk management is appropriate, such as annual full-body skin examination and minimizing ultraviolet (UV) exposure.
Risk to relatives	• Principles of Cancer Risk Assessment and Counseling (EVAL-A)
Reproductive options	• Principles of Cancer Risk Assessment and Counseling (EVAL-A)

Note: All recommendations are category 2A unless otherwise indicated.

BRCA PATHOGENIC/LIKELY PATHOGENIC VARIANT-POSITIVE MANAGEMENT

Ovarian/Fallopian Tube/Peritoneal/Uterine Cancers References

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Note: All recommendations are category 2A unless otherwise indicated.

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NCCN Guidelines Version 1.2025
Pancreatic Cancer Screening

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Discussion

PANCREATIC CANCER SCREENING

- **Emerging data have examined the efficacy of pancreatic cancer screening in select individuals at increased risk for exocrine pancreatic cancer. To date, most such studies have restricted pancreatic cancer screening to individuals with:**
  1. **A known P/LP germline variant in a pancreatic cancer susceptibility gene (*ATM, BRCA1, BRCA2, CDKN2A, MLH1, MSH2, MSH6, EPCAM, PALB2, STK11,* and *TP53*; see GENE-A) and a family history of pancreatic cancer (first-degree or second-degree relative) from the same side of the family as the germline P/LP variant; or**
  2. **A family history of exocrine pancreatic cancer in ≥1 first-degree and ≥1 second-degree relatives from the same side of the family, even in the absence of a known P/LP germline variant; or**
  3. **Some groups have recommended pancreas surveillance for P/LP variant carriers in the absence of a family history.**

- **For individuals considering pancreatic cancer screening, the Panel recommends that screening be performed in experienced high-volume centers. The Panel recommends that such screening only take place after an in-depth discussion about the potential limitations to screening, including cost, the high incidence of benign or indeterminate pancreatic abnormalities, and uncertainties about the potential benefits of pancreatic cancer screening.**
- **Consider screening using annual contrast-enhanced MRI/magnetic resonance cholangiopancreatography (MRCP) and/or endoscopic ultrasound (EUS), with consideration of shorter screening intervals, based on clinical judgment, for individuals found to have potentially concerning abnormalities on screening. Studies have typically started screening with contrast-enhanced MRCP and/or EUS in individuals at increased risk for pancreatic cancer. The Panel emphasizes that most small cystic lesions found on screening will not warrant biopsy, surgical resection, or any other intervention.**

Consider pancreatic cancer screening (preferably in the setting of a longitudinal study) for the following:	
• Individuals with P/LP germline variants in *STK11*	• Beginning at age 30–35 years (or 10 years younger than the earliest exocrine pancreatic cancer diagnosis in the family, whichever is earlier).
• Individuals with P/LP germline variants in *CDKN2A*	• Beginning at age 40 years (or 10 years younger than the earliest exocrine pancreatic cancer diagnosis in the family, whichever is earlier).
• Individuals with P/LP germline variants in *ATM* or *BRCA2*	• Beginning at age 50 years (or 10 years younger than the earliest exocrine pancreatic cancer diagnosis in the family, whichever is earlier).
• Individuals with P/LP germline variants in one of the other pancreatic cancer susceptibility genes (*BRCA1, MLH1, MSH2, MSH6, EPCAM, PALB2, TP53*)	• GENE-A ▸ Beginning at age 50 years (or 10 years younger than the earliest exocrine pancreatic cancer diagnosis in the family, whichever is earlier) for individuals with exocrine pancreatic cancer in ≥1 first- or second-degree relatives from the same side of (or presumed to be from the same side of) the family as the identified P/LP germline variant.[a] ▸ The Panel does not currently recommend pancreatic cancer screening for carriers of P/LP variants in genes other than *ATM, BRCA2, STK11,* and *CDKN2A* in the absence of a close family history of exocrine pancreatic cancer.

[a] Abe T, et al. J Clin Oncol 2019;37:1070-1080.

Note: All recommendations are category 2A unless otherwise indicated.

Continued

PANCREATIC CANCER SCREENING

Hereditary Pancreatitis Genes

- **For individuals with P/LP variants in *PRSS1* or other hereditary pancreatitis genes AND a clinical phenotype consistent with hereditary pancreatitis[b]**
  - **Consider pancreatic cancer screening 20 years after onset of pancreatitis, or at age 40 years, whichever is earlier.**

[b] The Panel recognizes that patients with hereditary pancreatitis (sometimes caused by pathogenic germline variants in *PRSS1*, *SPINK1*, and other genes) have increased lifetime risks of pancreatic cancer. The clinical significance of pathogenic germline variants in these genes is unclear, when such variants are identified in individuals lacking a clinical history of pancreatitis. As such, the Panel recommends germline testing for *PRSS1*, *SPINK1*, and other pancreatitis genes in individuals with a personal and/or family history of exocrine pancreatic cancer only if there is a personal and/or family history suggestive of hereditary pancreatitis.

Note: All recommendations are category 2A unless otherwise indicated.

LI-FRAUMENI SYNDROME

Establishing a Diagnosis and Management Plan for Patients with a P/LP *TP53* Variant Found on Germline Genetic Testing

Introduction

- **The presence of a *TP53* P/LP variant on a germline genetic test may indicate a diagnosis of LFS. However, it is important to recognize that somatic *TP53* variants frequently confound germline testing results, especially when testing is performed in older adults and/or patients with cancer.**
- **Late post-zygotic aberrant clonal expansions containing a *TP53* P/LP variant, limited to the hematologic compartment or to a tumor, may be detected in the blood or saliva through germline testing, particularly using NGS technology. The phenomenon of aberrant clonal expansion is well described and is most often due to CHIP, which can be demonstrated in healthy populations at increasing frequency with increasing age. If CHIP is misinterpreted as LFS, unwarranted clinical interventions may be advised (eg, LFS screening and prevention). Further, the finding of CHIP itself may portend adverse clinical outcomes, such as an increased risk of future development of hematologic neoplasia and increased non-hematologic mortality.**
- **Careful examination of the patient's complete blood count (CBC) and peripheral blood smear may be warranted in all cases reporting the discovery of a *TP53* P/LP variant, and testing of non-hematopoietic ancillary tissues and/or offspring may help to delineate bona fide mosaic involvement of different germ layers or other diagnoses (see Table 1).**

Considerations Prior to Providing an LFS Diagnosis in a Patient Found to Have a *TP53* P/LP Variant on a Germline Genetic Test

- **Does the personal and/or family history meet LFS criteria (CRIT-7)?**
  - **Yes: Review Tissue Source Considerations and Test Metrics; and if no concerns, provide LFS diagnosis and manage accordingly; see LIFR-A 4 of 6 if LFS diagnosis**
  - **No: Review Tissue Source Considerations and Test Metrics; Consider testing of additional tissue sources and/or close relatives to delineate among possibilities in Table 1.**

Continued

Note: All recommendations are category 2A unless otherwise indicated.

LI-FRAUMENI SYNDROME: ADULT SURVEILLANCE

Tissue Source Considerations: Was the tissue source used for germline genetic testing a reliable germline tissue for the patient?

- **Blood and/or saliva**
  - **Personal history of a hematologic malignancy with active blood involvement and/or prior allogeneic hematopoietic cell transplantation: Blood and/or saliva is an unsuitable source of DNA for germline testing for these patients. DNA from cultured skin fibroblasts, hair follicles, or other non-hematopoietic origin tissue(s) is required to confirm germline origin. Blood or saliva may be used for germline genetic testing in patients with a prior or well-controlled hematologic malignancy and no evidence of active disease.**
  - **Personal history of CBC abnormalities at the time of sample collection: Peripheral blood smear review and evaluation by a hematologist is warranted to rule out an undiagnosed hematologic disorder, such as clonal cytopenia of undetermined significance or overt hematologic neoplasm. Testing of cultured skin fibroblasts, hair follicles, or other non-hematopoietic origin tissue(s) or offspring may be warranted to delineate the diagnosis (see Table 1).**
  - **Age >60 and/or history of cytotoxic therapy prior to sample collection: These patients are at increased risk for clonal hematopoiesis and hematologic malignancies. Examination of the CBC is warranted to rule out an undiagnosed hematologic disorder. Referral to a hematologist for peripheral blood smear review and evaluation may be appropriate. Testing of cultured skin fibroblasts, hair follicles, or other non-hematopoietic origin tissue(s) or offspring may be warranted to delineate the diagnosis (see Table 1).**

Test Metrics: Is the *TP53* variant allele fraction <30% and/or are there other abnormal test metrics/results that raise the possibility of somatic interference (eg, multiple other mosaic variants or deletion/duplications)?

- **Tissue source:**
  - **Blood or saliva: Rule out a tissue source issue per "Tissue Source Considerations"**
  - **Cultured skin fibroblasts: A low variant allele fraction variant in this tissue source can be due to:**
    - ◊ **Somatic variant acquired during the culturing process**
    - ◊ **Somatic variant previously acquired in only a subset of the skin cells sampled (eg, from prior sun exposure)**
    - ◊ **Multi-tissue post-zygotic mosaicism (see Table 1, Mosaic LFS)**
    - ◊ **Technical issues (see below)**
- **Tumor somatic interference:**
  - **Somatic *TP53* variants restricted to a tumor can be detected in the peripheral blood or saliva on a germline test due to blood/saliva contamination with ctDNA and/or circulating tumor cells. Patients with a high volume of tumor burden, especially metastatic disease, and/or tumors involving the blood (eg, hematologic neoplasms, especially acute leukemias, myelodysplastic syndrome, and chronic lymphocytic leukemia) are at higher risk for tumor somatic interference. DNA from cultured skin fibroblasts, hair follicles, or other non-hematopoietic origin/non-tumor contaminated tissue(s) is required to confirm germline origin.**
- **Technical limitations:**
  - **Standard NGS tests utilized by most commercial germline genetic testing companies are not quantitative. Thus, a VAF <30% can be due to technical issues such as differences in the efficiency of capture or sequencing of the normal versus variant-containing allele. Testing by an orthogonal method (eg, Sanger sequencing for single nucleotide variants [SNVs] or microarray for copy number variants [CNVs]) may help clarify this possibility.**
- **When a *TP53* PV is identified for the first time in a family at an allele frequency near 50% suggesting it was present at the time of fertilization, testing for the variant should be performed on the patient's siblings and parents to determine if this was de novo or inherited. Particularly when the proband is a pediatric patient, the parents may not have developed cancer and family history alone may not be sufficient to distinguish between de novo or inherited variants. Germ cell mosaicism has been reported as a cause of LFS in siblings. Even if parents test negative for the variant, all children and future children should be tested due the possibility of recurrence due to germ cell mosaicism.**

Continued

Note: All recommendations are category 2A unless otherwise indicated.

LI-FRAUMENI SYNDROME: ADULT SURVEILLANCE

Table 1: Workup and Management Depending on Etiology of *TP53* Mutation Found on Genetic Testing[a]

	Blood or Saliva (VAF)	Fibroblast (VAF)[b]	Tumor (VAF)[b]	Parent Testing[c]	Offspring Testing[c]	Management
All/Majority of body tissues involved						
Li Fraumeni syndrome spectrum – inherited	Positive (40%–60%)	Positive (40%–60%)	Positive (0%–100%)	One parent positive	50% risk	LFS
Li Fraumeni syndrome spectrum – *de novo*[d]	Positive (40%–60%)	Positive (40%–60%)	Positive (0%–100%)	Both parents negative	50% risk[d]	LFS
Multiple body tissues involved (post-zygotic mosaicism)						
Multi-tissue, confirmed constitutional post-zygotic mosaicism	Positive in more than one tissue (>1%–100%)			Both parents negative	Negative or 50% risk (if gonadal mosaic)	LFS[e] Strongly consider consultation with LFS expert regarding management
***TP53* mutation origin in blood disorder or cancer cells only**						
Blood only hematologic neoplasm or precursor condition	Positive (>1%–100%)	Negative	Positive (>1%–100%)	Both parents negative	Negative	Hematologic workup and treatment
Tumor only somatic interference from tumor (ctDNA or circulating tumor cells in blood/saliva)	Positive (>1%–100%) in setting of widely metastatic/ advanced cancer	Negative	Positive (>1%–100%)	Both parents negative	Negative	Cancer treatment
***TP53* mutation origin uncertain[a]**						
Unclear etiology (clonal hematopoieisis vs. constitutional post-zygotic mosaicism unable to be determined)	Positive (>1%–50%)	Negative	Positive or Negative (VAF solid tumor <VAF blood)	Both parents negative	Negative	Strongly consider consultation with LFS expert regarding workup and management

See footnotes on next page

Note: All recommendations are category 2A unless otherwise indicated.

LI-FRAUMENI SYNDROME: ADULT SURVEILLANCE

FOOTNOTES FOR TABLE 1

[a] Despite ancillary testing of multiple tissues and/or parental and/or offspring testing, it is sometimes not possible to determine to which of the above diagnostic categories a patient belongs. Management should be individualized based on available information. Consultation with experts in LFS diagnosis is strongly recommended.

[b] Testing of cultured skin fibroblasts, tumor, and/or other alternative tissues is recommended to aid in diagnostic clarity in all of these diagnostic categories if the personal and/or family history are not consistent with a diagnosis of LFS and/or if there are tissue source or test metric concerns as detailed in LIFR-A 2 of 6 (Castillo D, et al. Cancer Epidemiol Biomarkers Prev 2022;31:1621-1629; Schwartz AN, et al. JCO Precis Oncol 2021;5:1677-1686).

[c] Parental and offspring testing is recommended in all of these diagnostic categories to clarify the diagnosis and management of the patient and close relatives unless there is a clear alternative diagnosis (eg, the patient has an active hematologic neoplasm with blood involvement as the source of the *TP53* P/LP variant).

[d] Sibling testing should be performed in the case of presumed de novo LFS with negative parental testing given the possibility of gonadal mosaicism in one of the parents or non-paternity. Despite negative testing in ancillary tissues, consider LFS screening if the patient's personal cancer history may suggest a clinical diagnosis of LFS (LIFR-A 4 of 6).

[e] Management for mosaic LFS is per usual LFS management at this time (LIFR-A 4 of 6). Strongly consider consultation with an LFS expert for further workup and management recommendations.

Continued

Note: All recommendations are category 2A unless otherwise indicated.

LI-FRAUMENI SYNDROME: ADULT SURVEILLANCE

Site	Screening/Surveillance Procedure and Interval
Breast cancer (female)	• Breast awareness,[f] starting at age 18 y • Clinical breast exam, every 6–12 mo starting at age 20 y[g] • Breast screening ▸ Age 20–29[g] y, annual breast MRI[h] screening with and without contrast[i] ▸ Age 30–75 y, annual breast MRI[h] screening with and without contrast and mammogram ▸ Age >75 y, management should be considered on an individual basis ▸ For individuals with a *TP53* P/LP variant who are treated for breast cancer, and who have not had a bilateral mastectomy, screening with annual breast MRI and mammogram should continue as described above. • Discuss option of RRM ▸ Counseling should include a discussion regarding degree of protection, reconstruction options, and risks. In addition, the family history and residual breast cancer risk with age and life expectancy should be considered during counseling. • Address psychosocial and quality-of-life aspects of undergoing RRM.
Other cancer risks	• Comprehensive physical exam including neurologic examination with high index of suspicion for rare cancers and second malignancies in cancer survivors every 6–12 mo • Colonoscopy and upper endoscopy every 2–5 y starting at 25 y or 5 y before the earliest known colorectal or gastric cancer in the family, respectively. For patients who have received whole body or abdominal therapeutic RT, colonoscopy screening is recommended 5 y after treatment of disease. • Annual dermatologic examination starting at 18 y • Annual whole body MRI[j,k,l] • Annual brain MRI may be performed as part of the whole body MRI or as a separate exam. • Annual prostate-specific antigen (PSA) starting at age 40 y for prostate cancer early detection. • For pancreatic cancer screening recommendations, see PANC-A.

[f] Females should be familiar with their breasts and promptly report changes to their health care provider. Periodic, consistent BSE may facilitate breast self awareness. Premenopausal individuals may find BSE most informative when performed at the end of menses.

[g] Or at the age of the earliest diagnosed breast cancer in the family, if <20 y.

[h] The criteria for high-quality breast MRI include a dedicated breast coil, the ability to perform biopsy under MRI guidance, radiologists experienced in breast MRI, and regional availability. Breast MRI is preferably performed on days 7–15 of a menstrual cycle for premenopausal patients. FDA Drug Safety Communication: FDA identifies no harmful effects to date with brain retention of gadolinium-based contrast agents for MRIs; review to continue.

[i] Or mammogram, if MRI is unavailable. Breast MRI is preferred because of concerns regarding the risk of radiation exposure in P/LP variant carriers.

[j] Whole body MRI is not uniformly available. If whole body MRI is not available, then individuals with LFS are encouraged to participate in clinical trials or consider alternate comprehensive imaging methods. Other components of screening are being evaluated in protocols, including biochemical screening and regular blood screening for hematologic malignancies. FDA Drug Safety Communication: FDA identifies no harmful effects to date with brain retention of gadolinium-based contrast agents for MRIs; review to continue.

[k] Ballinger M, Best A, Mai P, et al. Baseline surveillance in Li-Fraumeni syndrome using whole-body magnetic resonance imaging: a meta-analysis. JAMA Oncol 2017;3:1634-1639.

[l] Screening through whole body MRI has been broadly demonstrated to be feasible and of potential utility in the early detection of cancer among classic LFS families, though it also results in the detection of false-positive findings and possible cancer overdiagnosis. Furthermore, screening utility has not been evaluated among those with a germline *TP53* P/LP variant without a classic family history of LFS, who are increasingly identified through multigene panel tests.

Continued

Note: All recommendations are category 2A unless otherwise indicated.

LI-FRAUMENI SYNDROME: ADULT SURVEILLANCE

	Screening/Surveillance Procedure and Interval
Other aspects of managing LFS	• The screening and management of LFS is complex, and LFS is rare; it is preferred that individuals with LFS be followed at centers with expertise in the management of this syndrome. • Because of the remarkable risk of additional primary neoplasms, screening should be considered for cancer survivors with LFS and a good prognosis from their prior tumor(s). • Address limitations of screening for many cancers associated with LFS. • Pediatricians should be apprised of the risk of childhood cancers in affected families and review screening recommendations for children with LFS.[m] • Therapeutic RT for cancer should be avoided when possible unless locoregional risk reduction or overall survival from RT is greater than the risk of downstream secondary malignancies; diagnostic radiation should be minimized to the extent feasible without sacrificing accuracy. ▸ For patients diagnosed with breast cancer, mastectomy is preferred over lumpectomy/radiation to reduce radiation-induced sarcoma risk. • Screening recommendations should take into account personal and family history of cancer (5–10 years before earliest diagnosis). Provide additional surveillance based on family history of cancer. • Provide education regarding signs and symptoms of cancer. • Address psychosocial and quality-of-life aspects of the complex management of LFS. • There is controversy over how to manage cancer risk in incidental *TP53* carriers who do not meet classic LFS criteria; some data suggest lower cancer risks in *TP53* P/LP carriers who do not have a family history consistent with LFS.
Reproductive options	• Principles of Cancer Risk Assessment and Counseling (EVAL-A)
Risk to relatives	• Principles of Cancer Risk Assessment and Counseling (EVAL-A)

Pediatric Surveillance (LIFR-A 6 of 6)

[m] For additional information on the management of children with LFS, see Kratz C, et al. Clin Cancer Res 2017;23:e38-e45.

Note: All recommendations are category 2A unless otherwise indicated.

Continued

LI-FRAUMENI SYNDROME: PEDIATRIC SURVEILLANCE

	Screening/Surveillance Procedure and Interval
Cancer risks	• Comprehensive physical exam including neurologic examination with high index of suspicion for rare cancers and second malignancies in cancer survivors every 6–12 mo beginning in infancy • Annual whole body MRI[j,k,l] beginning in infancy • Annual brain MRI may be performed as part of the whole body MRI or as a separate exam beginning in infancy • For ACC, ultrasound every 3–4 mo beginning in infancy

[j] Whole body MRI is not uniformly available. If whole body MRI is not available, then individuals with LFS are encouraged to participate in clinical trials or consider alternate comprehensive imaging methods. Other components of screening are being evaluated in protocols, including biochemical screening and regular blood screening for hematologic malignancies. FDA Drug Safety Communication: FDA identifies no harmful effects to date with brain retention of gadolinium-based contrast agents for MRIs; review to continue.

[k] Ballinger M, Best A, Mai P, et al. Baseline surveillance in Li-Fraumeni syndrome using whole-body magnetic resonance imaging: a meta-analysis. JAMA Oncol 2017;3:1634-1639.

[l] Screening through whole body MRI has been broadly demonstrated to be feasible and of potential utility in the early detection of cancer among classic LFS families, though it also results in the detection of false-positive findings and possible cancer overdiagnosis. Furthermore, screening utility has not been evaluated among those with a germline *TP53* P/LP variant without a classic family history of LFS, who are increasingly identified through multigene panel tests.

Note: All recommendations are category 2A unless otherwise indicated.

COWDEN SYNDROME (CS)/*PTEN* HAMARTOMA TUMOR SYNDROME (PHTS) MANAGEMENT

Site	Screening/Surveillance Procedure and Interval
General	• Due to the rarity of the syndrome and complexities of diagnosing and managing individuals with CS, referral to a specialized team or centers with expertise is recommended. • Annual comprehensive physical exam starting at age 18 y or 5 y before the youngest age of diagnosis of a component cancer in the family (whichever comes first), with particular attention to thyroid exam. • Education regarding the signs and symptoms of cancer.
Breast cancer (female)	• Breast awareness[a] starting at age 18 years. • Clinical breast exam, every 6–12 months, starting at age 25 years or 5–10 years before the earliest known breast cancer in the family (whichever comes first). • Breast screening ▸ Annual mammography and breast MRI screening with and without contrast starting at age 30 years or 10 years before the earliest known breast cancer in the family (whichever comes first).[b,c] ▸ Age >75 years, management should be considered on an individual basis. ▸ For individuals with a *PTEN* P/LP variant who are treated for breast cancer, and have not had a bilateral mastectomy, screening with annual mammogram and breast MRI should continue as described above. • Discuss option of RRM in individuals with P/LP variants identified. For those with clinical CS/PHTS syndrome, consideration of risk-reducing surgery should be based on family history. ▸ Counseling should include a discussion regarding degree of protection, reconstruction options, and risks. In addition, the family history and residual breast cancer risk with age and life expectancy should be considered during counseling. • Address psychosocial and quality-of-life aspects of undergoing RRM.
Colorectal cancer	• Colonoscopy, starting at age 35 y unless symptomatic or if close relative with colorectal cancer (CRC) before age 40 y, then start 5–10 y before the earliest known CRC in the family. Colonoscopy should be done every 5 y or more frequently if patient is symptomatic or polyps are found.

[a] Females should be familiar with their breasts and promptly report changes to their health care provider. Periodic, consistent BSE may facilitate breast self awareness. Premenopausal individuals may find BSE most informative when performed at the end of menses.
[b] The appropriateness of imaging modalities and scheduling is still under study.
[c] The criteria for high-quality breast MRI include a dedicated breast coil, the ability to perform biopsy under MRI guidance by experienced radiologists in breast MRI, and regional availability. Breast MRI is preferably performed on days 7–15 of a menstrual cycle for premenopausal females. FDA Drug Safety Communication: FDA identifies no harmful effects to date with brain retention of gadolinium-based contrast agents for MRIs; review to continue.

Continued

Note: All recommendations are category 2A unless otherwise indicated.

COWDEN SYNDROME (CS)/*PTEN* HAMARTOMA TUMOR SYNDROME (PHTS) MANAGEMENT

Site	Screening/Surveillance Procedure and Interval
Endometrial cancer	• For endometrial cancer screening,[d] consider starting by age 35 years. ▸ Encourage patient education and prompt response to symptoms (eg, abnormal bleeding). Patients are encouraged to keep a calendar in order to identify irregularities in their menstrual cycle. ▸ Because endometrial cancer can often be detected early based on symptoms, individuals should be educated regarding the importance of prompt reporting and evaluation of any abnormal uterine bleeding or postmenopausal bleeding. The evaluation of these symptoms should include endometrial biopsy. ▸ Endometrial cancer screening does not have proven benefit in individuals with CS/PHTS. However, endometrial biopsy is both highly sensitive and highly specific as a diagnostic procedure. Screening via endometrial biopsy every 1 to 2 years can be considered. ▸ Transvaginal ultrasound to screen for endometrial cancer in postmenopausal individuals has not been shown to be sufficiently sensitive or specific as to support a positive recommendation, but may be considered at the clinician's discretion. Transvaginal ultrasound is not recommended as a screening tool in premenopausal individuals due to the wide range of endometrial stripe thickness throughout the normal menstrual cycle. • Discuss option of hysterectomy[e] upon completion of childbearing and counsel regarding degree of protection, extent of cancer risk, and reproductive desires. Risk of ovarian cancer is not elevated; therefore, ovaries can be left in situ. • Address psychosocial and quality-of-life aspects of undergoing risk-reducing hysterectomy.
Kidney cancer	• Consider renal ultrasound starting at age 40 y, then every 1–2 y.
Neurologic	• Consider psychomotor assessment in children at diagnosis and brain MRI if there are symptoms.
Skin	• There may be an increased risk of melanoma, and the prevalence of other skin characteristics with CS/PTHS may independently make routine dermatology evaluations of value. Annual dermatology exams are recommended.
Thyroid	• Annual thyroid ultrasound starting at age 7 y. This may also be considered for children at 50% risk of inheriting a known P/LP variant whose parents wish to delay genetic testing until age 18 y.
Reproductive options	• Principles of Cancer Risk Assessment and Counseling (EVAL-A)
Risk to relatives	• Principles of Cancer Risk Assessment and Counseling (EVAL-A)

[d] There are limited data regarding the lifetime risk of endometrial cancer in CS/PHTS. Surveillance screening and surgical intervention should be on an individual basis.
[e] Oophorectomy is not indicated for CS/PHTS alone.

Note: All recommendations are category 2A unless otherwise indicated.

BREAST, OVARIAN, UTERINE, AND PROSTATE CANCER RISK REDUCTION STRATEGIES FOR TRANSGENDER, NON-BINARY, AND GENDER DIVERSE PEOPLE WITH HEREDITARY CANCER SYNDROMES

General

- The following section introduces special considerations for risk reduction strategies for individuals who are transgender, non-binary, and gender diverse and is anchored in the following principles:
  - The terms “transgender,” “non-binary,” and “gender diverse” include a wide variety of physical and psychological states referring to individuals whose gender identity differs from the biologic sex at birth (sometimes referred to as “sex assigned at birth”). Many of these individuals pursue gender-affirming hormonal and/or surgical treatments at some point in their lives, which may impact their cancer risks and risk reduction options.
  - Our focus is on hereditary increased cancer risks due to the presence of a germline P/LP in a cancer-related gene. These risks may be altered by gender-affirming treatments and should be considered in risk reduction strategies.
  - There are several variables associated with magnitude of cancer risk in transgender, non-binary, and gender diverse people who have a hereditary predisposition to cancer:
    - ◊ Status of decision regarding gender transition/affirmation
    - ◊ Age at transition/affirmation (can be a several-year process)
    - ◊ Use, dosage, and duration of gender-affirming hormones
    - ◊ Types of gender-affirming surgeries
    - ◊ Presence of additional traditional risk factors (eg, family history)
  - There are no prospective data on appropriate cancer risk reduction and/or screening options for transgender, non-binary, or gender diverse individuals who are at average or high risk, regardless of average risk or increased risk.
  - Recommendations for risk reduction must be made on a case-by-case basis depending on all of the variables involved.

Strategies for Risk Assessment and Care of Individuals Who Are Transgender, Non-binary, and Gender Diverse

- One way to approach risk reduction choices is to focus on those organs at risk based on biologic sex at birth.
  - Female organs at risk:
    - ◊ Ovaries/fallopian tubes
    - ◊ Uterus
    - ◊ Breasts
  - Male organs at risk:
    - ◊ Prostate
      Breasts

Continued

Note: All recommendations are category 2A unless otherwise indicated.

BREAST, OVARIAN, UTERINE, AND PROSTATE CANCER RISK REDUCTION STRATEGIES FOR TRANSGENDER, NON-BINARY, AND GENDER DIVERSE PEOPLE WITH HEREDITARY CANCER SYNDROMES

Ovarian Cancer: Risk Reduction Principles and Strategies

- There are several PVs associated with an increased risk for ovarian cancer, including *BRCA1, BRCA2, ATM, BRIP1, PALB2, RAD51C, RAD51D,* and LS genes.
- There is no known effective screening for ovarian cancer.
- It is not known what effect gender-affirming hormones have on ovarian or fallopian tube tissue.
- RRSO is recommended for individuals with one or both intact ovaries and fallopian tubes, as it is for cisgender women—see GENE-A for RRSO recommendations and age at the time of surgery for the specific PV found.
- RRSO may be a consideration at an earlier age than recommended to alleviate gender dysphoria in conjunction with appropriate health care professionals.
- Individuals considering RRSO before natural menopause should be counseled about the adverse events, including loss of fertility, menopausal symptoms, cardiovascular disease, and bone loss associated with premature menopause.
- There are no data on the effect of medical ovarian suppression on ovarian cancer risk.

Uterine Cancer: Risk Reduction Principles and Strategies

- There are several PVs associated with an increased risk for uterine cancer, including *PTEN* and LS genes.
- It is not known what effect gender-affirming testosterone therapy has on uterine tissue. However, as androgens are partially aromatized to estrogen, this may increase circulating estrogen levels and pose a risk to the uterus.
- Screening with transvaginal ultrasound with or without random endometrial biopsies is done in some settings but its benefit is unclear.
- Hysterectomy may be a consideration at an earlier age than recommended to alleviate gender dysphoria in conjunction with appropriate health care professionals. See GENE-A and NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal, Endometrial, and Gastric for PV-specific hysterectomy recommendations and recommended age at the time of surgery.
- All individuals with an intact uterus should be counseled about the early warning signs of uterine cancer.
- There are no data on the effect of medical ovarian suppression on uterine cancer risk.

Prostate Cancer: Risk Reduction Principles and Strategies

- There are several PVs associated with an increased risk for prostate cancer, including *BRCA1, BRCA2*, and possibly *ATM*.
- It is not known what effect gender-affirming estrogen or anti-androgens have on the risk of prostate cancer, although some studies have reported diffuse atrophy and basal cell hyperplasia in prostate tissue among individuals on hormone therapy. Theoretically these changes may make the prostate gland less prone to develop cancer, but there are no data to support this. Gender-affirming hormone therapy has also been shown to alter PSA levels, thus reducing their efficacy as a screening tool. The Panel still advises PSA screening as per the NCCN Guidelines for Prostate Cancer Early Detection.
- See GENE-A and NCCN Guidelines for Prostate Cancer for PV-specific screening recommendations.

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Note: All recommendations are category 2A unless otherwise indicated.

BREAST, OVARIAN, UTERINE, AND PROSTATE CANCER RISK REDUCTION STRATEGIES FOR TRANSGENDER, NON-BINARY, AND GENDER DIVERSE PEOPLE WITH HEREDITARY CANCER SYNDROMES

Breast Cancer: Risk Reduction Principles and Strategies:

- There are several PVs associated with an increased risk for breast cancer, including *BRCA1, BRCA2, ATM, BARD1, CDH1, CHEK2, NF1, PALB2, PTEN, RAD51C, RAD51D, STK11,* and *TP53*. Risk reducing strategies may differ by biologic sex at birth.
- Level of risk differs by gene and may guide risk reduction decisions (see GENE-A for more details).
- For transgender male and/or non-binary individuals with a P/LP in a breast cancer gene who have had reduction mammoplasty with retention of breast tissue, or no surgery, breast screening may begin at an earlier age and may include mammography and breast MRI. See GENE-A for gene-specific screening recommendations, including age to begin screening.

Female sex at birth

- It is unclear if the use of gender-affirming hormone therapy with testosterone alters the risk of breast cancer in individuals with a hereditary susceptibility to breast cancer, although long-term testosterone in cisgender females has been shown to reduce breast glandular tissue and increase connective tissue.
- Gender-affirming breast surgery, known as “top surgery,” typically involves reduction mammoplasty with retention of some breast tissue and the nipple areolar complex.
- Individuals with a known P/LP in a breast cancer gene may want to consider RRM in which >95% of the breast tissue is removed. Nipple-sparing surgery is thought to be safe in this setting. However, even with nipple sparing the aesthetic outcome may not be as good as top surgery where some breast tissue is retained. For individuals with a personal or family history consistent with a breast cancer P/LP, it is recommended that genetic testing be performed prior to breast surgery to inform the type of surgery. Individuals considering removal of all breast tissue should be referred to a plastic surgeon to discuss options for using tissue or implants to create a masculine profile if desired.
- For transgender male individuals with a P/LP in a breast cancer gene who have had reduction mammoplasty with retention of some breast tissue, or no breast surgery, breast cancer screening may begin at an earlier age and may include mammography and breast MRI. See GENE-A for gene-specific screening recommendations, including age to begin screening. This approach is also supported by the ACR guidelines.
- The term “breast cancer” may be associated with femininity; thus, the term “chest cancer,” instead of breast cancer, may be preferred in individuals who identify as men.

Male sex at birth

- Gender-affirming hormone therapy with estrogens and anti-androgens in transgender women increases breast tissue, which includes the formation of ducts, lobules, and acini, similar to that in cisgender women, and this should not be described as gynecomastia. Breast changes occur within 6 months after starting therapy and result in increased breast density. In situ and invasive breast cancers have been reported in this population. Anecdotally, these breast tumors tend to occur at an earlier age than the average population. Breast cancer risk in individuals who are biologically male at birth, even with breast cancer P/LP variants, is low, and while estrogen and anti-androgens may increase breast cancer risk, they are not contraindicated in individuals taking female-promoting (gender-affirming) hormones.
- While there are limited data on the benefit of radiographic screening of breast tissue with mammography and/or breast MRI in transgender women at increased hereditary risk who are taking gender-affirming hormone therapy, there are case reports of breast cancer detection in this setting and NCCN supports the rationale for breast cancer screening of cisgender males at increased hereditary risk. This area clearly represents a major research gap in the care of transgender women who have a hereditary risk for breast cancer. Taking into account that the risk for breast cancer has been shown to be elevated in transgender women compared to transgender men, breast screening modalities for transgender women at increased hereditary risk should be decided on a case-by-case basis, and may be based on age, family history, the duration of use of gender-affirming hormone therapy and/or the amount of breast tissue present; digital mammography and tomosynthesis rather than MRI is recommended by radiology guidelines. For those who have chosen implant reconstruction, MRI without contrast can be performed to assess implant integrity; however, this would not detect cancer.

Continued

Note: All recommendations are category 2A unless otherwise indicated.

BREAST, OVARIAN, UTERINE, AND PROSTATE CANCER RISK REDUCTION STRATEGIES FOR TRANSGENDER, NON-BINARY, AND GENDER DIVERSE PEOPLE WITH HEREDITARY CANCER SYNDROMES

Additional Considerations

- Transgender, non-binary, and gender diverse individuals encounter many challenges to health care, including stigmatization, denial of services, discrimination, abuse, and possible higher rates of mortality due to lack of access to appropriate preventive care.
- Individuals pursuing gender-affirming care should be followed at centers of excellence with access to a multidisciplinary team that understands their unique needs and provides a safe and welcoming environment. The team should include surgeons, primary care specialists, oncologists, radiologists, pathologists, endocrinologists, pediatricians, psychologists, genetic counselors, and social workers, all of whom are trained in the appropriate care of the transgender population and can address medical, psychologic, and social care needs.
- There is a need for formal education in the care of transgender, non-binary, and gender diverse individuals at every level of the health care system, with a particular focus in breast/chest cancer screening.
- There is a need for research regarding the impact of gender-affirming hormones and puberty-blocking agents and how they interact with hereditary susceptibility to cancer syndromes as well as optimal prevention strategies for these populations.
- Most electronic health data, including SEER data, census data, and even EMRs do not incorporate gender identity, thus hindering the collection of health data in these populations and denying appropriate screening invitations to these individuals.
- A National Registry on the health outcomes of transgender, non-binary, and gender diverse populations is needed to fill the many gaps in the magnitude and management of risks associated with gender-affirming treatment in the setting of hereditary cancer susceptibilities.
- As in all research involving human participants, care must be taken to preserve the privacy and protection of this population.

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Note: All recommendations are category 2A unless otherwise indicated.

Summary of Genes and/or Syndromes Included/Mentioned in Other NCCN Guidelines

NCCN Guideline	Specific Sections Included in Table of Contents or Text	Genes and/or Syndromes Included/Mentioned in Guideline
Treatment Guidelines		
Acute Lymphocytic Leukemia (ALL)	Familial Genetic Alterations in ALL	*RUNX1, ETV6, PAX5, IKZF1, TP53*
Acute Myeloid Leukemia (AML)	Refer to MDS on next page	*RUNX1*, *ANKRD26*, *CEBPA*, *DDX41*, *ETV6*, *GATA2*, *MBD4*, *MECOM/EVI1* complex, *SAMD9/SAMD9L*, *TERC/TERT*, *ATG2B/GSKIP*
Basal Cell Skin Cancer	Principles of Cancer Risk Assessment and Counseling	Gorlin syndrome (*PTCH1*), xeroderma pigmentosa
Biliary Tract Cancers	Principles of Molecular Testing	Evidence remains insufficient for definitive recommendations regarding specific criteria to guide genetic risk assessment in hepatobiliary cancers or for universal germline testing in these tumors
Bladder Cancer Urothelial cancer (including renal pelvis and ureter)	Clinical Presentation and Initial Evaluation Urothelial Carcinoma of the Ureter	Lynch syndrome (LS)
Breast Cancer		Refers to Genetic/Familial: BOP (Breast, Ovarian, Pancreatic) Guidelines
Central Nervous System Cancers	Cancer Risk Assessment and Counseling	*TP53* (Li-Fraumeni syndrome [LFS]), LS, familial adenomatous polyposis (FAP); refers to Genetic/Familial: BOP (Breast, Ovarian, Pancreatic) Guidelines and Genetic/Familial: Colorectal, Endometrial, and Gastric Guidelines
Colon Cancer	Principles of Pathologic and Molecular Review	Refers to Genetic/Familial: Colorectal, Endometrial, and Gastric Guidelines
Esophageal and Esophagogastric Junction (EGJ) Cancers	Principles of Genetic Risk Assessment for Esophageal and Esophagogastric Junction (EGJ) Cancers	*RHBDF2*; Bloom syndrome (BS)/*BLM*, *RECQL3*; Fanconi anemia (FA)/*FANCD1*, *BRCA2*, *PALB2*
Gastric Cancer		Refers to Genetic/Familial: Colorectal, Endometrial, and Gastric Guidelines
Gastrointestinal Stromal Tumors (GIST)	Principles of Mutation Testing	*KIT*, *PDGFRA*, *SDHB*, *NF1*

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Summary of Genes and/or Syndromes Included/Mentioned in Other NCCN Guidelines

NCCN Guideline	Specific Sections Included in Table of Contents or Text	Genes and/or Syndromes Included/Mentioned
Treatment Guidelines (Continued)		
Hepatocellular Cancers	Principles of Molecular Testing	Evidence remains insufficient for definitive recommendations regarding specific criteria to guide genetic risk assessment in hepatobiliary cancers or for universal germline testing in these tumors
Kidney Cancer	Hereditary Renal Cell Carcinoma section	von Hippel-Lindau (VHL) syndrome; hereditary papillary renal carcinoma (HPRC)/*MET*; Birt-Hogg-Dube syndrome (BHDS)/*FLCN*; tuberous sclerosis complex (TSC)/*TSC1*, *TSC2*; hereditary leiomyomatosis and renal cell carcinoma (HLRCC)/*FH*; *BAP1* tumor predisposition syndrome (TPDS)/*BAP1*; hereditary paraganglioma/pheochromocytoma (PGL/PCC) syndrome/*SDHA*/*SDHB*/*SDHC*/*SDHD*
Melanoma: Cutaneous	Risk Factors for Development of Single or Multiple Primary Melanomas	*CDKN2a*, *CDK4*, *MC1R*, *BAP1* (including uveal), *TERT*, *MITF*, *PTEN* and potential other genes
Melanoma: Uveal	Risk Factors for Development of Uveal Melanoma	*BAP1, PALB2, MBD4*
Mesothelioma: Peritoneal	Principles of Pathologic Review	*BAP1*
Mesothelioma: Pleural	Principles of Pathologic Review	*BAP1* TPDS
Myelodysplastic Syndromes	• Genetic Familial High-Risk Assessment: Heritable Hematologic Malignancy Predisposition Syndromes • Gene Mutations Associated with Heritable Hematologic Malignancy Predisposition Syndromes	*CEBPA, DDX41, ATG2B/GSKIP*, XP C/*XPC*, *ERCC6L2*, *ANKRD26, ETV6, GATA2, RUNX1, LIG-4*, *SAMD9*/*SAMD9L, SRP72*, Diamond-Blackfan anemia, FA, Shwachman-Diamond syndrome, short telomere syndromes, congenital neutropenia, myeloid neoplasms associated with Down syndrome, constitutional mismatch repair deficiency (CMMRD), *BRCA1/BRCA2*, LFS/*TP53*, RASopathies, other rare DNA repair syndromes/*BLM, MBD4, XPC*
Neuroblastoma	Principles of Pathology	*ALK*
Neuroendocrine and Adrenal Tumors	Principles of Hereditary Cancer Risk Assessment and Genetic Counseling	Hereditary PGL/PCC syndrome/*MAX*, *SDHA*, *SDHAF2*, *SDHB*, *SDHC*, *SDHD*, *TMEM127*; multiple endocrine neoplasia type 1 (MEN1); MEN type 2 (MEN2)/*RET*; MEN type 4 (MEN4)/*CDKN1B*; NF1 (*NF1*); TSC (*TSC1*,*TSC2*); VHL syndrome; LFS/*TP53*; LS (*MLH1*, *EPCAM*/*MSH2*, *MSH6*, *PMS2*); FAP/*APC*
Non-Small Cell Lung Cancer	Principles of Molecular and Biomarker Analysis	*EGFR p.T790M*

Note: All recommendations are category 2A unless otherwise indicated.

Summary of Genes and/or Syndromes Included/Mentioned in Other NCCN Guidelines

NCCN Guideline	Specific Sections Included in Table of Contents or Text	Genes and/or Syndromes Included/Mentioned
Treatment Guidelines (Continued)		
Ovarian Cancer		Refers to Genetic/Familial BOP (Breast, Ovarian, Pancreatic) Guidelines
Pancreatic Cancer	Principles of Cancer Risks Assessment and Counseling	Refers to Genetic/Familial BOP (Breast, Ovarian, Pancreatic) Guidelines
Pediatric Acute Lymphoblastic Leukemia	Genetic Risk Groups for B-ALL	LFS/*TP53* association with low hypodiploid ALL
Pediatric Central Nervous System Cancers	Introduction to Pediatric Diffuse High-Grade Gliomas; Principles of Neuropathology	NF1, LFS, LS/CMMRD, *APC* (FAP), *PTCH1* (Gorlin syndrome)
Prostate Cancer	Principles of Genetics and Molecular/Biomarker Analysis	*BRCA1*, *BRCA2*, *ATM*, *PALB2*, *CHEK2*, *HOXB13*, LS/*MLH1*, *MSH2*, *MSH6*, *PMS2*
Rectal Cancer	Principles of Pathologic and Molecular Review	LS, FAP, attenuated FAP (AFAP)
Small Bowel Adenocarcinoma	Workup and Primary Treatment	Refers to Genetic/Familial: Colorectal, Endometrial, and Gastric Guidelines
Soft Tissue Sarcoma	Principles of Cancer Risk Assessment and Counseling	Neurofibromatosis/*NF1*; LFS/*TP53*; LS; FAP
Squamous Cell Skin Cancer	Principles of Cancer Risk Assessment and Counseling	XP and recessive dystrophic epidermolysis bullosa (RDEB); refers to Genetic/Familial BOP (Breast, Ovarian, Pancreatic) Guidelines
Systemic Mastocytosis	Diagnostic Algorithm	*TPSAB1*
Thyroid Carcinoma	• Germline Mutation of *RET* PV • Principles of Cancer Risk Assessment and Counseling	MEN2/*RET*
Uterine Neoplasms	• Principles of Pathology and Molecular Analysis (Endometrial Carcinoma) • Principles of Pathology and Molecular Analysis (Uterine Sarcoma)	LS, *POLE*, *SMARCA4*
Wilms Tumor (Nephroblastoma)	Principles of Cancer Risk Assessment and Counseling	Denys-Drash syndrome (*WT1*), WAGR/WAGRO syndrome (*WT1*), Perlman syndrome (*DIS2L2*), Beckwith-Wiedemann syndrome (*CDKNIC*), Frasier syndrome (*WT1*), Bohring-Opitz syndrome (*ASXL1*), MULIBREY syndrome (*TRIM37*), LFS (*TP53*), trisomy 18 syndrome

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Summary of Genes and/or Syndromes Included/Mentioned in Other NCCN Guidelines

NCCN Guideline	Specific Sections Included in Table of Contents	Genes and/or Syndromes Included/Mentioned
Detection, Prevention, and Risk Reduction Guidelines		
Breast Cancer Risk Reduction	• Familial Risk Assessment • Components of Risk/Benefit Assessment and Counseling • Comparison of Predictive Models of Risk of Breast Cancer and Risk of Carrying Pathogenic/Likely Pathogenic Variants of BRCA	Refers to Genetic/Familial BOP (Breast, Ovarian, Pancreatic) Guidelines
Breast Cancer Screening and Diagnosis	• Increased Risk, Screening/Follow-Up	
Colorectal Cancer Screening	• Risk Assessment for Colorectal Cancer • Increased Risk Based on Personal History of Childhood, Adolescent, and Young Adult Cancer • Increased Risk Based on Positive Family History	LS
Prostate Cancer Early Detection	Baseline Evaluation, Risk Assessment, and Early Detection Evaluation	Such risk genes include, but are not limited to, *BRCA2, BRCA1, ATM, CHEK2, PALB2, HOXB13, MLH1, MSH2, MSH6, PMS2, EPCAM, and TP53.*
Supportive Care Guidelines		
Survivorship	Principles of Cancer Risk Assessment and Counseling	Refers to some of the other NCCN Guidelines containing inherited cancer content
Special Populations		
Adolescent and Young Adult (AYA)	Comprehensive Initial Assessment	

Note: All recommendations are category 2A unless otherwise indicated.

National Comprehensive Cancer Network®

NCCN Guidelines Version 1.2025 Genetic/Familial High-Risk Assessment: Breast, Ovarian, and Pancreatic

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ABBREVIATIONS

ACC	adrenocortical carcinoma
AFAB	assigned female at birth
AFAP	attenuated familial adenomatous polyposis
AMAB	assigned male at birth
AT	ataxia-telangiectasia
BHDS	Birt-Hogg-Dube syndrome
BRRS	Bannayan-Riley-Ruvalcaba syndrome
BS	Bloom syndrome
BSE	breast self examination
CBC	complete blood count
CHIP	clonal hematopoiesis of indeterminate potential
CLIA	Clinical Laboratory Improvement Amendments
CMMRD	constitutional mismatch repair deficiency
CNS	central nervous system
CNV	copy number variant
CPS + EG	clinical-pathologic stage + estrogen receptor status and histologic grade
CRC	colorectal cancer
CS	Cowden syndrome
ctDNA	circulating tumor DNA
DTC	direct to consumer
EMR	electronic medical record
EUS	endoscopic ultrasound
FA	Fanconi anemia
FAP	familial adenomatous polyposis
GI	gastrointestinal
GIST	gastrointestinal stromal tumor
HDGC	hereditary diffuse gastric cancer
HLRCC	hereditary leiomyomatosis and renal cell cancer
HPRC	hereditary papillary renal carcinoma
HRT	hormone replacement therapy
JPS	juvenile polyposis syndrome
LS	Lynch syndrome
LFS	Li-Fraumeni syndrome
LNG-IUD	levonorgestrel intrauterine device
MEN	multiple endocrine neoplasia
MMR	mismatch repair
MRCP	magnetic resonance cholangiopancreatography
NF	neurofibromatosis
NGS	next-generation sequencing
OCP	oral contraceptive pill
P/LP	pathogenic/likely pathogenic
PCC	pheochromocytoma
PGL	paraganglioma
PHTS	*PTEN* hamartoma tumor syndrome
PJS	Peutz-Jeghers syndrome
PRS	polygenic risk score
PSA	prostate-specific antigen
PV	pathogenic variant
RDEB	recessive dystrophic epidermolysis bullosa
RRM	risk-reducing mastectomy
RRSO	risk-reducing salpingo-oophorectomy
SDH	succinate dehydrogenase
SEER	Surveillance, Epidemiology, and End Results
SNP	single nucleotide polymorphism
SNV	single nucleotide variant
UUAB	unassigned at birth
UV	ultraviolet
TPDS	tumor predisposition syndrome
TSC	tuberous sclerosis complex
VAF	variant allele frequency
VHL	Von Hippel-Lindau
VUS	variant of uncertain significance
XP	xeroderma pigmentosum

NCCN Categories of Evidence and Consensus	
Category 1	Based upon high-level evidence (≥1 randomized phase 3 trials or high-quality, robust meta-analyses), there is uniform NCCN consensus (≥85% support of the Panel) that the intervention is appropriate.
Category 2A	Based upon lower-level evidence, there is uniform NCCN consensus (≥85% support of the Panel) that the intervention is appropriate.
Category 2B	Based upon lower-level evidence, there is NCCN consensus (≥50%, but <85% support of the Panel) that the intervention is appropriate.
Category 3	Based upon any level of evidence, there is major NCCN disagreement that the intervention is appropriate.

All recommendations are category 2A unless otherwise indicated.

Discussion

This discussion corresponds to the NCCN Guidelines for Genetic/Familial High-Risk Assessment: Breast, Ovarian, and Pancreatic.
Last updated: February 12, 2024.

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Overview

All cancers develop as a result of pathogenic or likely pathogenic (P/LP) variants in certain genes, such as those involved in the regulation of cell growth and/or DNA repair,[1,2] although not all of these P/LP variants are inherited from a parent. For example, sporadic P/LP variants can occur in somatic/tumor cells only, and de novo P/LP variants can occur for the first time in a germ cell (ie, egg or sperm) or in the fertilized egg itself during early embryogenesis. However, family studies have long documented an increased risk for several forms of cancer among first-degree relatives (ie, parents, siblings, children) and second-degree relatives (ie, grandparents, aunts or uncles, grandchildren, nieces or nephews) of affected individuals. These individuals may have an increased susceptibility to cancer as the result of one or more P/LP variants present in parental germline cells; cancers developing in these individuals may be classified as hereditary or familial cancers.

Hereditary cancers are often characterized by P/LP variants associated with increased risk for certain cancers and transmission to offspring through the mother and/or father.[3,4] They often have an early age of onset and exhibit an autosomal dominant inheritance pattern (ie, occur when the individual has a P/LP variant in only one copy of a gene). Familial cancers share some but not all features of hereditary cancers. For example, although familial breast cancers occur in a given family more frequently than in the general population, they generally do not exhibit the inheritance patterns or onset age consistent with hereditary cancers. Familial cancers may be associated with chance clustering of sporadic cancer cases within families, genetic variation in lower penetrance genes, a shared environment, or combinations of these factors.[5-8]

An individual suspected of being at risk for hereditary cancer should be offered genetic counseling.[9,10] This is consistent with recommendations from the U.S. Preventive Services Task Force (USPSTF).[11] Assessment of an individual's risk for familial or hereditary cancer is based on a thorough evaluation of the personal and family history. With respect to hereditary cancers, advances in molecular genetics have identified a number of genes associated with inherited susceptibility to breast, ovarian, and pancreatic cancer (eg, *BRCA1/2, PALB2, ATM*) and have provided a means of characterizing the specific P/LP variant present in certain individuals and families exhibiting an increased risk for cancer. The field of cancer genetics has implications for all aspects of cancer-related care of individuals with hereditary or familial cancers, including prevention, screening, and treatment.[12]

The NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines®) for Genetic/Familial High-Risk Assessment: Breast, Ovarian, and Pancreatic were developed with an acute awareness of the preliminary nature of much of our knowledge regarding the clinical application of the rapidly emerging field of molecular genetics, and with an appreciation for the need for flexibility when applying these guidelines to individual families. Furthermore, it should be emphasized that these Guidelines were not developed as a substitute for professional genetic counseling. Rather, they are intended to: 1) serve as a resource for health care providers to identify individuals who may benefit from cancer risk assessment and genetic counseling and testing; to guide decisions related to genetic testing; and 3) facilitate a multidisciplinary approach in the comprehensive care of individuals at increased risk for hereditary breast, ovarian, and pancreatic cancer. The current NCCN Guidelines® for Genetic/Familial High-Risk Assessment: Breast, Ovarian, and Pancreatic focus primarily on assessment of P/LP variants associated with increased risk of breast, ovarian, pancreatic, and prostate cancer, including *BRCA1, BRCA2, CDH1, PALB2, PTEN,* and *TP53*, and recommended approaches to genetic counseling/testing and care strategies in individuals with these P/LP variants. Where possible, P/LP variants in more recently identified

genes have been addressed to the extent possible given the limited information available. Recommendations regarding P/LP variants associated with pancreatic cancer, and pancreas screening for individuals harboring such variants, were added to the NCCN Guidelines in the 2020 update. Additionally, testing criteria for those with or at risk for prostate cancer have also been included in the NCCN Guidelines.

A glossary of genetic terms is included in Table 1 for reference.

Literature Search Criteria and Guidelines Update Methodology

Prior to the update of this version of the NCCN Guidelines for Genetic/Familial High-Risk Assessment: Breast, Ovarian, and Pancreatic, an electronic search of the PubMed database was performed to obtain key literature using the following search terms: (hereditary breast cancer) OR (familial breast cancer) OR (hereditary ovarian cancer) OR (familial ovarian cancer) OR (Li-Fraumeni syndrome) OR (tp53 breast cancer) OR (Cowden syndrome) OR (pten hamartoma tumor syndrome) OR (pten breast cancer) OR (brca breast cancer) OR (brca ovarian cancer) OR (brip1 ovarian cancer) OR (cdh1 breast cancer) OR (palb2 breast cancer) OR (stk11 breast cancer) OR (rad51c ovarian cancer) OR (rad51d ovarian cancer) OR (hereditary pancreas cancer) OR (hereditary pancreatic cancer) OR (familial pancreas cancer) OR (familial pancreatic cancer) OR (brca pancreas cancer) OR (brca pancreatic cancer) OR (cdkn2a pancreas cancer) OR (cdkn2a pancreatic cancer) OR (cancer genetic testing) OR (cancer genetic counseling). The PubMed database was chosen because it remains the most widely used resource for medical literature and indexes peer-reviewed biomedical literature.

The search results were narrowed by selecting studies in humans published in English. Results were confined to the following article types: Practice Guidelines; Randomized Controlled Trial; Meta-Analysis; Systematic Reviews; Multicenter Study; and Validation Studies. The data from key PubMed articles as well as articles from additional sources deemed as relevant to these guidelines as discussed by the panel during the Guidelines update have been included in this version of the Discussion section. Recommendations for which high-level evidence is lacking are based on the panel's review of lower-level evidence and expert opinion.

Sensitive/Inclusive Language Usage

NCCN Guidelines strive to use language that advances the goals of equity, inclusion, and representation. NCCN Guidelines endeavor to use language that is person-first; not stigmatizing; anti-racist, anti-classist, anti-misogynist, anti-ageist, anti-ableist, and anti-weight-biased; and inclusive of individuals of all sexual orientations and gender identities. NCCN Guidelines incorporate non-gendered language, instead focusing on organ-specific recommendations. This language is both more accurate and more inclusive and can help fully address the needs of individuals of all sexual orientations and gender identities. NCCN Guidelines will continue to use the terms men, women, female, and male when citing statistics, recommendations, or data from organizations or sources that do not use inclusive terms. Most studies do not report how sex and gender data are collected and use these terms interchangeably or inconsistently. If sources do not differentiate gender from sex assigned at birth or organs present, the information is presumed to predominantly represent cisgender individuals. NCCN encourages researchers to collect more specific data in future studies and organizations to use more inclusive and accurate language in their future analyses.

Genetic Risk Assessment and Counseling

Cancer genetic risk assessment and genetic counseling is a multi-step process involving the identification and counseling of individuals at risk for familial or hereditary cancer. The purpose of cancer genetic counseling is to educate individuals about the genetic, biological, and environmental

factors related to a cancer diagnosis and/or risk for disease to help derive personal meaning from cancer genetic information, and to empower them to make educated, informed decisions about genetic testing, cancer screening, and cancer prevention. Many patients undergoing genetic testing do not receive proper counseling.[13] Further, testing rates are inadequate among some populations with higher risk, such as African American individuals.[14,15] A genetic counselor, clinical geneticist, oncologist, surgeon, oncology nurse, or other health professional with expertise and experience in cancer genetics should be involved in every stage of the process.[9]

Testing is clinically indicated in individuals for whom there is a personal or family history suggesting genetic cancer susceptibility and for whom results will aid in risk management and treatment. The selection of genes for which testing is indicated is based on the personal and familial characteristics that determine the individual's prior probability of being a carrier of a P/LP variant, and on the psychosocial degree of readiness of the person to receive genetic test results. Genetic risk assessment is a dynamic process and can change if additional relatives are diagnosed with cancer. The genetic testing strategy is greatly facilitated when a P/LP variant has already been identified in another family member. In that case, the genetic testing laboratory can limit the search for P/LP variants in additional family members to the same location in the gene. However, if there is reason to suspect more than one P/LP variant in the family, then broader testing may be considered.

For the majority of families in whom presence of a P/LP variant is unknown, it is best to consider testing an affected family member first, especially a family member with early-onset disease, bilateral disease, or multiple primaries, because that individual has the highest likelihood of a positive test result. The testing of the unaffected individual (or of unaffected family members) is reasonable when no affected family member is available for testing. In such cases, it is most informative to test the unaffected individual or unaffected close relative with the highest likelihood of testing positive for the P/LP variant. This may include the relative closest to the family member with the youngest age at diagnosis, bilateral disease, multiple primary tumors, or other cancers associated with a suspected hereditary syndrome. A negative test result in such cases, however, is considered indeterminate and does not provide the same level of information as when there is a known P/LP variant in the family. Thus, one should be mindful that, when testing unaffected individuals (in the absence of having tested affected family members), significant limitations may exist in interpreting the test results, and testing multiple family members may be indicated since absence of a P/LP variant in one unaffected relative does not rule out a P/LP variant in other family members. The maternal and paternal sides of the family should be considered independently for familial patterns of cancer. "Limited" family structure is defined as two or fewer first- or second-degree female relatives who survive past age 45 (on either side of the family) and/or possessing no or inadequate information about one's birth parents.[16]

Individuals who have received allogeneic hematopoietic cell transplantation (HCT) should not have molecular genetic testing performed on blood samples. In such cases, DNA of the individual being tested should be extracted from a fibroblast culture, if available. If this is not possible, buccal cells or saliva may be considered as an alternative source for DNA; however, a study has reported that over time, buccal epithelial cells are replaced by donor-derived cells in allogeneic HCT recipients.[17,18] Therefore, genetic testing using saliva or buccal swab samples may be limited given this known risk of contamination or malignant cells from the hematologic malignancy. Fibroblasts are also indicated when testing individuals with active or recent hematologic malignancies.[19]

A counseling dilemma is posed by the finding of a variant of uncertain significance (VUS), a genetic alteration that may actually represent a benign polymorphism unrelated to an increased cancer risk or may indicate an increased cancer risk. Retrospective analyses have estimated that 82.1% to 91.2% of the time, if a VUS is reclassified, it is downgraded to benign or likely benign, while 8.7% to 17.9% are upgraded from VUS to pathogenic.[20,21] Therefore, VUS should not be used to alter medical management. These patients should be considered for referral to research studies that aim to define the functional impact of the gene variant, such as variant reclassification programs through clinical labs or registries. Some examples of these programs and registries include ClinVar (the archival database at the National Center for Biotechnology Information [NCBI]); the NIH-funded Clinical Genome Resource (ClinGen; https://www.clinicalgenome.org/); the international Evidence-based Network for the Interpretation of Germline Mutant Alleles (ENIGMA; https://enigmaconsortium.org/); and the International Society for Gastrointestinal Hereditary Tumors (InSIGHT; http://insight-group.org/). It is important to note that there may be inconsistencies among how some programs and registries interpret the clinical actionability of some VUS,[22,23] and there are discordant variant interpretations across laboratories.[24] These inconsistencies may lead to confusion regarding medical management, and careful counseling and skilled interpretation are required. RNA studies (when appropriate) may be a consideration to further define functional impact of variants.[25] Family members should not be tested for a VUS for the purposes of clinical management unless there are conflicting data between laboratories regarding the classification of a variant. In the event where there are discrepancies in classification, careful consideration must be taken regarding family history, testing family members, and if other functional studies could aid in variant classification. Clinicians and scientists should work together to develop a VUS classification system as more information is discovered in research studies.[26] Risk management strategies in carriers of a VUS or likely benign variant should be based on family history of cancer.

Carriers of a P/LP variant should be encouraged to participate in clinical trials or genetic registries. Carriers should be encouraged to recontact their genetics providers every few years for updates, as laboratories may issue amended reports as the knowledge base surrounding hereditary cancer risk expands.

Evaluating the Source of Genetic Testing Information

Reports regarding germline findings that may impact medical management should come from laboratories that are certified by the College of American Pathologists (CAP) and Clinical Laboratory Improvement Amendments (CLIA), with some U.S. states (eg, New York) having additional reporting requirements. Direct-to-consumer (DTC) services and tumor profiling both provide genetic test results. The testing typically used by companies providing ancestry information directly to consumers is microarray-based single nucleotide polymorphism (SNP) testing that has not been validated for clinical use. These companies do not provide comprehensive genetic analysis that includes gross deletion or duplication analysis. Third-party services are available to assist patients with interpreting their raw data, but these services are not government-regulated. In addition to the errors inherent in working with raw uncurated data from DTC labs, other limitations of these services include inadequate informed consent process, uncertain clinical validity and utility, and lack of medical oversight.[27] Currently available tests also only provide limited founder P/LP variant results without the benefit of family history. An analysis of concordance between DTC testing results and results from confirmatory testing for 49 patients showed a false-positive rate of 40%, as well as variant classification errors in 8 patients.[28] Given the limitations of the information obtained from DTC services, confirmatory germline testing by a certified laboratory is clinically indicated, and changes to medical

management based solely on DTC testing results are not recommended.[28] Testing offered through DTC services may have other limitations as well that could impact informed decision-making and interpretation of test results.[29] These limitations include use of terms that are not clearly defined for consumers (eg, “clinical grade”, “medical grade”, “diagnostic grade”); unclear procedures for processing and receiving results and for variant reclassification; inadequate genetic counseling; and unclear use of consumers’ health information.[29]

Incidental germline findings discovered through other sources (eg, participation in a research study) should be reviewed by a genetics professional.[30] Confirmatory testing in these cases may be clinically indicated, especially if the reporting laboratory is not appropriately certified.

Tumor Genomic Testing

Tumor profiling can be considered complementary to germline testing. However, the absence of a P/LP variant for a given gene from tumor profiling does not rule out the possibility of a germline P/LP variant in that gene. Tumor genomic testing tends to be designed to address treatment actionability and prognosis.[31] Therefore, a variant interpreted as P/LP in the germline may be interpreted as normal or as a VUS in the tumor, if that variant has no clear clinical implications. In addition, the sensitivity of most tumor testing is lower (particularly for intermediate-sized deletions and duplications) than that for most dedicated germline tests, sometimes due to filtering out of germline findings reported in tumor sequencing results. In a study of 21,333 patients with cancer who underwent both tumor and germline testing at an NCCN Member Institution, tumor-only sequencing missed 10.5% of clinically actionable P/LP variants.[32] If a patient meets testing criteria for germline testing for a given gene, then confirmatory germline testing should be considered through a CLIA-approved lab despite tumor profiling results.

Circulating tumor DNA (ctDNA) assays may be used by some labs. ctDNA has the potential to identify both somatic and germline variants.[33] However, since the primary intent of tumor testing is to inform treatment decision-making, ctDNA assays are not validated for reporting or interpretation of germline variants. The sensitivity, false-positive rates, and positive predictive value of ctDNA tests for early-stage disease, which are needed to derive clinical utility and to determine clinical validity, are also not fully defined.[34,35] The psychological impact of ctDNA testing also remains unknown. If a germline variant that could impact medical management is detected with a ctDNA assay, then confirmatory testing with a CLIA-approved assay intended for detection and interpretation of germline results is recommended.

Multi-Gene Testing

Next-generation sequencing allows for the sequencing of multiple genes simultaneously. This is referred to as multi-gene testing. Multi-gene testing can detect P/LP variants not found in single-gene testing.[36-38] Since more than one gene can explain an inherited cancer syndrome, phenotype-directed testing based on personal and family history through a multi-gene panel test is often more efficient and/or cost-effective.[39-41] Multi-gene testing may also be considered for those who tested negative for one particular syndrome, but whose personal and family history is suggestive of an inherited susceptibility.[39,42] It is now common practice to order multi-gene panel tests that include genes beyond the original indication for which testing is warranted. Phenotype needs to be considered when ordering multi-gene panel tests, to ensure that the relevant genes are included.[43]

There are several issues to consider regarding multi-gene testing. First, commercially available tests may differ significantly on a number of factors, such as number of genes analyzed, turnaround time, insurance coverage, laboratory expertise, variant reclassification protocol, methods

of DNA/RNA analysis, and availability of financial assistance for cascade testing of relatives, among others. Therefore, the specific laboratory and multi-gene test should be chosen carefully.[39] In addition, P/LP variants identified for more than one gene add complexity that may lead to difficulty in making risk management recommendations.[42] A management plan based on genetic test results should only be developed for identified P/LP variants that are clinically actionable.

A major dilemma regarding multi-gene testing is that there are limited data and a lack of clear guidelines regarding degree of cancer risk associated with some of the genes assessed, and how to communicate and manage risk for carriers of these genes.[44-48] This issue is compounded by the low incidence rates of hereditary disease, leading to a difficulty in conducting adequately powered studies.[44] Multi-gene tests include moderate-penetrance genes, and they often also include low-penetrance genes for which there are little available data regarding degree of cancer risk and guidelines for risk management.[39,49] Analysis from a prospective, multicenter cohort study including 2984 patients with cancer unselected based on cancer type, disease stage, family history of cancer, age of diagnosis, and ethnicity showed that, with use of an 80-gene panel test, a P/LP variant was found in 13.3%, with a highly penetrant variant found in 5%.[50] About half of the identified variants were of moderate or low penetrance, and a VUS was also found in about half the sample. In another study utilizing a 21-gene panel in 9714 patients diagnosed with multiple primary cancers, a P/LP variant was found in 13.6%, with P/LP variant frequency increasing with number of primaries diagnosed (P = .00056).[51] The use of tailored panels that are disease-focused and include clinically actionable cancer susceptibility genes is preferred over large panels that include genes of uncertain clinical relevance. Also, certain variants in a gene may be associated with a different degree of risk than other variants in that gene. For example, the presence of the c.7271T>G missense P/LP variant in *ATM* is associated with an increased risk for early-onset breast cancer.[52-54]

Multi-gene tests also increase the likelihood of detecting a VUS.[37-39,45,55-57] An analysis of germline genetic testing results through 2019 for 200,000 patients with breast cancer and 15,000 patients with ovarian cancer diagnosed between 2013 and 2017 showed that VUS rates increased from 2013 to 2017 for both the patients diagnosed with breast cancer (8.5%–22.4%) and the patients diagnosed with ovarian cancer (8.1%–28.3%).[58] This study also demonstrated racial and ethnic differences in VUS rates, with Asian, Black, and Hispanic patients having significantly higher VUS rates than white patients in 2017 (P < .001), for both breast and ovarian cancer. There are mixed data about the potential for harm due to misinterpretation of VUS results (eg, over-treatment), with a 2017 study reporting that half of patients with VUS who were not considered increased risk for carrying a P/LP variant undergo risk-reducing mastectomy (RRM), suggesting potential overtreatment.[13] In contrast, a 2021 meta-analysis including 22 studies showed that individuals carrying a P/LP variant had higher rates of risk-reducing surgery compared to individuals with a VUS, indicating that individuals with a VUS may not be very commonly undergoing inappropriate risk management.[59]

There is also an increase in the chance of finding genotypically distinct cell lines (ie, genetic mosaicism) with next-generation sequencing.[60] Clones of non-cancerous cells (ie, aberrant clonal expansion) containing a P/LP *TP53* variant have been found in healthy adults undergoing multi-gene testing. This phenomenon can often be attributed to clonal hematopoiesis, a condition in which a hematopoietic stem cell begins making blood cells with the same acquired P/LP variant.[19] When there is no evidence of a hematologic malignancy, then it is referred to as clonal hematopoiesis of indeterminate potential (CHIP). Age-related CHIP is associated with increased risk of hematologic malignancies,[61,62] but may also lead to

unnecessary clinical intervention. Ancillary testing of non-lymphoid non-cancerous tissue can be used to help determine the true presence of a germline variant.[19]

Polygenic risk scores (PRS) are now sometimes included in some genetic test reports. PRS are groups of SNPs associated with a specific disorder or disease, such as cancer. Studies evaluating the validity of PRS to refine risks in those with hereditary cancer have been conducted primarily with breast and prostate cancers. Two studies identified PRS that were strongly associated with ER-negative breast cancer in carriers of a *BRCA1* P/LP variant, overall breast cancer in carriers of a *BRCA2* P/LP variant, and high-grade serous ovarian cancer in carriers of both *BRCA1* and *BRCA2* P/LP variants.[63,64] Two studies of male carriers of a *BRCA1/2* P/LP variant identified PRS associated with breast cancer risk and prostate cancer risk.[65,66] Studies have also evaluated the potential clinical utility of incorporating PRS into a risk-stratified approach for screening for prostate cancer[67] and for identifying age of onset of aggressive prostate cancer.[68] Studies of PRS have largely been done with those of European ancestry.[69,70] Studies with larger samples from diverse populations are needed. Given that the clinical value of PRS has not yet been established, these should not be used to inform clinical management at this time.

Pre- and Post-Test Counseling

For individuals potentially meeting established criteria for one or more of the hereditary cancer syndromes, genetic testing should be considered along with appropriate pre- and post-test counseling. Pre-test counseling should include a discussion of why the test is being offered and how test results may impact medical management, cancer risks associated with the P/LP variant in question, the significance of possible test results (positive, true negative, uninformative negative, VUS, mosaic results; see *Principles of Cancer Risk Assessment and Counseling* in the algorithm for the complete definitions of these terms), the likelihood of a positive result, technical aspects and accuracy of the test, cost considerations, risks of genetic discrimination, psychosocial aspects, confidentiality issues, implications for treatment decision-making, the potential significance of the test results for family members, and other topics.[7] A discussion of confidentiality issues should include an explanation of the federal Genetic Information Nondiscrimination Act (GINA) enacted in 2008, which prohibits most health insurers and employers from discrimination on the basis of genetic test results.[71] Since some patients with cancer who have a poor prognosis may be unable to receive results directly, a plan for results disclosure should be discussed, such as the patient consenting to Release of Information of test results to a spouse or other close relative. A detailed family history should be collected, which involves development of an expanded pedigree, beginning with the health of the individual diagnosed with cancer and proceeding outward to include first-, second-, and third-degree relatives on both the maternal and paternal sides. Factors that limit the informativeness of the pedigree are small family size, a small number of individuals of the susceptible gender for sex-limited cancers, reduced penetrance, early deaths in family members (which precludes the possibility that they will develop adult diseases), prophylactic surgeries that remove an organ from subsequent risk for cancer (eg, hysterectomy for uterine fibroids in which the ovaries are also removed), adoptions, and inaccurate or incomplete information on family members (eg, in the case of adoption or divorce).[5,72] It is also important to know the ancestry/ethnicity of the individual, since members of certain groups (eg, Ashkenazi Jewish) have increased risks of carrying P/LP variants for specific diseases. Any family members who received genetic testing should also be noted, as well as testing results. Finally, a detailed medical and surgical history from the proband should be collected, and a physical examination should be performed by a qualified clinician when appropriate.

The presentation of testing information is most effective when tailored to the age and education of the person undergoing counseling, and that individual's personal exposure to the disease, level of risk, and social environment.[7] Information could be delivered in person or over the phone.[73,74] Telehealth (ie, real-time two-way videoconference) is also increasingly utilized as a feasible alternative for in-person genetic counseling.[74] Remote options (eg, telephone, telehealth) have the potential to help improve genetic testing rates in areas with inadequate access.[74]

Post-test counseling includes disclosure of results, a discussion of the associated medical risks, an assessment of the impact of the results on the emotional state of the individual, a discussion of the impact of the results on the comprehensive care of the individual (including discussion of therapeutic implications by a qualified health care professional), and how and where the patient will be screened for cancer risk.[9] Counseling should include making the individual aware of any available resources, such as disease-specific support groups, high-risk clinics, advocacy groups, and research studies.[75] The counselor should discuss the importance of genetic counseling and testing for relatives who also may be at increased risk.

Since some P/LP variants are associated with rare autosomal recessive conditions (eg, Fanconi anemia is associated with *BRCA2, BRIP1,* and*PALB2* variants), the proband should be advised regarding possible inherited cancer risk to relatives and their own options for risk assessment and management. Testing of a partner of a carrier of a P/LP variant may also be considered to inform reproductive decision-making.[76] See *Autosomal Recessive Risk in Cancer Genes – Multi-Gene Panel Testing* in the algorithm for a full list of the P/LP variants covered in these Guidelines that are associated with autosomal recessive conditions.

Pre- and post-test genetic counseling with involvement of an expert in cancer genetics is recommended. However, the panel acknowledges that most genetic testing is conducted by providers with limited expertise in genetics and often without pre-test genetic counseling.[77-79] Shortages in genetics health providers,[80] expansion of testing indications, aggressive marketing, and increased accessibility of testing due to plummeting costs inclusive of DTC models for testing provide the impetus for the panel to identify scenarios in which referral to a genetics health provider should be considered. These scenarios are as follows: identification of a P/LP variant; negative results despite tumor profiling, personal history, or family history suggestive of inherited condition; VUS result that warrants further evaluation or for which a patient or provider considers using to guide management; mosaic/possibly mosaic result or clonal hematopoiesis (CH); discrepant interpretation of variants (eg, discordant results across laboratories); interpretation of PRS; and detection of P/LP variants from DTC testing.

Many patients who have been diagnosed with cancer and have a P/LP variant are at increased risk for additional primary cancers in the future. Management of those risks may be appropriate after treatment of the current cancer or may be combined with treatment for a current cancer. For example, a patient with breast cancer and a pathogenic variant in *BRCA1* or *BRCA2* may consider bilateral mastectomies to treat their current cancer and also to reduce the risk of a future primary breast cancer. These patients may also consider oophorectomy for treatment of hormone receptor-positive breast cancer and also for reducing ovarian cancer risk.

Best practices for communicating an individual's personal risk relative to published estimated lifetime risks of cancer include the following: 1) presenting risk estimates as a range rather than a single estimate (eg, 30% to 40%); 2) presenting absolute risk versus relative risk terminology;

3) acknowledging the margin of error associated with risk estimates and how these are impacted by number of individuals with a P/LP variant; and 4) acknowledging that risk estimates can change over time. Specifically, patients who are older will have lower remaining lifetime risks. Over time, patients with a P/LP variant benefit from re-consultation with a medical provider who is familiar with inherited risk for cancer. This re-consultation is important for the following reasons: 1) increases compliance with screening guidelines, since screening behaviors may decrease over time; 2) allows the patient to re-evaluate personal choices about risk-reducing surgeries, based on changing life stage and circumstances; and 3) provides opportunities to "check in" with the patient about following up-to-date risk management guidelines, discuss additional or emerging genetic testing options, and review improved risk models. Cancer risk estimates can change based on larger case-control studies. Similarly, recommendations for screening and risk reduction can change based on new technologies and data. The frequency of follow-up with the patient will depend on factors such as age, reproductive planning, comorbidities, risk-reducing surgeries, and others as applicable.

Counseling may be warranted for those with negative or indeterminate results, as reasons for a negative result include the following scenarios: P/LP variant exists in a gene variant that was not recognized due to limitations in technology; P/LP variant exists in a gene variant that was not evaluated; and potential presence of a P/LP variant in a family member that was not detected in the individual. The determination of a "true negative" result depends on the specific family history of cancer, the specific P/LP variant found, and the relationship to any family members who test positive. When an individual has tested negative, it may still be appropriate to consider increased screening and risk reduction measures for cancer, based on family history. Over time, this individual may be a candidate for additional genetic testing due to additional family history or as new genes are identified to be associated with cancer risk or as technology advances.

Additional information and the full list of elements that should be included in pre- and post-test genetic counseling can be found in the *Principles of Cancer Risk Assessment and Counseling* in the algorithm.

Reproductive Options

The outcomes of genetic testing can have a profound impact on family planning decisions for individuals of reproductive age who are found to be carriers of a P/LP variant. Counseling for reproductive options such as prenatal diagnosis and assisted reproduction using preimplantation genetic testing (PGT) and donor gametes may therefore be warranted for couples expressing concern over their future offspring's carrier status of a P/LP variant. Such counseling should include a comprehensive discussion of reproductive options, extent of cancer risk balanced with cancer worry, degree of protection for breast, ovarian and uterine cancer, management of menopausal symptoms, hormone replacement therapy (HRT), related medical or surgical history, and consideration of a gestational carrier.

Prenatal diagnosis involves postimplantation genetic analysis of an early embryo, utilizing chorionic villi or amniotic fluid cell samples; genetic testing is typically conducted between week 12 and week 16 of gestation, and testing results may potentially lead to a couple's decision to terminate the pregnancy.[81,82] PGT has emerged as an alternative method of genetic testing in early embryos. PGT involves the testing of 1 or 2 cells from embryos in very early stages of development (ie, 6–8 cells) after in vitro fertilization (IVF). This procedure allows for the selection of unaffected embryos to be transferred to the uterus,[81,82] and may therefore offer the advantage of avoiding potential termination of pregnancy. The PGT process requires the use of IVF regardless of the fertility status of the couple (ie, also applies to couples without infertility issues), and IVF may not always lead to a successful pregnancy. Lastly, the technology or

expertise may not be readily available in a couple's geographic location. If eggs/embryos are cryopreserved, pregnancy may be achieved with uterus in place, with or without fallopian tubes or ovaries.

Various factors, both medical and personal, must be weighed in the decision to utilize prenatal diagnosis or PGT. Medical considerations may include factors such as the age of onset of the hereditary cancer, penetrance, severity or associated morbidity and mortality of the cancer, and availability of effective cancer risk reduction methods or effective treatments.[81,82] For example, results from two systematic reviews have suggested that carrying a P/LP *BRCA1/2* variant may be associated with diminished ovarian reserve.[83,84] Although the use of prenatal diagnosis or PGT is relatively well established for severe hereditary disorders with very high penetrance and/or early onset (eg, Fanconi anemia), its use in conditions associated with lower penetrance and/or later onset (eg, hereditary breast or ovarian cancer syndrome) remains somewhat controversial from both an ethical and regulatory standpoint. Personal considerations for the decision to utilize prenatal diagnosis or PGT may include individual ethical beliefs, value systems, cultural and religious beliefs, and social and economic factors. Successful births have been reported with the use of PGT and IVF in carriers of a *BRCA1/2* P/LP variant,[85,86] but data in the published literature are still very limited. In addition, data pertaining to long-term safety or outcomes of PGT and assisted reproduction in carriers of a P/LP variant are not yet available.

High-Penetrance Breast and/or Ovarian Cancer Susceptibility Genes

Specific patterns of hereditary breast and ovarian cancers have been found to be linked to P/LP variants in the *BRCA1/2* genes.[87,88] In addition, two very rare hereditary cancer syndromes exhibiting an increased risk for breast cancer are Li-Fraumeni syndrome (LFS) and Cowden syndrome, which are related to germline P/LP variants in the *TP53* and *PTEN* genes, respectively.[89,90] *PALB2, STK11,* and *CDH1* are also considered high penetrance breast cancer susceptibility genes.[91-98] These hereditary syndromes share several features beyond elevation of breast cancer risk. These syndromes arise from germline P/LP variants that are not within sex-linked genes; hence, the variants can be inherited from either parent. The syndromes are associated with breast cancer onset at an early age and development of other types of cancer, and exhibit an autosomal dominant inheritance pattern (see Table 1). Offspring of an individual with one of these hereditary syndromes have a 50% chance of inheriting the P/LP variant. In addition, individuals with these hereditary syndromes share increased risks for multiple cases of early-onset disease as well as bilateral disease. The P/LP variants associated with these hereditary syndromes are considered to be highly penetrant. In addition, the manifestations (ie, expression) of these hereditary syndromes are often variable in individuals within a single family (eg, age of onset, tumor site, number of primary tumors). The risk of developing cancer in individuals with one of these hereditary syndromes depends on numerous variables including the gender and age of the individual.

Prior to 2020, the NCCN Guidelines for Genetic/Familial High-Risk Assessment: Breast and Ovarian (Breast, Ovarian, and Pancreatic as of 2020) focused largely on testing criteria for *BRCA1/2* and appropriate risk management for carriers of a *BRCA1* or *BRCA2* P/LP variant. Sections on LFS and Cowden syndrome/*PTEN* hamartoma tumor syndrome (PHTS) were also included. Based on strong evidence that genes beyond *BRCA1/2, TP53,* and *PTEN* confer markedly increased risk of breast and/or ovarian cancers, these Guidelines have been expanded; see the sections below on other P/LP variants associated with breast/ovarian cancer.

BRCA-Related Breast/Ovarian Cancer Syndrome

Both the *BRCA1* and *BRCA2* genes encode for proteins involved in tumor suppression. *BRCA1/2* P/LP variants can be highly penetrant (for definition, see Table 1), although the probability of cancer development in carriers of *BRCA1/2* P/LP variants is variable, even within families with the same variant.[99-101] At present, it is unclear whether penetrance is related only to the specific P/LP variant identified in a family or whether additional factors, either genetic or environmental, affect disease expression. Epigenetic modification can also influence disease penetrance for a P/LP variant.[102] It is generally accepted, however, that carriers of *BRCA1/2* P/LP variants have an excessive risk for both breast and ovarian cancer that warrants consideration of more intensive screening and preventive strategies.

Breast Cancer Risk

Estimates of penetrance for lifetime risk for primary breast cancer range from 60% to 72% for carriers of a *BRCA1* P/LP variant and 55% to 69% for carriers of a *BRCA2* P/LP variant.[103,104] Risk for contralateral breast cancer in carriers of a *BRCA2* P/LP variant is age-dependent and greatest in those diagnosed with breast cancer at an early age (ie, <40 years).[104,105] Risk is also greater in *BRCA1* P/LP variant carriers compared to *BRCA2* P/LP variant carriers (20-year cumulative risk 30%–40% and 25%, respectively).[104,105] A study of UK Biobank data showed that, among carriers of a *BRCA1/2* P/LP variant, breast cancer risk was greater in those with a first-degree relative diagnosed with breast cancer, compared to those who did not have this family history.[106]

While the evidence is mixed, we do not currently have evidence to support that *BRCA*-associated breast cancers are more aggressive and/or have poorer outcomes. A meta-analysis including 13 studies showed that carriers of a *BRCA1* P/LP variant with breast cancer had worse overall survival (OS) compared to those without a *BRCA1* or *BRCA2* P/LP variant (hazard ratio [HR], 1.50; 95% CI, 1.11–2.04), while OS did not significantly differ between those harboring a *BRCA2* P/LP variant and those without a *BRCA1* or *BRCA2* P/LP variant (HR, 0.97; 95% CI, 078–1.22).[107] Another meta-analysis including 60 studies and 105,220 patients with breast cancer also found that carriers of a *BRCA1* P/LP variant had worse OS compared to non-carriers (HR, 1.30; 95% CI, 1.11–1.52; *P* = .001).[108] Carriers of a *BRCA2* P/LP variant had worse breast cancer-specific survival compared to non-carriers (HR, 1.29; 95% CI, 1.03–1.62; *P* = .03), though OS was not significantly different. This meta-analysis also showed that, among patients with triple-negative breast cancer, *BRCA1/2* P/LP variants are associated with better OS (HR, 0.49; 95% CI, 0.26–0.92; *P* = .03). However, this subgroup analysis only included two studies. A third meta-analysis including 66 studies also showed that a *BRCA2* P/LP variant was associated with worse breast cancer-specific survival (HR, 1.57; 95% CI, 1.29–1.86), but study results were too heterogeneous for the analysis to be conclusive.[109] Results of the prospective cohort Prospective Outcomes in Sporadic versus Hereditary breast cancer (POSH) study including 2733 females with breast cancer showed no significant differences in OS between carriers of a *BRCA1/2* P/LP variant and non-carriers 2, 5, and 10 years after diagnosis.[110]

BRCA1/2 P/LP variants are associated with early-onset primary breast cancer. In a sample of 21,401 families who met German Consortium for Hereditary Breast and Ovarian Cancer testing criteria for *BRCA1/2* P/LP variants, a P/LP variant was detected in 13.7% of families with a single case of breast cancer diagnosed at <36 years of age.[111] An analysis of 6478 patients who were diagnosed with breast cancer before 50 years of age showed that carriers of a *BRCA1* P/LP variant had worse OS compared to patients who were not carriers of a P/LP *BRCA1/2* variant (HR, 1.28; 95% CI, 1.05–1.57; *P* = .01), but this association was no longer statistically significant when taking into account disease and treatment characteristics (HR, 1.20; 95% CI, 0.97–1.47; *P* = .09).[112] *BRCA2* P/LP

variants were not significantly associated with decreased OS in these analyses, except for the first 5 years of follow-up (HR, 1.56; 95% CI, 1.06–2.28; *P* = .02).

Some histopathologic features have been reported to occur more frequently in breast cancers of individuals with a germline *BRCA1/2* P/LP variant. For example, several studies have shown that *BRCA1*-related breast cancer is more likely to be characterized as ER-/PR-negative and HER2-negative (ie, "triple negative").[93,113-119] Studies have reported *BRCA1* P/LP variants in 4.4% to 16% of patients with triple-negative breast cancer.[93,118,120-128] One cohort study showed an absolute lifetime risk of 40% for hormone receptor-positive (ER+ and/or PR+) breast cancer in carriers of a P/LP *BRCA2* variant.[93] The case-control BRIDGES study showed an association between P/LP *BRCA2* variant and increased risk for hormone receptor-positive (ER+ and/or PR+) HER2-negative breast cancer (odds ratio [OR], 11.53; 95% CI, 8.92–14.90), though a significant association was also identified for triple negative breast cancer (OR, 10.07; 95% CI, 7.61–13.32).[119] The Breast Cancer Association Consortium and the CARRIERS case-control studies showed associations between a *BRCA2* P/LP variant and increased risk of ER-positive breast cancer (1.46%; OR, 5.68; 95% CI, 4.65–6.96 and 1.09%; OR, 4.66; 95% CI, 3.52–6.23, respectively).[127,128] Another case-control study showed that the 20-year survival rate in carriers of a *BRCA2* P/LP variant with ER-positive tumors was 62.2%, compared to 83.7% in those with ER-negative tumors, though this difference was only statistically significant in those <50 years of age (n = 199; 68.3% vs. 91.3%, respectively; *P* = .03).[129] A case-control study of carriers of the Icelandic founder *BRCA2* variant 999del5 showed that ER-positive disease was associated with increased mortality risk, compared to those with ER-negative disease (HR, 1.94; 95% CI, 1.22–3.07; *P* = .005).[130] However, prevalence of ER-negative disease was not significantly greater in carriers of a P/LP *BRCA2* variant than in non-carriers (75.6% vs. 70.2%, respectively; *P* = .11). The explanation for the association between *BRCA2* P/LP variant with ER-positive tumors and poor survival outcomes is currently unknown and warrants investigation, though one hypothesized explanation includes difference in estrogen signaling pathways and increased sensitivity to ovarian hormones for these tumors.[130,131]

Among patients with triple-negative disease, carriers of a P/LP *BRCA* variant were diagnosed at a younger age compared with non-carriers.[121,132] In a study of a large cohort of patients with triple-negative breast cancer (N = 403), the median age of diagnosis among carriers of a P/LP *BRCA1* variant (n = 65) was 39 years.[120] Patients in this population-based study were unselected for family history or age. Among the group of patients with early-onset (age at diagnosis <40 years) triple-negative breast cancer (n = 106), the incidence of *BRCA1* P/LP variants was 36%; the incidence was 27% among those diagnosed before 50 years of age (n = 208). Results from the prospective cohort POSH study showed that, among 558 patients with triple-negative breast cancer, 2-year OS was greater in carriers of a *BRCA1/2* P/LP variant than in non-carriers (95% vs. 91%, respectively; HR, 0.59; 95% CI, 0.35–0.99; *P* = .047), but 5- and 10-year OS did not differ significantly between these groups.[110] A SEER analysis from California and Georgia including females diagnosed with breast cancer showed that, among 5461 diagnosed with triple-negative breast cancer, cancer-specific mortality was lower among carriers of a P/LP *BRCA1* variant (HR, 0.49; 95% CI, 0.35–0.69) and carriers of a P/LP *BRCA2* variant (HR, 0.60; 95% CI, 0.41–0.89), compared to non-carriers.[133]

Carriers of a P/LP *BRCA1/2* variant who were assigned male at birth also have a greater risk for cancer susceptibility.[134,135] Among male patients with breast cancer unselected for family history, 4% to 14% tested positive for a germline *BRCA2* P/LP variant.[136-139] For males carrying a P/LP *BRCA2* variant, the cumulative lifetime risk for breast cancer has been

estimated at 1.8% to 7.1%.[140-142] The cumulative lifetime risk for male carriers of a P/LP *BRCA1* variant is 0.2% to 1.2%.[141,142] In contrast, for males who are not carriers of a P/LP *BRCA1/2* variant, the lifetime risk for breast cancer has been estimated at approximately 0.1% (1 in 1000).[138,143]

Ovarian Cancer Risk

Increased risks for cancers of the ovary, fallopian tube, and peritoneum are observed in carriers of a P/LP *BRCA1/2* variant.[144-146] In the setting of an invasive ovarian cancer diagnosis, a P/LP *BRCA1* variant has been found in 3.8% to 14.5% of patients, and a P/LP *BRCA2* variant has been found in 4.2% to 5.7% of patients.[147-151] *BRCA1* variants have an estimated 48.3% (95% CI, 38.8%–57.9%) cumulative risk of ovarian cancer by age 70, while the cumulative risk by age 70 is 20.0% (95% CI, 13.3%–29.0%) for carriers of a P/LP *BRCA2* variant.[152]

Several studies have reported more favorable survival outcomes among carriers of a P/LP *BRCA1/2* variant in patients with ovarian cancer compared with patients who are non-carriers.[153-159] Survival outcomes appear to be most favorable for carriers of a P/LP *BRCA2* variant.[153,157,160] A systematic review and meta-analysis including 13 references with 4565 patients (1131 *BRCA1/2* P/LP variant carriers) showed that 5-year survival was higher in the P/LP carriers than in non-carriers (risk difference, 14.9%; $P = .0002$; relative risk [RR], 1.36; $P = .001$), but the difference in risk was less pronounced for 10-year survival (risk difference, 8.6%; $P = .042$; RR, 1.25; $P = .12$).[161] *BRCA2* P/LP variants are also associated with significantly higher response rates (compared with non-carriers or with carriers of a *BRCA1* P/LP variant) to primary chemotherapy. In contrast, *BRCA1* P/LP variants were not associated with prognosis or improved chemotherapy response.[157]

The histology of ovarian cancers in carriers of a P/LP *BRCA1/2* variant is more likely to be characterized as serous adenocarcinoma and high grade compared with ovarian cancers in non-carriers, although endometrioid and clear cell ovarian cancers also have been reported in the former population.[146,149,162-166] P/LP variants are also associated with non-mucinous ovarian carcinoma as opposed to mucinous.[147,150] Mucinous epithelial ovarian carcinomas may be associated with other P/LP variants, such as *TP53*,[167] which are implicated in LFS (see below). Non-epithelial ovarian carcinomas (eg, germ cell and sex cord-stromal tumors) are not significantly associated with a *BRCA1/2* P/LP variant,[168] though ovarian sex cord tumor with annular tubules is associated with *STK11* P/LP variants.[97,98] Current data show that ovarian low malignant potential tumors (ie, borderline epithelial ovarian tumors) are also not associated with a *BRCA1/2* P/LP variant.[147]

In studies of carriers of a P/LP *BRCA1/2* variant who underwent risk-reducing salpingo-oophorectomy (RRSO) for occult gynecologic neoplasia, both invasive carcinoma and intraepithelial lesions were identified in 4.5% to 9% of cases based on rigorous pathologic examinations of the ovaries and fallopian tubes.[169-171] Tubal intraepithelial carcinoma (TIC) is thought to represent an early precursor lesion for serous ovarian cancers, and TIC (with or without other lesions) was detected in 5% to 8% of cases from patients carrying a P/LP *BRCA1/2* variant who underwent RRSO.[169,172,173] The fimbriae or distal tube was reported to be the predominant site of origin for these early malignancies found in carriers of a P/LP *BRCA1/2* variant.[169,173,174] Although TIC appeared to present more frequently among carriers of a P/LP *BRCA1/2* variant compared with non-carriers undergoing RRSO,[173,174] TIC has also been documented among patients with serous carcinomas unselected for family history or *BRCA* P/LP variant status.[175] Because TIC was identified in individuals who underwent surgery for risk reduction (for carriers of a P/LP *BRCA1/2* variant) or other gynecologic indications, the incidence and significance of these early lesions within the general population is unclear.

Prostate Cancer Risk

Germline *BRCA1/2* P/LP variants are associated with increased risk for prostate cancer.[176-179] Carriers of a P/LP *BRCA1* variant have an estimated 7% to 26% cumulative lifetime risk of prostate cancer, while the cumulative lifetime risk is 19% to 61% for carriers of a P/LP *BRCA2* variant.[65,142,180] There is evidence that advanced or metastatic prostate cancer is associated with carrying a *BRCA2* P/LP variant; it is not yet known if an aggressive phenotype is also associated with *BRCA1* P/LP variant.[181-183] An international study including 5545 patients with prostate cancer (with European ancestry) showed that the frequency of a *BRCA2* P/LP variant was significantly higher in patients with aggressive disease (ie, died from prostate cancer, metastatic disease, T4 disease, or T3 with Gleason score ≥8) than in patients with non-aggressive disease (OR, 3.19; 95% CI, 1.94–5.25).[183] A study of a large cohort of patients from Spain with prostate cancer (N = 2019) showed that carriers of a P/LP *BRCA1/2* variant had significantly higher rates of aggressive prostate cancer (Gleason score ≥8), nodal involvement, and distant metastasis compared with non-carriers.[184] In a sample of 692 patients with metastatic prostate cancer, unselected for family history or age at diagnosis, 5.3% carried a *BRCA2* P/LP variant, and 0.9% carried a *BRCA1* P/LP variant.[182] In addition, analyses from a treatment center database showed that *BRCA1/2* and *ATM* (see below under *NCCN Genetic Testing Criteria: Testing Criteria Related to Prostate Cancer*) P/LP variant rates were highest in patients with metastatic disease (8.2%). This study also showed that carriers with prostate cancer had significantly decreased survival, compared with patients who were non-carriers (5 years vs. 16 years, respectively; $P < .001$).[185] This association remained statistically significant when controlling for race, age, prostate-specific antigen (PSA), and Gleason score. Ashkenazi Jewish ancestry is also associated with *BRCA1/2* P/LP variants in patients with prostate cancer, with rates for *BRCA1* being 0% to 2%, and rates for *BRCA2* being 1% to 3%.[176,186-189]

Pancreatic Cancer Risk

Prior to more widespread testing of individuals with pancreatic cancer for germline variants in cancer predisposition genes, studies showed that *BRCA1/2* P/LP variant rates in pancreatic cancer cases ranged from 1% to 11% for *BRCA1* and 0% to 17% for *BRCA2*.[190-198] However, some of these studies included only patients with familial pancreatic cancer[193,194,197] or those of Ashkenazi Jewish ancestry,[195] both of whom may have a greater likelihood of testing positive for a *BRCA1/2* P/LP variant. More recent studies that used panel testing confirm that some pancreatic cancers harbor actionable *BRCA1/2* P/LP variants (0%–3% for *BRCA1* and 1%–6% for *BRCA2*).[199-203] Cumulative lifetime risk of pancreatic cancer is as high as 3% for males with a *BRCA1/2* P/LP variant and 2.3% for females with a *BRCA1/2* P/LP variant.[142] Patients with pancreatic cancer and Ashkenazi Jewish ancestry may have a greater likelihood of testing positive for a *BRCA1/2* P/LP variant, with prevalence of detected P/LP variants in this group ranging from 5.5% to 19%, with P/LP variants being more common for *BRCA2*.[195,196,198,204]

More information on genes associated with pancreatic cancer can be found below, under *Hereditary Pancreatic Cancer*.

Other Cancer and Health Risks

Some studies have suggested an increased risk specifically of serous uterine cancer in carriers of a P/LP *BRCA1/2* variant.[205-209] Analyses from a multicenter prospective cohort study including 1083 carriers of a P/LP *BRCA1* variant who underwent RRSO without hysterectomy showed an increased risk for serous and/or serous-like endometrial cancer.[210] A Dutch cohort study including 5980 carriers of a P/LP *BRCA1/2* variant showed a 2- to 3-fold increased risk for endometrial cancer, with the highest risks for serous-like (HR, 10.48; 95% CI, 2.95–37.20) and *p53*-abnormal endometrial cancer (HR, 15.71; 95% CI, 4.62–53.40) in carriers of a P/LP *BRCA1* variant.[209] A systematic review and meta-analysis

including 11 studies with 13,871 carriers of a P/LP *BRCA1/2* variant showed that the prevalence of endometrial cancer was 0.62% in carriers of a P/LP *BRCA1* variant and 0.47% in carriers of a P/LP *BRCA2* variant (relative RR, 1.18; 95% CI, 0.7–2.0).[211] For uterine papillary serous carcinoma, the prevalence rates were 0.20% for *BRCA1* and 0.08% for *BRCA2* (relative RR, 1.39; 95% CI, 0.5–3.7). It has been suggested that the increased risk for endometrial cancer observed in some carriers of *BRCA1/2* P/LP variants may be due to the use of tamoxifen therapy by these patients rather than the presence of a P/LP variant.[212-214]

A meta-analysis including five studies of patients with uterine serous cancer and Ashkenazi Jewish ancestry showed that *BRCA1/2* P/LP variant prevalence was greater in those with uterine serous cancer than in controls (also of Ashkenazi Jewish ancestry) (OR, 5.4; 95% CI, 2.2–13.1).[205] In a retrospective case control study including 2627 Jewish Israeli carriers of a P/LP *BRCA1/2* variant (88% Ashkenazi Jewish), risk of developing uterine cancer was increased, with an observed-to-expected ratio of 3.98 (95% CI, 2.17–6.67; $P < .001$).[208] This association persisted regardless of uterine cancer histology.

The absolute risk of uterine cancer in carriers of a P/LP *BRCA1/2* variant appears low overall, despite some evidence of increased risk. However, genetic testing, including for a P/LP *BRCA1* variant, may be considered for patients diagnosed with serous endometrial cancer.

Studies that investigated associations between *BRCA2* P/LP variant and cutaneous melanoma have drawn inconsistent conclusions, though there is some evidence of an association.[215] One study showed that females carrying a P/LP *BRCA2* variant have an elevated risk for leukemia (standardized incidence ratio [SIR], 4.76; 95% CI, 1.21–12.96; $P = .03$), particularly females who have received chemotherapy (SIR, 8.11; 95% CI, 2.06–22.07; $P = .007$).[216] Analyses of 3184 *BRCA1* and 2157 *BRCA2* families in the Consortium of Investigators of Modifiers of *BRCA1/2* showed that the cumulative lifetime risk of gastric cancer is 3.5% in both male and female carriers of a *BRCA2* pathogenic variant (compared to 1.6% and 0.7% in male and female carriers of a *BRCA1* pathogenic variant, respectively).[142] A case-control analysis from Japan including 65,108 patients showed associations between gastric cancer and *BRCA1* (OR, 5.2; 95% CI, 2.6–10.5) and *BRCA2* (OR, 4.7; 95% CI, 3.1–7.1) P/LP variants, biliary tract cancer and P/LP *BRCA1* variant (OR, 17.4; 95% CI, 5.8–51.9), and esophageal cancer and P/LP *BRCA2* variant (OR, 5.6; 95% CI, 2.9–11.0).[217] Finally, an analysis of 490 families with a known *BRCA1/2* P/LP variant showed an increased risk for ocular melanoma in carriers of a P/LP *BRCA2* variant (RR, 99.4; 95% CI, 11.1–359.8), though absolute risk is low.[218]

In cases where both partners carry a P/LP *BRCA2* variant, there may be a high risk for the offspring to develop Fanconi anemia, a rare autosomal recessive condition.[76] A review of 27 cases of Fanconi anemia with biallelic P/LP variants in *BRCA2* (FA-D1) showed a 97% cumulative risk of malignancy by age 5.2 years (79% risk of leukemia by age 10 years, 83% risk of any solid tumor by age 6.7 years, 85% risk of a brain tumor by age 9 years, and 63% risk of a Wilms tumor by age 6.7 years).[219] Some case reports have also identified biallelic *BRCA1* P/LP variants causing Fanconi anemia-like disorder,[220,221] particularly FANCS, a severe form of Fanconi anemia characterized by developmental delay, short stature, and microcephaly.[222,223]

Risk Management

Recommendations for the medical management of *BRCA*-related cancers are based on an appreciation of the early onset and increased risk for associated cancers. An individual from a family with a known *BRCA1/2* P/LP variant who tests negative for the familial variant should be followed according to the recommendations for the general population for breast

cancer (eg, the NCCN Guidelines for Breast Cancer Screening and Diagnosis [available at www.NCCN.org]).

Breast Cancer Risk Management

Screening

Mammography has served as the standard screening modality for detection of breast cancer during the last few decades. There are currently no data indicating that mammography on its own reduces mortality in females with genetically increased risk for breast cancer.[224] Also, false-negative mammography results are common and have been correlated with factors such as presence of a *BRCA1/2* P/LP variant and high breast tissue density,[225-228] both of which may occur more frequently among younger females. Rapidly growing or aggressive breast tumors—also more common among younger females —have also been associated with decreased sensitivity of mammographic screening methods.[225,229] Prospective studies on comparative surveillance modalities in females at high risk for familial breast cancer (ie, confirmed or suspected *BRCA1/2* P/LP variant based on family history) have consistently reported higher sensitivity of MRI screening (77%–94%) compared with mammography (33%–59%) in detecting breast cancers. False-positive rates were higher with MRI in some reports, resulting in a slightly lower or similar specificity with MRI screening (81%–98%) compared with mammography (92%–100%).[230-235] The sensitivity with ultrasound screening (33%–65%) appeared similar to that of mammography in this high-risk population.[231,233-235] In a prospective screening trial (conducted from 1997–2009) that evaluated the performance of annual MRI and mammography in females (aged 25–65 years; N = 496) with confirmed P/LP *BRCA1/2* variant, sensitivity with MRI was significantly higher compared with mammography during the entire study period (86% vs. 19%; $P < .0001$).[236] Factors such as age, P/LP variant type, or invasiveness of the tumor did not significantly influence the relative sensitivity of the two screening modalities. Importantly, the large majority (97%) of cancers detected by MRI screening were early-stage tumors.[236] At a median follow-up of 8 years from diagnosis, none of the survivors (n = 24) had developed distant recurrence. In an analysis of 606 females with either a family history of breast cancer or who harbor a P/LP variant associated with increased risk for breast cancer, sensitivity of breast MRI screening was reported to be 79%, while specificity was reported to be 86%.[237]

All of these studies discussed above evaluated a screening strategy that was conducted on an annual basis, and many of the studies included individuals without known *BRCA1/2* P/LP variant status. A study of 1219 carriers of a P/LP *BRCA1* variant and 732 carriers of a P/LP *BRCA2* variant showed that the increased sensitivity of mammography in addition to MRI was greater for carriers of a P/LP *BRCA2* variant (12.6%) than for carriers of a P/LP *BRCA1* variant (3.9%).[238] In a retrospective study, a different screening interval was evaluated, using alternating mammography and MRI screening every 6 months in females with a confirmed P/LP *BRCA1/2* variant (N = 73).[239] After a median follow-up of 2 years, 13 breast cancers were detected among 11 females; 12 of the tumors were detected by MRI screening but not by mammography obtained 6 months earlier. The sensitivity and specificity with MRI screening was 92% and 87%, respectively.[239]

The optimal surveillance approach in individuals assigned female at birth who are at high risk for familial breast cancer remains uncertain, especially for those between the ages of 25 and 30 years. While some studies have reported an association between radiation exposure from mammography and increased risk for breast cancer in carriers of a P/LP *BRCA1/2* variant,[240,241] current data are insufficient to support risks of radiation. Nevertheless, one of the potential benefits of incorporating MRI modalities into surveillance strategies may include minimizing the radiation risks associated with mammography, in addition to the higher sensitivity of MRI

screening in detecting tumors. The use of MRI, however, may potentially be associated with higher false-positive results and higher costs relative to mammography. The combined use of digital mammography (two-dimensional, 2D) in conjunction with digital breast tomosynthesis (DBT) appears to improve cancer detection and reduce false-positive call back rates.[242-251] Tomosynthesis allows acquisition of three-dimensional (3D) data using a moving x-ray and digital detector. These data are reconstructed using computer algorithms to generate thin sections of images. The combined use of 2D and DBT results in double the radiation exposure compared with mammography alone. However, this increase in radiation dose falls below dose limits of radiation set by the U.S. Food and Drug Administration (FDA) for standard mammography. The radiation dose can be minimized by newer tomosynthesis techniques that create a synthetic 2D image, which may obviate the need for a conventional digital image.[243,252,253] In carriers of a *BRCA1/2* P/LP variant who are <30 years of age, breast MRI screening is preferred over mammography due to lack of data to support benefit due to less sensitivity for detection of tumors associated with mammography. Studies have reported that deposits of gadolinium, a component of MRI contrast agents, remain in the brain of some patients who undergo 4 or more contrast MRI scans, long after the last administration.[254,255] Retention of gadolinium has also been seen in the bone.[256] In 2017, the FDA issued an update stating that its review of available data had not identified adverse health effects from gadolinium retained in the brain and that patients should read a medication guide prior to receiving gadolinium. However, review of the evidence will continue.

The appropriate imaging modalities and surveillance intervals are still under investigation. In a report based on a computer simulation model that evaluated different annual screening strategies in carriers of a P/LP *BRCA1/2* variant, a screening approach that included annual MRI starting at 25 years of age combined with alternating digital mammography/MRI starting at 30 years of age was shown to be the most effective strategy when radiation risks, life expectancy, and false-positive rates were considered.[257] Future prospective trials are needed to evaluate the different surveillance strategies in individuals at high risk for familial breast cancer. For an individual assigned female at birth who is a carrier of a *BRCA1/2* P/LP variant, training in breast awareness with regular monthly practice should begin at 18 years of age, and clinical breast examinations should be conducted every 6 to 12 months, beginning at 25 years of age. Between the ages of 25 and 29 years, these individuals should have annual breast MRI screening with contrast (to be performed on days 7 to 15 of menstrual cycle for premenopausal individuals) or annual mammograms only if MRI is not available. The age to begin screening can be individualized if the family history includes a breast diagnosis prior to 30 years of age.[230,232,235,258,259] Breast MRI screening is preferred over mammogram in the 25- to 29-year age group. High-quality breast MRI screening should consist of the following: dedicated breast coil, ability to perform biopsy under MRI guidance, experienced radiologists in breast MRI, and regional availability. Between 30 and 75 years of age, annual mammogram and breast MRI with contrast should both be done. After 75 years of age, management should be considered on an individual basis. In females treated for breast cancer who have not had bilateral mastectomy, mammography and breast MRI screening with contrast should continue as recommended based on age. Emerging evidence suggests that abbreviated-protocol breast MRI is a screening strategy that warrants further investigation in carriers of a *BRCA1/2* P/LP variant.[260,261]

Carriers of a *BRCA1/2* P/LP variant who were assigned male at birth should have an annual clinical breast examination and undergo training in breast self-examination with regular monthly practice starting at 35 years of age. A 12-year longitudinal observational study evaluated the outcomes of mammography screening in 1869 males who were at increased risk of developing breast cancer (ie, personal or family history of breast cancer and/or germline P/LP variant associated with breast cancer, mostly

BRCA1 and *BRCA2*).[262] Node-negative breast cancer was identified in five males (18 per 1000 examinations), which is greater than the cancer detection rates in both average-risk and high-risk females who undergo breast screening. Harboring a P/LP variant (n = 47) was associated with breast cancer (OR, 7; 95% CI, 2–29; *P* = .006). Because of the lack of screening, males diagnosed with breast cancer have historically presented with advanced stage disease.[263] Annual mammogram in males may be considered, especially in those carrying a *BRCA2* P/LP variant, beginning at age 50 or 10 years before the earliest known male breast cancer in the family (whichever comes first). Though gynecomastia may be associated with breast cancer, it is not a risk factor for breast cancer.[264] As per the American College of Radiology (ACR) Appropriateness Criteria, gynecomastia does not need to be present in order to obtain a diagnostic mammogram.[265]

Bilateral Total Mastectomy

Two meta-analyses show that prophylactic bilateral mastectomy reduces the risk for breast cancer.[266,267] Only one of these analyses showed that risk-reducing surgery is significantly associated with reduced mortality.[267] Retrospective studies and small prospective studies provide support for concluding that RRM provides a high degree of protection against breast cancer in females carrying a P/LP *BRCA1/2* variant.[268-271]

It is important that the potential psychosocial effects of RRM are addressed. A 2018 Cochrane review including 20 studies that evaluated psychosocial effects of RRM showed that patients are generally satisfied with their decision, with reported decreases in worry about breast cancer, but negative impacts on body image and sexuality have also been reported. Additional research is needed to further evaluate the psychosocial impact of RRM.[272] RRM is also associated with long-term physical symptoms, such as lower sensitivity to touch, pain, tingling, infection, and edema.[267] Multidisciplinary consultations are recommended prior to surgery and should include the discussions of the risks and benefits of surgery, and surgical breast reconstruction options. Immediate breast reconstruction is an option following RRM, and early consultation with a reconstructive surgeon is recommended for those considering either immediate or delayed breast reconstruction.[273] Nipple-sparing mastectomy has been suggested to be a safe and effective risk reduction strategy for patients carrying a *BRCA1/2* P/LP variant,[274] although more data and longer follow-up are needed.

The NCCN Guidelines Panel supports discussion of the option of RRM for individuals assigned female at birth on a case-by-case basis. Counseling for this risk-reducing surgery should include discussion of extent of cancer risk reduction/protection, risks associated with surgeries, breast reconstructive options, and management of menopausal symptoms. Since risk of breast cancer remains increased with age in carriers of a *BRCA1/2* P/LP variant,[275] age and life expectancy should also be considered during this counseling, as well as family history. It is important to address the psychosocial and quality-of-life aspects of undergoing risk-reducing surgical procedures.[276]

Chemoprevention

The use of selective estrogen receptor modulators (ie, tamoxifen, raloxifene) has been shown to reduce the risk for invasive breast cancer in individuals considered at high risk for developing breast cancer, especially ER-positive disease.[277-284] However, only limited data are available on the specific use of these agents for primary prevention in patients with *BRCA1/2* P/LP variants. As previously discussed, patients with *BRCA1/2* P/LP variants who are diagnosed with breast cancer have elevated risks for developing contralateral breast tumors. In one of the largest prospective series of carriers of a P/LP *BRCA1/2* variant evaluated, the mean cumulative lifetime risks for contralateral breast cancer were estimated to be 83% for carriers of a P/LP *BRCA1* variant and 62% for

carriers of a P/LP *BRCA2* variant.[103] Patients carrying a P/LP *BRCA1/2* variant who have intact contralateral breast tissue (and who do not undergo oophorectomy or receive chemoprevention) have an estimated 40% risk for contralateral breast cancer at 10 years, though risk is dependent on age of first breast cancer diagnosis.[285] Case-control studies from the Hereditary Breast Cancer Clinical Study Group reported that the use of tamoxifen protected against contralateral breast cancer with an OR of 0.38 (95% CI, 0.19–0.74) to 0.50 (95% CI, 0.30–0.85) among carriers of a P/LP *BRCA1* variant and 0.42 (95% CI, 0.17–1.02) to 0.63 (95% CI, 0.20–1.50) among carriers of a P/LP *BRCA2* variant.[286,287] This translates to an approximately 45% to 60% risk reduction for contralateral tumors among carriers of a P/LP *BRCA1/2* variant with breast cancer. The data were not consistent in regard to the protective effects of tamoxifen in the subset of carriers of a P/LP *BRCA1/2* variant who also underwent oophorectomy. In addition, no data were available on the estrogen receptor status of the tumors. An evaluation of the subset of healthy carriers of a P/LP *BRCA1/2* variant in the Breast Cancer Prevention Trial revealed that breast cancer risk was reduced by 62% in carriers of a P/LP *BRCA2* variant receiving tamoxifen relative to placebo (risk ratio, 0.38; 95% CI, 0.06–1.56).[288] However, an analysis of 288 females who developed breast cancer during their participation in this trial showed that tamoxifen use was not associated with a reduction in breast cancer risk in carriers of a P/LP *BRCA1* variant.[288] These findings may be related to the greater likelihood for development of estrogen receptor-negative tumors in carriers of a P/LP *BRCA1* variant relative to carriers of a P/LP *BRCA2* variant. However, this analysis was limited by the very small number of individuals with a P/LP *BRCA1/2* variant (n = 19; 7% of participants diagnosed with breast cancer). Common single-nucleotide polymorphisms have been identified in genes (*ZNF423* and *CTSO*) that are involved in estrogen-dependent regulation of *BRCA1* expression.[289] These gene variants were associated with alterations in breast cancer risk during treatment with selective estrogen receptor modulators, and may eventually pave the way for predicting the likelihood of benefit with these chemopreventive approaches in individual patients.

The aromatase inhibitors (AIs) exemestane and anastrozole have been demonstrated to be effective in preventing breast cancer in postmenopausal individuals considered to be at high risk of developing breast cancer.[290,291] However, to date, there is little evidence supporting the use of AIs as an effective chemopreventive approach for individuals with a *BRCA1/2* P/LP variant. A retrospective study showed that AIs may reduce the risk of contralateral breast cancer in females with a *BRCA1/2* P/LP variant and ER-positive breast cancer who take AIs as adjuvant therapy, but these data are currently published in abstract form only.[292]

Studies on the effect of oral contraceptive use on breast cancer risk among carriers of a P/LP *BRCA1/2* variant have reported conflicting data. In one case-control study, use of oral contraceptives was associated with a modest but statistically significant increase in breast cancer risk among carriers of a P/LP *BRCA1* variant (OR, 1.20; 95% CI, 1.02–1.40), with breast cancer risk in these carriers being associated with 5 or more years of oral contraceptive use (OR, 1.33; 95% CI, 1.11–1.60), breast cancer diagnosed before 40 years of age (OR, 1.38; 95% CI, 1.11–1.72), and use of oral contraceptives before 1975 (OR, 1.42; 95% CI, 1.17–1.75).[293] Oral contraceptive use was not significantly associated with breast cancer in carriers of a *BRCA2* P/LP variant in this study. In another case-control study, use of oral contraceptives for at least 5 years was associated with a significantly increased risk for breast cancer in carriers of a P/LP *BRCA2* variant (OR, 2.06; 95% CI, 1.08–3.94); results were similar when only the cases with oral contraceptive use on or after 1975 were considered.[294] Oral contraceptive use for at least 1 year was not significantly associated with breast cancer risk in carriers of a P/LP *BRCA1* or *BRCA2* variant in this study. In a third case-control study, the use of low-dose oral contraceptives for at least 1 year was associated with significantly

decreased risks for breast cancer among carriers of a P/LP *BRCA1* variant (OR, 0.22; 95% CI, 0.10–0.49; *P* < .001), though not for carriers of a P/LP *BRCA2* variant.[295] A case control study found an increase in breast cancer risk for *BRCA1* mutation carriers who started oral contraception before the age of 20 years (OR, 1.45; 95% CI, 1.20–1.75; *P* = .0001). Associations after age 20 were not found to be statistically significant.[296]

To summarize, findings from case-control studies are inconsistent regarding the effect of oral contraceptive use on the association of P/LP *BRCA1* or *BRCA2* variant and breast cancer risk. Oral contraceptive use for more than 5 years may be associated with increased risk. Findings from meta-analyses are also conflicting, with several showing that oral contraceptive use is not significantly associated with breast cancer risk in carriers of a P/LP *BRCA1/2* variant,[297-299] while others show mixed results based on subgroup analysis, study type, and population.[300-302] Another 2022 meta-analysis including 12 studies showed that the use of oral contraceptives was associated with an increased risk of breast cancer in carriers of both *BRCA1* and *BRCA2* P/LP variants, particularly in those who used oral contraceptives for 5 years or longer.[303] A study examining a hypothetical cohort of 10,000 females found that the use of combined oral contraceptives was associated with increased breast cancer risk in those with a P/LP *BRCA1* variant, assuming 10 years of continuous oral contraceptive use. The breast cancer risk difference attributable to oral contraceptive use increased throughout life for carriers of a P/LP *BRCA1/2* variant (compared to ovarian and endometrial cancers, which showed decreasing incidences as age increased).[304]

Differences in the study design used by these case-control studies make it difficult to compare outcomes between studies, and likely account for the conflicting results. The design of these studies might have differed with regard to factors such as the criteria for defining the “control” population for the study (eg, non-*BRCA1/2* carriers vs. P/LP variant carriers without a cancer diagnosis), consideration of family history of breast or ovarian cancer, baseline demographics of the population studied (eg, nationality, ethnicity, geographic region, age groups), age of onset of breast cancer, and formulations or duration of oral contraceptives used.

Ovarian/Uterine Cancer Risk Management

Bilateral Salpingo-Oophorectomy

Carriers of a confirmed *BRCA1/2* P/LP variant are at increased risk for both breast and ovarian cancers (including fallopian tube cancer and primary peritoneal cancer).[144,145] Although the risk for ovarian cancer is generally considered to be lower than the risk for breast cancer in carriers of a P/LP *BRCA1/2* variant,[305-307] the absence of reliable methods of early detection and the poor prognosis associated with advanced ovarian cancer have lent support for the performance of bilateral RRSO after completion of childbearing.

A 2014 observational prospective study of 5783 females carrying a P/LP *BRCA1/2* variant showed that ovarian cancer is more prevalent in individuals carrying a *BRCA1* (4.2%) P/LP variant than those carrying a *BRCA2* (0.6%) P/LP variant.[308] In carriers of a P/LP *BRCA1* variant, prevalence of ovarian, fallopian tube, and peritoneal cancers found during risk-reducing surgery was 1.5% for those <40 years of age and 3.8% in those between the ages of 40 and 49 years.[308] The highest incidence rate for carriers of a P/LP *BRCA1* variant was observed between the ages of 50 and 59 years (annual risk, 1.7%); for carriers of a P/LP *BRCA2* variant, the highest incidence rate was observed between the ages of 60 and 69 years (annual risk, 0.6%). A more recent retrospective cohort study including 474 carriers of a P/LP *BRCA1/2* variant who were diagnosed with high-grade serous ovarian cancer showed that age of diagnosis was significantly greater in carriers of a P/LP *BRCA2* variant, compared to carriers of a P/LP *BRCA1* variant (58.4 vs. 53.3 years; *P* = .001).[309] Therefore, the recommended age for RRSO should be younger for

carriers of a P/LP *BRCA1* variant than for carriers of a P/LP *BRCA2* variant.

The effectiveness of RRSO in reducing the risk for ovarian cancer in carriers of a *BRCA1/2* P/LP variant has been demonstrated in a number of studies. For example, results of a meta-analysis involving 10 studies of carriers of a *BRCA1/2* P/LP variant showed an approximately 80% reduction in the risk for ovarian or fallopian tube cancer following RRSO.[310] In a large prospective study of females who carried deleterious *BRCA1/2* variants (N = 1079), RRSO significantly reduced the risk for *BRCA1*-associated gynecologic tumors (including ovarian, fallopian tube, or primary peritoneal cancers) by 85% compared with observation during a 3-year follow-up period (HR, 0.15; 95% CI, 0.04–0.56; *P* = .005).[311] An observational study of 5783 females carrying a P/LP *BRCA1/2* variant showed that risk-reducing oophorectomy reduces risk for ovarian, fallopian tube, or peritoneal cancer by 80% (HR, 0.20; 95% CI, 0.13–0.30) and all-cause mortality by 77% (HR, 0.23; 95% CI, 0.13–0.39).[308] RRSO reduces mortality at all ages in carriers of a P/LP *BRCA1* variant, but among carriers of a P/LP *BRCA2* variant, RRSO is only associated with reduced mortality in those between the ages of 41 and 60 years.[308]

A 1% to 4.3% residual risk for a primary peritoneal carcinoma has been reported in some studies.[170,310,312-315] An analysis of 36 carriers of a *BRCA1/2* P/LP variant who developed peritoneal carcinomatosis following RRSO showed that 86% were carriers of a *BRCA1* P/LP variant specifically.[316] When comparing to 113 carriers of a P/LP *BRCA1/2* variant who did not develop peritoneal carcinomatosis following RRSO, females who eventually developed peritoneal carcinomatosis were older at time of RRSO (*P* = .025) and had a greater percentage of serous tubal intraepithelial carcinoma (STIC) in their RRSO specimen (*P* < .001), supporting the removal of the fallopian tubes as part of the risk-reducing procedure. A systematic review and individual patient data meta-analysis including 17 studies and 3121 patients showed that STIC at RRSO was strongly associated with increased risk of peritoneal carcinomatosis (HR, 33.9; 95% CI, 15.6–73.9; *P* < .001).[317] Further, an analysis from a multicenter prospective cohort study (N = 1083) showed an increased risk for serous and/or serous-like endometrial cancer in females carrying a P/LP *BRCA1* variant who underwent RRSO without hysterectomy.[210]

RRSO may provide an opportunity for gynecologic cancer detection in carriers of a P/LP *BRCA1/2* variant. An analysis of 966 RRSO procedures showed that invasive or intraepithelial ovarian, tubal, or peritoneal neoplasms were detected in 4.6% of carriers of a P/LP *BRCA1* variant and 3.5% of carriers of a P/LP *BRCA2* variant.[318] Carrying a *BRCA1/2* P/LP variant was associated with detection of clinically occult neoplasms during RRSO (*P* = .006). Another study including 2557 asymptomatic carriers of P/LP *BRCA1/2* variant enrolled in the Hereditary Breast and Ovarian Cancer in the Netherlands Study showed that high-grade serous carcinoma was detected in 1.5% of carriers of a P/LP *BRCA1* variant and in 0.6% of carriers of a P/LP *BRCA2* variant at time or RRSO.[319] The fallopian tubes were the primary location of cancer in 73.3% of carriers for whom cancer was detected.

In early studies, RRSO was reported to reduce the risk for breast cancer in carriers of a P/LP *BRCA1/2* variant.[266,310,314,315,320-323] In the case-control international study by Eisen et al, a 56% (OR, 0.44; 95% CI, 0.29–0.66; *P* < .001) and a 43% (OR, 0.57; 95% CI, 0.28–1.15; *P* = .11) breast cancer risk reduction (adjusted for oral contraceptive use and parity) were reported following RRSO in carriers of a *BRCA1* and a *BRCA2* P/LP variant, respectively.[320] A study comparing breast cancer risk in females carrying a P/LP *BRCA1/2* variant who had undergone RRSO with carriers of these P/LP variants who opted for surveillance only also showed reduced breast cancer risk in females who underwent RRSO (HR, 0.47; 95% CI, 0.29–0.77).[315] These studies were further supported by a meta-

analysis that found similar reductions in breast cancer risk of approximately 50% for carriers of a P/LP *BRCA1/2* variant following RRSO.[310]

Results of a prospective cohort study suggested that RRSO may be associated with a greater reduction in breast cancer risk for carriers of a P/LP *BRCA2* variant compared with carriers of a *BRCA1* P/LP variant.[311] Another retrospective analysis including 676 females with stage I or II breast cancer and a P/LP *BRCA1/2* variant showed that oophorectomy was associated with decreased risk of mortality from breast cancer in carriers of a P/LP *BRCA1* variant (HR, 0.38; 95% CI, 0.19–0.77; *P* = .007), but not in carriers of a P/LP *BRCA2* variant (*P* = .23).[324]

The reduction in breast cancer risk following RRSO was questioned in a prospective cohort study from the Netherlands (N = 822), which did not find a statistically significant difference in breast cancer incidence between carriers of a *BRCA1/2* P/LP variant who opted for an RRSO and females who did not, regardless of whether the P/LP variant was *BRCA1* or *BRCA2*.[325] Study investigators argued that previous study findings showing a 50% decrease in breast cancer risk may have been influenced by bias, specifically inclusion of patients with a history of breast or ovarian cancer in the comparison group and immortal person-time bias. One study that corrected for immortal person-time bias as a result of this analysis continued to find a protective effect of RRSO on breast cancer incidence in carriers of a P/LP *BRCA1/2* variant (HR, 0.59; 95% CI, 0.42–0.82; *P* < .001).[326] Another prospective cohort analysis including 1289 carriers of a P/LP *BRCA1/2* variant unaffected with breast cancer (196 eventually being diagnosed) also showed that, when RRSO was treated as a time-dependent variable, it was no longer associated with breast cancer risk.[327] A meta-analysis including 19 studies of the association between RRSO and breast cancer risk and mortality showed a protective effect in studies published earlier than 2016, but not in studies published in 2016 or later (*n* = 3).[321]

Results from one of the earlier studies showed that greater reductions in breast cancer risk were observed in females carrying a P/LP *BRCA1* variant who had an RRSO at ≤40 years of age (OR, 0.36; 95% CI, 0.20–0.64) relative to carriers of a P/LP *BRCA1* variant aged 41 to 50 years who had this procedure (OR, 0.50; 95% CI, 0.27–0.92).[320] A nonsignificant reduction in breast cancer risk was found for females aged ≥51 years, although only a small number of females were included in this group.[320] However, results from another early study also suggested that RRSO after 50 years of age is not associated with a substantial decrease in breast cancer risk.[314] A 2017 study showed that oophorectomy was not significantly associated with decreased risk of breast cancer in carriers of a P/LP *BRCA1/2* variant (*N* = 3722).[328] However, stratified analyses in carriers of a P/LP *BRCA2* variant who were diagnosed with breast cancer before 50 years of age showed that oophorectomy was associated with an 82% reduction in breast cancer (HR, 0.18; 95% CI, 0.05–0.63; *P* = .007). The risk reduction in carriers of a P/LP *BRCA1* variant was not statistically significant (*P* = .51). A 2020 study including 853 premenopausal carriers of a P/LP *BRCA1/2* variant showed the opposite: that premenopausal RRSO decreased breast cancer risk in carriers of a *BRCA1* P/LP variant (HR, 0.45; 95% CI, 0.22–0.92), but not in carriers of a *BRCA2* P/LP variant (HR, 0.77; 95% CI, 0.35–1.67).[329] Analysis for this study began observation 6 months after genetic testing to avoid event-free time bias.

A large case series published in 2021 addressed the permanent exposure hypothesis that has potentially dampened the strength of the conclusions drawn from previous studies on the association between RRSO and breast cancer risk reduction.[330] Specifically, some of these earlier studies assumed that this association remains constant each year following RRSO. This study, which included 876 families with a known *BRCA1* or

BRCA2 P/LP variant, showed that RRSO reduced risk of breast cancer within 5 years following the surgery (HR, 0.28; 95% CI, 0.10–0.63 and HR, 0.19; 95% CI, 0.06–0.71, respectively). More than 5 years after RRSO, breast cancer risk reduction diminished but continued to be significant for carriers of a *BRCA1* P/LP variant (HR, 0.64; 95% CI, 0.38–0.97), while the reduction was no longer statistically significant for carriers of a *BRCA2* P/LP variant (HR, 0.99; 95% CI, 0.84–1.00).

To summarize, studies suggest a benefit of RRSO on breast cancer risk, but the magnitude of the effect based on age remains uncertain.

Two systematic reviews showed that HRT does not negate the reduction in breast cancer risk associated with the surgery.[331,332] One of these reviews showed that breast cancer risk tended to be lower in females who received estrogen only, compared to estrogen plus progesterone (OR, 0.62; 95% CI, 0.29–1.31).[331] It is important to have a discussion about the potential risks and benefits of HRT in carriers of a P/LP variant following RRSO, given the limitations inherent in nonrandomized studies.[333,334]

Salpingectomy (surgical removal of the fallopian tube with delayed oophorectomy) reduces the risk of ovarian cancer in the general population and is an option for premenopausal patients with hereditary cancer risk who are not yet ready for oophorectomy in the context of a clinical trial.[335-337] Salpingectomy is currently not proven to improve outcomes and continues to be a procedure still under investigation. CA-125 and pelvic ultrasound are recommended for preoperative planning. Continuation of combination oral contraceptives or hormonal intrauterine device (IUD) for continued ovarian cancer risk reduction while ovaries remain in place may be considered. Clinical trials of interval salpingectomy with delayed oophorectomy are ongoing (eg, NCT02321228, NCT01907789, NCT04294927).

Some studies suggest a link between *BRCA* P/LP variants and development of serous uterine cancer (primarily with *BRCA1*),[209] although the overall risk for uterine cancer was not increased when controlling for tamoxifen use.[205,206,210] Individuals who undergo hysterectomy at the time of RRSO are candidates for estrogen-alone HRT, which is associated with a decreased risk of breast cancer, compared to combined estrogen and progesterone, which is required when the uterus is left in situ.[331,332,338] Risk of pelvic floor dysfunction or urinary incontinence after hysterectomy is influenced by factors other than hysterectomy alone. Long-term follow-up studies indicate that the risks are <5% if there is no preceding pelvic organ prolapse.[339,340] For patients who choose to undergo RRSO, the provider may discuss the risks and benefits of concurrent hysterectomy, but more data are needed to determine the magnitude of the association between *BRCA* variants and development of serous uterine cancer.

HRT is generally not contraindicated and thus should be discussed with premenopausal patients who do not have a personal history of breast cancer.[341] HRT recommendations should be tailored depending on each patient's personal history of breast cancer and/or breast cancer risk reduction strategies. In patients for whom the uterus is left in place at time of RRSO, there are several hormone replacement options. There is evidence that levonogestrel IUD is associated with lower risk of breast cancer compared to risk of breast cancer from orally administered progestin.[342] However, combination estrogen/progestin HRT continues to be an option after RRSO, though counseling should include bleeding precautions and uterine cancer risk awareness. Combined estrogen with a selective estrogen receptor modulator (eg, bazedoxifene) is also an option.[343]

The NCCN Guidelines Panel recommends RRSO for carriers of a known *BRCA1/2* P/LP variant, typically between 35 and 40 years of age for carriers of a *BRCA1* P/LP variant. Since ovarian cancer onset tends to be

later in carriers of a *BRCA2* P/LP variant, it is reasonable to delay RRSO for management of ovarian cancer risk until between 40 and 45 years of age, unless age at diagnosis in the family warrants earlier age for consideration of this prophylactic surgery.[308] Peritoneal washings should be performed at surgery, and pathologic assessment should include fine sectioning of the ovaries and fallopian tubes.[171,172] The protocol published by CAP (2009) can be consulted for details on specimen evaluation.[344] See the NCCN Guidelines for Ovarian Cancer for treatment of findings (available at www.NCCN.org).

The decision to undergo RRSO is a complex one and should be made ideally in consultation with a gynecologic oncologist, especially when the patient wishes to undergo RRSO before the age at which it is typically recommended. Topics that should be addressed include impact on reproduction, impact on breast and ovarian cancer risk, risks associated with premature menopause (eg, osteoporosis, cardiovascular disease, cognitive changes, changes to vasomotor symptoms, sexual concerns), and other medical issues. Preoperative menopause management consultation may be considered for patients who are premenopausal at time of RRSO.[345,346]

Chemoprevention

With respect to the evidence regarding the effect of oral contraceptives on cancer risks in carriers of a known *BRCA1/2* P/LP variant, case-control studies have demonstrated that oral contraceptives reduced the risk for ovarian cancer by 45% to 50% in carriers of a P/LP *BRCA1* variant and by 60% in carriers of a P/LP *BRCA2* variant.[347,348] Moreover, risks appeared to decrease with longer duration of oral contraceptive use.[348] An analysis of four meta-analyses, one review, one case-control study, and one retrospective cohort study showed that oral contraceptive use was associated with reduced risk of ovarian cancer in carriers of a known *BRCA1/2* P/LP variant.[349] This review also showed that longer duration of use was associated with decreased ovarian cancer risk. A modeling study including hypothetical cohorts of 10,000 females with a P/LP *BRCA1* variant and 10,000 females with a P/LP *BRCA2* variant showed that combined oral contraceptive use was associated with short-term increased risk of breast cancer, but decreased long-term risk of ovarian cancer and endometrial cancer (regardless of variant).[304] However, this study found that the long-term benefit was reduced following menopausal HRT after bilateral salpingo-oophorectomy. Oral contraceptives may be considered for the purpose of ovulation suppression and are not contraindicated for birth control purposes.

Screening

Studies assessing whether ovarian cancer screening procedures are sufficiently sensitive or specific have yielded mixed results. The UK Collaborative Trial of Ovarian Cancer Screening (UKCTOCS), which assessed multimodality screening with transvaginal ultrasound (TVUS) and CA-125 versus either TVUS alone or no screening, showed that multimodality screening is more effective at detecting early-stage cancer; however, after a median of 11 years of follow-up, a significant mortality reduction was not observed.[350,351] In phase II of the UK Familial Ovarian Cancer Screening Study (UK FOCSS), 4348 females with an estimated lifetime ovarian cancer risk no less than 10% underwent ovarian cancer screening via serum CA-125 tests every 4 months (with the risk of ovarian cancer algorithm [ROCA] used to interpret results) and TVUS (annually or within 2 months if abnormal ROCA score).[352] Thirteen patients were diagnosed with ovarian cancer as a result of the screening protocol, with 5 of the 13 patients being diagnosed with early-stage cancer. Sensitivity, positive predictive value, and negative predictive value of the screening protocol for detecting ovarian cancer within 1 year were 94.7%, 10.8%, and 100%, respectively. A third study including 3692 females who were at increased familial/genetic risk of ovarian cancer (ie, known P/LP *BRCA1/2* variant in the family and/or family history of multiple breast and/or ovarian

cancers) showed that a ROCA-based screening protocol (ie, serum CA-125 testing every 3 months with annual TVUS annually or sooner depending on CA-125 test results) identified 6 incidental ovarian cancers, of which 50% were early stage.[353] The results of these studies suggest a potential stage shift when a ROCA-based ovarian cancer screening protocol is followed in high-risk females, though it remains unknown whether this screening protocol impacts survival. TVUS and serum CA-125 screening are recommended for preoperative planning.

Risk Management for Other Cancers

Screening for prostate cancer starting at 40 years of age is recommended for carriers of a P/LP *BRCA2* variant and should be considered for carriers of a P/LP *BRCA1* variant.[179] See the NCCN Guidelines for Prostate Cancer Early Detection (available at www.NCCN.org). General melanoma risk management is also indicated, such as annual full body skin exam and minimizing ultraviolet (UV) exposure. There are no specific screening guidelines for melanoma, though more information can be found at the website for the Skin Cancer Foundation (www.skincancer.org). Information on pancreas screening can be found below under *Hereditary Pancreatic Cancer.*

Other P/LP Variants Associated with Breast/Ovarian Cancer

Prior to 2020, the NCCN Guidelines for Genetic/Familial High-Risk Assessment: Breast, Ovarian, and Pancreatic focused largely on testing criteria for *BRCA1/2, PTEN,* and *TP53* and appropriate risk management for carriers of these P/LP variants. There is now strong evidence that genes beyond *BRCA1/2* confer markedly increased risk of breast and/or ovarian cancers. These genes include *ATM, BARD1, BRIP1, CDH1, CHEK2, MSH2, MSH6, MLH1, PMS2, EPCAM, NF1, PALB2, RAD51C, RAD51D,* and *STK11.* The panel's recommendations for cancer risk management intervention for carriers of P/LP variants associated with breast and/or ovarian cancer risk are based on absolute lifetime risk estimates. Cancer risk management intervention may be recommended when a carrier's absolute risk exceeds that of the average-risk population (ie, 12%–13% for breast cancer and 1%–2% for ovarian cancer, based on SEER registry data[354,355]).[47,356] Strength of the evidence supporting risk estimates should also be evaluated when determining appropriate risk management for carriers of a P/LP variant. For example, prospective cohort studies in a population-based setting can be considered very strong evidence, while limited conclusions can be drawn from case series or studies with small samples.[356]

The age at which breast screening is recommended may be impacted by the presence of risk factors such as family history of breast cancer, especially early-onset breast cancer.[47] In those with a family history of early-onset breast cancer, breast screening may begin 5 to 10 years earlier than the youngest breast cancer diagnosis in the family. In individuals assigned female at birth treated for breast cancer who have not had bilateral mastectomy, breast screening should continue as recommended based on age. Currently there is insufficient evidence to recommend RRM in carriers of moderately penetrant P/LP variants,[47] though this option may be considered and discussed in the presence of a family history of breast cancer. Absolute risk estimates for breast cancer provided in the NCCN Guidelines for Genetic/Familial High-Risk Assessment: Breast, Ovarian, and Pancreatic are for primary breast cancer unless otherwise noted. With the exception of *BRCA2,* risk of hereditary contralateral breast cancer risk decreases once postmenopausal and is equivalent to sporadic breast cancer risk after age 65.[105]

RRSO may be considered when risk of developing ovarian cancer exceeds that of the average-risk population. The panel uses a threshold of 5% for a recommendation to discuss RRSO. For P/LP variants for which lifetime risk estimates are <5% but greater than population risk (eg,

PALB2), RRSO may be considered based on family history.[357] The decision to carry out RRSO should not be made lightly, given the impact of premature menopause.[47] RRSO is recommended for ovarian cancer risk management in carriers of a P/LP variant in an ovarian cancer susceptibility gene. However, some may choose to not receive an RRSO.

The P/LP variants described below may be included concurrently in panel testing (see *Multi-Gene Testing* above). Lower penetrance genes that may be included as part of multi-gene testing but for which there is currently insufficient evidence of an association with breast and/or ovarian cancer include: *FANCC*, *MRE11A*, *MUTYH* heterozygotes, *NBN*, *RECQL4*, *RAD50*, *RINT1, SLX4, SMARCA4*, and *XRCC2*. Risk management recommendations for these genes should take into account family history and other clinical factors. A more comprehensive review of these lower-penetrance genes is described in another publication.[358]

Information regarding testing criteria and risk management for LFS (associated with germline *TP53* P/LP variant) and Cowden syndrome/PHTS (associated with germline *PTEN* P/LP variant) can be found in their respective sections, below.

ATM

P/LP variants in the *ATM* (ataxia-telangiectasia mutated) gene may increase the risk for breast cancer. A meta-analysis including 19 studies showed that the cumulative lifetime risk for primary breast cancer in individuals with an *ATM* P/LP variant is 6% by age 50 years and 33% by age 80 years.[359] An analysis of 251 females who tested positive for ≥1 P/LP variant in a breast cancer susceptibility gene showed that the cumulative lifetime risk for primary breast cancer in individuals with an *ATM* P/LP variant is 31.2% by age 70 years.[360] A comparative modeling analysis published in 2022 showed that the mean model-estimated lifetime risk of developing primary breast cancer was 20.9% (95% CI, 23.4%–31.7%) in females who carry an *ATM* P/LP variant.[361] A meta-analysis of three cohort studies of relatives with ataxia-telangiectasia showed an estimated RR of 2.8 (90% CI, 2.2–3.7; $P < .001$).[362] Other analyses of patients with breast cancer showed that about 1% had an *ATM* P/LP variant.[93,119,124,127,128,363-366] Studies to date suggest lifetime risk of developing primary breast cancer in females who carry an *ATM* P/LP variant in the range of 20% to 30%.[52,119,359,361] Ten-year cumulative risk of developing contralateral breast cancer in females who carry an *ATM* P/LP variant is 4%, though this estimate is based on 7 cases.[105] Therefore, additional studies are needed to confirm and refine this estimate.

The association between specific types of *ATM* genetic variants and breast cancer susceptibility is less clear,[367-370] with some evidence showing that certain missense P/LP variants may act in a dominant-negative fashion to increase cancer risk, relative to truncating P/LP variants.[367,368] A meta-analysis including five studies showed that carriers of an *ATM* P/LP variant have a 38% lifetime risk of developing primary breast cancer, with carriers of the c.7271T>G missense P/LP variant having a 69% risk of developing primary breast cancer by 70 years of age.[52] An analysis from a case-control study (42,671 breast cancer cases and 42,164 controls) showed a significant association between the c.7271T>G variant and primary breast cancer risk (OR, 11.60; 95% CI, 1.50–89.90; $P = .001$).[53] An analysis of 27 families in which P/LP *ATM* variants were identified showed an association between the c.7271T>G variant and increased risk for primary breast cancer (HR, 8.0; 95% CI, 2.3–27.4; $P < .001$).[54]

The 2022 comparative modeling analysis by Lowry et al showed that beginning annual MRI screening at age 30 to 35 years may reduce breast cancer mortality by more than 55% in carriers with a P/LP *ATM* variant.[361] The panel also recommends annual mammogram for carriers with a P/LP *ATM* variant beginning at 40 years of age. Age at which to initiate MRI in carriers with a P/LP *ATM* variant depends on a number of risk factors,

including family history, age, breast density, and patient preference. There are no data on the benefit of RRM for carriers of a P/LP *ATM* variant,[47] but this procedure may be considered based on family history. Results of the case-control WECARE study suggested that radiation exposure may be associated with increased risk for contralateral breast cancer in females who are carriers of very rare *ATM* missense variants.[371] However, these variants are not P/LP, and a meta-analysis including five studies showed that radiation therapy (with conventional dosing) is not contraindicated in patients with a heterozygous *ATM* P/LP variant.[52] Therefore, radiation therapy does not need to be avoided in these carriers who are diagnosed with cancer.

Large studies of patients with ovarian cancer have shown that there may be a slightly increased risk for ovarian cancer in carriers of an *ATM* P/LP variant,[160,364,372,373] but there is currently insufficient evidence to recommend RRSO in these carriers.[356] Given the association between *ATM* and development of the autosomal recessive condition ataxia telangiectasia, counseling for carriers of *ATM* P/LP variants should include a discussion of reproductive options. *ATM* P/LP variants have been found in patients with pancreatic cancer, with a lifetime risk of about 5% to 10% (see *Hereditary Pancreatic Cancer*, below).[200,374,375] There is emerging evidence that *ATM* P/LP variants are associated with increased risk for prostate cancer.[178,179,185,376-378] Prostate cancer screening may be considered at age 40 years (see the NCCN Guidelines for Prostate Cancer Early Detection; available at www.nccn.org).

BARD1

A modest association between breast cancer and P/LP variants in the *BRCA1*-associated RING domain 1 (*BARD1*) gene has been found in case-control studies with a prevalence rate of 0.1% to 0.51% in patients with breast cancer.[93,363,364,379-381] Studies show that *BARD1* is prevalent in 0.41% to 0.90% of patients with triple-negative breast cancer.[93,126-128] The Breast Cancer Association Consortium and the CARRIERS case-control studies also found associations between a *BARD1* P/LP variant and increased risk of triple-negative breast cancer (0.42%; OR, 9.29; 95% CI, 4.58–18.85 and 0.41%; OR, 3.18; 95% CI, 1.16–7.42, respectively).[127,128] The panel recommends annual mammogram for carriers of a P/LP *BARD1* variant beginning at 40 years of age, with consideration of annual breast MRI. Age at which to initiate MRI in carriers with a P/LP *BARD1* variant depends on a number of risk factors, including family history, age, breast density, and patient preference. RRM is not recommended in carriers of a *BARD1* P/LP variant, but this procedure may be considered based on family history.

BRIP1

Panel testing of germline DNA in patients with ovarian cancer has shown that the prevalence rate of P/LP variants in the *BRCA1* interaction protein C-terminal helicase 1 gene (*BRIP1*), a Fanconi anemia gene, is about 1%.[160,364,372,373,382] An analysis of 3236 females with epithelial ovarian cancer, 3431 controls, and 2000 unaffected high-risk females from an ovarian cancer screening trial (UKFOCSS) showed that *BRIP1* is associated with an increased risk for ovarian cancer ($P < .001$), with the RR for invasive epithelial ovarian cancer being 11.22 (95% CI, 3.22–34.10; $P < .001$) and 14.09 for high-grade serous disease (95% CI, 4.04–45.02; $P < .001$).[383] A German study including 706 patients with ovarian cancer who do not carry a P/LP *BRCA1/2* variant showed a significant association between a *BRIP1* P/LP variant and ovarian cancer risk (OR, 20.97; 95% CI, 12.02–36.57; $P < .0001$), including late-onset ovarian cancer risk, with the highest OR for ovarian cancer diagnosed after age 60 (OR, 29.91; 95% CI, 14.99–59.66; $P < .0001$).[384] An analysis of an Icelandic population (656 ovarian cancer cases, 3913 controls) also showed an association between *BRIP1* and increased risk for ovarian cancer (OR, 8.13; 95% CI, 4.74–13.95; $P < .001$).[385] The cumulative lifetime risk of developing ovarian cancer by 80 years of age in carriers of

a *BRIP1* P/LP variant is estimated to be 5.8% (95% CI, 3.6–9.1),[383] though lifetime risk of developing ovarian cancer may also be as high as 12%.[356] The panel recommends RRSO in carriers of a *BRIP1* P/LP variant at 45 to 50 years of age. A discussion about risk-reducing surgery may be initiated earlier if there is a family history of early-onset ovarian cancer. Ultimately, large prospective trials are needed to make a firm age recommendation regarding when a discussion about RRSO should begin in these variant carriers.

Regarding breast cancer, a case-control study including 10,901 patients with triple-negative breast cancer showed that *BRIP1* was prevalent in 0.43% of cases.[126] The panel has determined that more evidence is needed to provide breast screening recommendations in these carriers. *BRIP1* is associated with Fanconi anemia (group FANCJ), inherited in an autosomal recessive manner. Therefore, counseling for carriers of *BRIP1* P/LP variants should include a discussion of reproductive options.

CDH1

Germline P/LP variants in *CDH1* are associated with hereditary diffuse gastric cancer and lobular breast cancer, and studies have reported a cumulative lifetime risk for breast cancer of 39% to 52%.[94-96,386-388] Given the considerable risk for lobular breast cancer in carriers of a *CDH1* P/LP variant, the panel recommends screening with annual mammogram (or consideration of breast MRI) beginning at 30 years of age. Alternatively, screening may begin 5 to 10 years earlier than the youngest breast cancer diagnosis in the family. RRM may be discussed with these carriers.

There is controversy over how best to manage gastric cancer risk in individuals harboring a *CDH1* P/LP variant in the absence of a family history of gastric cancer. A small study found that more than half of the individuals with a *CDH1* P/LP variant who lacked a family history of gastric cancer had early-stage signet ring cell adenocarcinoma identified at the time of risk-reducing gastrectomy.[389] A retrospective review including 75 families with a known *CDH1* P/LP variant showed that penetrance for lifetime risk of gastric cancer is associated with positive family history.[390] See the NCCN Guidelines for Gastric Cancer (available at www.NCCN.org) for screening recommendations for gastric cancer for individuals with a *CDH1* P/LP variant. A report of two cases showed that *CDH1* P/LP variant may also be associated with cleft lip with or without cleft palate.[391]

CHEK2

Another breast cancer susceptibility gene that has been identified is *CHEK2* (cell cycle checkpoint kinase 2). Panel testing of germline DNA in large samples of patients with primary breast cancer has shown that the prevalence rate of a *CHEK2* P/LP variant is about 1% to 2%.[119,363-366,373] Deleterious *CHEK2* P/LP variants have been reported to occur with a higher frequency in Northern and Eastern European countries compared with North America.[358,392-394] The cumulative lifetime risk for primary breast cancer in females with *CHEK2* P/LP variants and familial breast cancer has been estimated to range from approximately 20% to 40%, and is higher in females with stronger family histories of breast cancer than in those without.[360,361,395,396] The estimated RR for primary breast cancer, based on data from two large case-control studies, was 3.0 (90% CI, 2.6–3.5).[362] The Breast Cancer Association Consortium and the CARRIERS case-control studies showed associations between a *CHEK2* P/LP variant and increased risk of ER-positive primary breast cancer (OR, 2.67; 95% CI, 2.30–3.11 and OR, 2.60; 95% CI, 2.05–3.31, respectively).[127,128] The BRIDGES study showed that carrying a *CHEK2* P/LP variant was associated with all breast cancer subtypes except for triple-negative breast cancer.[119]

Studies investigating the association between primary breast cancer risk and specific *CHEK2* variants have primarily been based on the truncating variant 1100delC. An analysis from the Copenhagen General Population

Study (N = 86,975) showed that *CHEK2* 1100delC heterozygotes had an increased risk for primary breast cancer when analyses were stratified by age and sex (HR, 2.08; 95% CI, 1.51–2.85).[397] A case-control study (10,860 cases and 9,065 controls) carried out by the CHEK2 Breast Cancer Case-Control Consortium of Europe and Australia showed that the 1100delC variant is associated with increased risk for primary breast cancer, even in females unselected for family history (OR, 2.34; 95% CI, 1.72–3.20; *P* < .001).[398] Another case-control study (44,777 cases and 42,997 controls) showed that heterozygous 1100delC carriers have a significantly increased risk of developing ER-positive breast cancer (OR, 2.55; 95% CI, 2.10–3.10; *P* < .001), but not ER-negative breast cancer (OR, 1.32; 95% CI, 0.93–1.88; *P* = 0.12).[399] Results from a meta-analysis including 18 case-control studies (26,336 cases and 44,219 controls) showed that the missense variant I157T is associated with a modestly increased risk for primary breast cancer (OR, 1.58; 95% CI, 1.42–1.75; *P* < .001).[400] A retrospective cohort study including 3783 carriers of a *CHEK2* P/LP variant showed that primary breast cancer risk was elevated in carriers of c.444 + 1G>A (OR, 2.63; 95% CI, 1.59–4.35; *P* < .001), ex8_9del (OR, 2.36; 95% CI, 1.53–3.64; *P* < .001), p.R117G (OR, 1.65; 95% CI, 1.12–2.44; *P* = .01), and 1100delC variants (OR, 1.76; 95% CI, 1.55–2.00; *P* < .001), compared to *CHEK2* wild-type.[401]

Ten-year cumulative risk of developing contralateral breast cancer in carriers of a *CHEK2* P/LP variant is 6-8%.[105,402] The 15-year cumulative risk of developing contralateral breast cancer in premenopausal individuals who carry a *CHEK2* P/LP variant is 20.5% (95% CI, 8.9%–47.4%), though this estimate is based on 7 cases and a wide confidence interval.[105] The risk of metachronous contralateral breast cancer in women >65 years of age is not significantly different compared to non-carriers. Risk of contralateral breast cancer is higher if the primary breast cancer was ER-positive.[403]

The 2022 comparative modeling analysis by Lowry et al showed that beginning annual MRI screening at age 30 to 35 years may reduce breast cancer mortality by more than 55% in carriers with a P/LP *CHEK2* variant.[361] The panel also recommends annual mammogram for carriers of a P/LP *CHEK2* variant beginning at 40 years of age. Age at which to initiate MRI in carriers with a P/LP *CHEK2* variant depends on a number of risk factors, including family history, age, breast density, and patient preference. There are no data on the benefit of RRM for carriers of a P/LP *CHEK2* variant, but this procedure may be considered based on family history.

There is emerging evidence that *CHEK2* P/LP variants are associated with increased risk for prostate cancer.[397,403,404] Prostate cancer screening may be considered at age 40 years (see the NCCN Guidelines for Prostate Cancer Early Detection; available at www.nccn.org).

MLH1, MSH2, MSH6, PMS2, EPCAM

Lynch syndrome results from a germline P/LP variant in 1 of 4 DNA mismatch repair (MMR) genes (*MLH1*, *MSH2*, *MSH6*, or *PMS2*).[405] Additionally, deletions in the *EPCAM* gene, which lead to hypermethylation of the *MSH2* promoter and subsequent *MSH2* silencing, cause Lynch syndrome.[406,407] Females with Lynch syndrome are at heightened risk for endometrial cancer.[408-411] With a lifetime risk of up to 60%, endometrial cancer is the second most common cancer in females with Lynch syndrome.[409] For ovarian cancer, estimates vary depending on the specific gene, with risk estimates ranging from 4% to 20% for *MLH1*, 8% to 38% for *MSH2/EPCAM*, and ≤1% to 13% for *MSH6*.[408,412-415] Risk for ovarian cancer is not increased in carriers of a P/LP *PMS2* variant.[415]

TVUS and serum CA-125 testing to screen for ovarian cancer in postmenopausal individuals has not been shown to be sufficiently sensitive or specific to warrant a routine recommendation.[416-418] Since there is no effective screening for ovarian cancer, individuals should be

educated on the symptoms that may be associated with the development of ovarian cancer, such as pelvic or abdominal pain, bloating, increased abdominal girth, difficulty eating, early satiety, or increased urinary frequency or urgency. Symptoms that persist for several weeks and are a change from baseline should prompt physician evaluation. Bilateral salpingo-oophorectomy (BSO) may reduce the incidence of ovarian cancer.[417,419-423] The decision and timing of BSO as an option should be individualized based on whether childbearing is complete, menopausal status, comorbidities, family history, patient preference, and Lynch syndrome gene, as risks for ovarian cancer vary by mutated gene. Estrogen replacement after premenopausal oophorectomy may be considered. There is insufficient evidence to recommend RRSO in *MSH6* and *PMS2* P/LP variant carriers. Risk reduction agents should be considered, with detailed discussion between the physician and patient outlining the associated risks and benefits.

While studies have found that 42% to 51% of breast cancers in patients with Lynch syndrome are mismatch repair deficient (dMMR) with abnormal immunohistochemistry (IHC) corresponding to their germline pathogenic MMR gene variant,[424,425] there are insufficient data supporting an increased risk for breast cancer for patients with Lynch syndrome.[127,128,412,415,426-428]

Patients of reproductive age should be advised regarding their options for prenatal diagnosis and assisted reproduction, including PGT. This discussion should include known risks, limitations, and benefits of these technologies. If both partners are a carrier of a P/LP variant in the same MMR or *EPCAM* gene, then they should also be advised about the risk for constitutional MMR deficiency (CMMRD) syndrome, a rare recessive syndrome.[429] More information regarding Lynch syndrome can be found in the NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal (available at www.NCCN.org).

NF1

Neurofibromatosis type 1 (NF1) is an autosomal dominant hereditary cancer syndrome that is caused by an *NF1* P/LP variant. NF1 is a neurocutaneous syndrome characterized by café-au-lait spots and axillary/inguinal freckling, associated with non-cancerous tumors of the nerve tissues. Individuals with NF1 have an increased risk for malignant peripheral nerve sheath tumors, other central nervous system (CNS) tumors, and gastrointestinal stromal tumors.[430-434] A population-based study in Finland of 1404 patients with NF1 showed an estimated lifetime cancer risk of 59.6%.[430] This study showed a significant association between NF1 and increased risk for breast cancer (SIR, 3.04; 95% CI, 2.06–4.31; $P < .001$). Among patients with breast cancer, NF1 was associated with poorer survival, with 5-year survival rates for patients with NF1 being 67.9%, compared to 87.8% in patients without NF1. Excess incidence was highest in females <40 years of age (SIR, 11.10; 95% CI, 5.56–19.50; $P < .001$). A population-based study in England of 848 patients with NF1 also showed an increased risk for breast cancer (SIR, 3.5; 95% CI, 1.9–5.9), especially among females <50 years (SIR, 4.9; 95% CI, 2.4–8.8).[435]

Given the increased risk for early-onset breast cancer in carriers of these P/LP variants, annual breast screening with mammography should begin at 30 years of age.[434,436] Screening with breast MRI could also be considered. The presence of neurofibromas in the breast may lead to false-positive MRI results, but more data are needed to determine the sensitivity and specificity of breast MRI in individuals with NF1. A prospective study of patients with NF1 from the United Kingdom (N = 448) showed that breast cancer risk in carriers of these P/LP variants is not significantly increased at ≥50 years of age.[433] Case-control analyses of females with NF1 from England showed that RR estimates for women aged 30 to 39 years was 6.5 (95% CI, 2.6–13.5) and 4.4 for women aged 40 to 49 years (95% CI, 2.5–7.0).[437] RR estimates then drop for women

aged 50 to 59 years (RR, 2.6; 95% CI, 1.5–4.2) and continue to drop as age increases (RR, 1.9; 95% CI, 1.0–3.3 for women aged 60–69 years and RR, 0.8; 95% CI, 0.2–2.2 for women aged 70–79 years). These studies show that, beginning at age 50, breast cancer risk in women with NF1 may not significantly differ from that of women in the general population. Therefore, breast MRI screening in patients with NF1 may be discontinued at 50 years of age. There are no data regarding the benefit of RRM for carriers of *NF1* P/LP variants. Therefore, RRM is not recommended in these patients, but this procedure may be considered based on family history. Complications related to NF1 (eg, neurologic complications) may appear early in life, and these have the potential to be severe.[438] Therefore, referral to a neurofibromatosis specialist for management is recommended.[434]

PALB2

PALB2 (partner and localizer of *BRCA2*) is a Fanconi anemia gene. *PALB2* P/LP variants are associated with increased risk for breast cancer, with studies of patients with breast cancer showing that 0.4% to 3% harbor a *PALB2* P/LP variant.[93,123,363-366,373,379,439,440] A meta-analysis of three studies estimated an RR of 5.3 (90% CI, 3.0–9.4),[362] while the most robust analysis to date included 524 families with a known P/LP *PALB2* variant and estimated an RR of 7.18 (95% CI, 5.82–8.85) for female breast cancer.[92] The Breast Cancer Association Consortium study, CARRIERS study, and BRIDGES study all showed associations between a *PALB2* P/LP variant and increased risk of triple-negative breast cancer.[119,127,128] *PALB2* P/LP variant is associated with a 41% to 60% lifetime risk of breast cancer.[91-93] However, an analysis of 251 females who tested positive for ≥1 P/LP variant in a breast cancer susceptibility gene showed that the cumulative lifetime risk for breast cancer in individuals with an *PALB2* P/LP variant was lower, at 29.4% by age 70 years.[360] The risk increases with increasing number of relatives affected with breast cancer. The analysis, which included 524 families with a known P/LP *PALB2* variant, showed that lifetime risk of breast cancer is as high as 76% when there is a family history of two first-degree relatives with breast cancer.[92] In a study of patients with breast cancer from Poland who underwent genetic testing, contralateral breast cancer was reported in 10% of *PALB2* carriers.[440] This study also showed that 10-year survival among *PALB2* carriers with breast cancer was 48%, compared to 72% in carriers of a *BRCA1* P/LP variant and 75% in non-carriers ($P < .001$). The cumulative lifetime risk for male carriers of a P/LP *PALB2* variant is 0.9% (by age 70).[92]

Ten-year cumulative risk of developing contralateral breast cancer in carriers of a *PALB2* P/LP variant is 5% to 8%.[105,402] The 15-year cumulative risk of developing contralateral ER-negative breast cancer in premenopausal individuals who carry a *PALB2* P/LP variant is 35.5% (95% CI, 15.0%–84.0%), though this estimate is based on 4 cases and a wide confidence interval.[105] The risk of contralateral breast cancer in carriers of a *PALB2* P/LP variant is only elevated in ER-negative disease. The risk of metachronous contralateral breast cancer in women >65 years of age is also not significantly different compared to non-carriers.

The panel recommends annual mammogram for carriers of a *PALB2* P/LP variant assigned female at birth beginning at 30 years of age. Breast MRI screening may also be considered. RRM for carriers of a *PALB2* P/LP variant may be considered. For individuals assigned male at birth, breast cancer screening similar to that for carriers of a *BRCA1* P/LP variant is reasonable.

Some studies suggest an association between *PALB2* and increased ovarian cancer risk.[160,441-443] The most robust data to date showing an association between *PALB2* and increased ovarian cancer risk come from the international study, which included 524 families with a known P/LP *PALB2* variant.[92] This study showed a 5% lifetime risk of ovarian cancer in carriers of a *PALB2* P/LP variant. RRSO may be considered in carriers of a *PALB2* P/LP variant starting at 45 to 50 years of age.[444,445]

PALB2 is associated with Fanconi anemia, inherited in an autosomal recessive manner.[446] Therefore, counseling for carriers of *PALB2* P/LP variants should include a discussion of reproductive options.

RAD51C and RAD51D

Genes in the *RAD51* protein family are involved in homologous recombination and DNA repair. *RAD51C* and *RAD51D* have been shown to be associated with increased risk for ovarian cancer. Panel testing of germline DNA in females with ovarian cancer has shown that the prevalence rate of the *RAD51C* or *RAD51D* P/LP variant is about 1%.[160,364,372,382] In a comparison of 1132 probands with a family history of ovarian cancer and 1156 controls, *RAD51C* was associated with an increased risk for ovarian cancer (RR, 5.88; 95% CI, 2.91–11.88; $P < .001$).[447] Analyses from the same trial (911 probands and 1060 controls) also showed an association between *RAD51D* and increased risk for ovarian cancer (RR, 6.30; 95% CI, 2.86–13.85; $P < .011$).[448] In a case-control analysis of 3429 females with epithelial ovarian cancer and 2772 controls, both *RAD51C* (OR, 5.2; 95% CI, 1.1–24; $P = .035$) and *RAD51D* (OR, 12.0; 95% CI, 1.5–90; $P = .019$) were associated with an increased risk for ovarian cancer.[449] A study including 6178 and 6690 families with a known P/LP *RAD51C* and *RAD51D* variant, respectively, showed that the cumulative risk of developing ovarian cancer by age 80 was 11% for carriers of a *RAD51C* P/LP variant and 13% for carriers of a *RAD51D* P/LP variant. [450]

The panel recommends RRSO in carriers of *RAD51C* and *RAD51D* P/LP variants starting at 45 to 50 years of age. A discussion about risk-reducing surgery may be initiated earlier if there is a family history of early-onset ovarian cancer. As with *BRIP1* P/LP variants, large prospective trials are needed to make a firm age recommendation regarding when a discussion about RRSO should begin in carriers of *RAD51C* and *RAD51D* P/LP variants.[356]

Regarding breast cancer, studies have shown prevalence rates of 0.23% to 0.45% for *RAD51C* and 0.29% to 0.38% for *RAD51D* in patients with triple-negative breast cancer.[123,126,451] Two large case-control analyses showed that both *RAD51C* and *RAD51D* P/LP variants were significantly associated with triple-negative disease.[93,119] The Breast Cancer Association Consortium study and the CARRIERS study showed associations between increased risk for ER-negative breast cancer and both *RAD51C* P/LP variant (OR, 3.99; 95% CI, 2.20–7.26 and OR, 2.19; 95% CI, 0.97–4.49, respectively) and *RAD51D* P/LP variant (OR, 2.92; 95% CI, 1.47–5.78 and OR, 3.93; 95% CI, 1.40–10.29, respectively), with prevalence rates of 0.26% and 0.24% for *RAD51C*, respectively, and 0.17% and 0.18% for *RAD51D*, respectively.[127,128] The panel recommends annual mammogram for carriers of a P/LP *RAD51C* and *RAD51D* variant beginning at 40 years of age, with consideration of annual breast MRI. *RAD51C* is associated with Fanconi anemia, inherited in an autosomal recessive manner. Therefore, counseling for carriers of a *RAD51C* P/LP variant should include a discussion of reproductive options.

STK11

Germline *STK11* P/LP variants are associated with Peutz-Jeghers syndrome (PJS), an autosomal dominant disorder characterized by gastrointestinal polyps, mucocutaneous pigmentation, and elevated risk for gastrointestinal cancers as well as breast and non-epithelial ovarian cancers, such as Sertoli-Leydig tumors. Breast cancer risk in females with PJS is 8% at 40 years of age, 13% at 50 years of age, 31% at 60 years of age, and 45% at 70 years of age.[97] Though there are no data on the benefit of RRM for carriers of *STK11* P/LP variants, RRM may be considered for these patients. Absolute risk of developing non-epithelial ovarian cancer (sex cord with annular tubules) is 18% to 21%.[97,98] Information regarding screening for patients with PJS can be found in the NCCN Guidelines for Genetic/Familial High-Risk Assessment: Colorectal (available at www.NCCN.org).

Emerging Evidence

A systematic review of 21 papers including 47 patients with biallelic P/LP variants in *NTHL1* showed that 55% of the female patients were diagnosed with breast cancer.[452] Another study including 29 carriers of biallelic *NTHL1* P/LP variants showed that 60% of females were diagnosed with breast cancer.[453] Though breast cancer risk may be elevated, the evidence currently does not support screening beyond that which is recommended for the general population.

In a study including 3422 patients with breast or ovarian cancer who underwent tumor and germline sequencing, a *RAD51B* P/LP variant was found in 0.26%, which is comparable to prevalence rates for *RAD51C* and *RAD51D*.[454] Breast screening may be considered in these carriers.

NCCN Genetic Testing Criteria

The NCCN genetic testing criteria for high-penetrance breast, ovarian, pancreatic, and prostate cancer are organized into three sections: 1) testing is clinically indicated; 2) testing may be considered; and 3) there is a low probability of testing results having documented clinical utility (ie, finding of high-penetrance genes). The testing criteria listed are for cancer susceptibility genes with strong or moderate evidence of actionability for breast, ovarian, pancreatic, and prostate cancer (eg, *BRCA1/2, CDH1 PALB2, PTEN, STK11,* and *TP53* for breast cancer; additionally, testing criteria for LFS and Cowden syndrome continue to be contained in their own dedicated sections; see below). Included genes may change with emerging clinical data. Further, the personal and/or family history criteria included may suggest the possibility of additional syndromes and would necessitate additional unlisted genes to be evaluated.

The NCCN Panel recommends that individuals from a family with a known P/LP variant in a breast, ovarian, pancreatic, and/or prostate cancer susceptibility gene be tested for the known variant. However, multigene panel testing is often indicated in these individuals if the family history suggests a different syndrome in addition to the known variant. In individuals from a family without a known P/LP variant, germline multigene testing is recommended for those individuals who meet the testing criteria described in the *Hereditary Cancer Testing Criteria* section in the algorithm. Multi-gene testing may be considered for individuals who meet testing criteria and who previously underwent single-gene and/or absent deletion duplication analysis but tested negative. Both first- and second-degree relatives of individuals who meet these testing criteria are also eligible for testing, except for second-degree relatives of individuals with pancreatic cancer or prostate cancer, for whom prior probability of a high-penetrance cancer susceptibility gene is low in the absence of additional family history of cancer; only first-degree relatives of these affected individuals should be offered testing, unless indicated based on additional family history.

Testing Criteria Related to Prostate Cancer

Approximately 11% of patients with prostate cancer and at least 1 additional primary cancer carry germline P/LP variants associated with increased cancer risk.[376] As described above, germline *BRCA1/2* P/LP variants are associated with increased risk for prostate cancer (see *BRCA-Related Breast/Ovarian Cancer Syndrome*, above).[176-179] There is emerging evidence that *ATM* and *CHEK2* P/LP variants are associated with increased risk for prostate cancer.[178,179,185,376-378,403] *HOXB13* P/LP variants have also been found in 1.4% to 4.5% of patients with prostate cancer.[178,376,455] Prostate tumors with intraductal or cribriform histology may have increased prevalence of somatic MMR gene alterations.[456] In addition, limited data suggest that germline homologous DNA repair gene mutations may be more common in prostate tumors of ductal or intraductal origin.[457] Studies examining the association between carrying a germline *BRCA2* P/LP variant and intraductal histology have been conflicting.[458,459] By definition, intraductal carcinoma includes cribriform proliferation of

malignant cells, as long as they remain confined to a preexisting gland that is surrounded by basal cells. These features are seen frequently with an adjacent invasive cribriform component and would be missed without the use of basal cell markers.

Testing criteria related to prostate cancer include diagnosis of metastatic prostate cancer, as well as diagnosis of prostate cancer in an individual with Ashkenazi Jewish ancestry or suspicious family history (ie, breast cancer that is triple-negative or diagnosed at an early age or in a male blood relative, ovarian cancer, pancreatic cancer, metastatic or high- or very-high-risk prostate cancer).[179] Any patient in the high- or very-high-risk stratification group as defined in the NCCN Guidelines for Prostate Cancer (available at www.NCCN.org) is also eligible for testing without any additional testing criteria. Consistent with the NCCN Guidelines for Prostate Cancer (available at www.NCCN.org), genetic testing may be considered in individuals diagnosed with intermediate-risk prostate cancer with intraductal/cribriform histology.

Systemic Therapy Decision-Making

Some of the NCCN treatment guidelines for *BRCA*-related cancers (Breast, Ovarian, Pancreatic Adenocarcinoma, Prostate; available at www.NCCN.org) recommend treatment with PARP (poly ADP-ribose polymerase) inhibitors for patients with germline or somatic *BRCA1/2* P/LP variants, as PARP inhibitors have been demonstrated to be active in these patients. These agents include olaparib[460,461] and talazoparib[462] for HER2-negative metastatic and as adjuvant treatment for high-risk HER2-negative breast cancer (olaparib only); niraparib,[463] olaparib,[464,465] and rucaparib[466,467] for chemotherapy-refractory ovarian cancer; olaparib[468] and rucaparib[469] for metastatic castration-resistant prostate cancer that has progressed following previous treatment; and olaparib and rucaparib as maintenance therapy options for metastatic pancreatic cancer.[470,471] Even though the focus of these Guidelines continues to be on management of breast, ovarian, and/or pancreatic cancer risk in individuals with associated hereditary syndromes, the Guidelines now identify intent to aid in systemic therapy and surgical decision-making as a scenario in which germline testing is clinically indicated. If a P/LP variant is detected through tumor profiling that has clinical implications if identified in the germline, then germline testing for this variant is indicated.

Founder Mutations

The rate of the three founder P/LP variants in those of Ashkenazi Jewish ancestry is 2.2% to 2.5%.[472-474] Studies have shown that genetic testing based on clinical guidelines emphasizing family history of breast, ovarian, pancreatic, prostate, or other cancers missed about 38% to 56% of P/LP variant carriers in those of Ashkenazi ancestry.[472,473,475,476] Therefore, there is some evidence to support population-based genetic testing for individuals with Ashkenazi Jewish ancestry. However, there are concerns about the demand on genetic counseling resources, the preparedness of health care professionals to provide cancer genetic counseling and management, and participants' fears and concerns about testing, including those regarding privacy, stigmatization, and the need for appropriate medical and or surgical treatment in patients and family members found to have a founder P/LP variant. Thus, universal testing for founder *BRCA1/2* P/LP variants in individuals of Ashkenazi Jewish ancestry, regardless of personal or family history, should be offered primarily in the setting of longitudinal research studies. If there is no access to longitudinal studies, then testing may be offered when pre- and post-test genetic counseling are available (see above). There remains a vital need for longitudinal data from research studies exploring various methods of providing population-based genetic testing of individuals with Ashkenazi Jewish ancestry in the United States.

In addition to the *BRCA1* and *BRCA2* pathogenic variants (PVs) in those of Ashkenazi ancestry, there are other ancestries in which founder

mutations have been identified. In these circumstances, the decision to test will depend on the prevalence of the PV in the local population, family history, clinical features, and age of cancer diagnosis. Examples where ancestry may, along with personal and/or family history, contribute to decisions about genetic testing include the following associations: numerous *BRCA1* and *BRCA2* PV in those of Spanish, Mexican, Central and South American descent[477-479]; *BRCA1* PV and Polish ancestry[480,481]; *BRCA1* and *BRCA2* PV and Bahamian ancestry[482]; *BRCA2* PV and Icelandic ancestry[479]; *BRCA1* and *BRCA2* PV in those of French Canadian ancestry[479]; and *BRCA1 and BRCA2* PV and Hungarian ancestry.[479] While emerging data derived from populations of Asian, Middle Eastern, and African origin have documented recurring mutations in *BRCA1* and *BRCA2* genes,[483-485] population allele frequency data are not yet available to inform testing individuals based solely on ancestry in the absence of personal and/or family history. Other founder mutations that are not *BRCA1* and *BRCA2* include the *TP53* PV c.1010G>A (p.Arg337His) PV, which has been observed in a subset of those of Brazilian ancestry,[486] and *CDKN2A* founder c.225_243del (p.Ala76fs) in those of Dutch ancestry.[487]

Breast Cancer Population Testing

In 2019, the American Society of Breast Surgeons published a consensus statement recommending genetic testing for all patients with breast cancer.[488] This recommendation was based on studies showing that criteria in testing guidelines miss some patients with breast cancer who harbor a P/LP variant[489,490] and that population-based multi-gene testing is more cost-effective than testing based on personal and family history criteria.[41,491] However, only 4.4% of patients with a high-penetrance mutation (ie, *BRCA1/2, PALB2, TP53, PTEN*) were missed in the Beitsch et al study.[489,492] Analyses from studies of postmenopausal patients with breast cancer showed rates of 3.6% to 5.6% harboring a P/LP variant.[493,494] Further studies have reported that about 7% of those aged ≤65 years harbor a P/LP variant that is highly or moderately penetrant for breast cancer.[493,495] A follow-up analysis of one of these studies examined age 60 as a cut-off for universal testing of patients with breast cancer and found that 8.2% of these patients harbor a P/LP variant associated with breast cancer.[496] In this analysis, about 2% of patients diagnosed with breast cancer at age ≤60 years who did not meet other testing criteria harbored a highly penetrant P/LP variant associated with breast cancer. This percentage increased to about 5% when expanding the genes to include *ATM*, *CHEK2*, and *NF1*. It is not likely that patients diagnosed with breast cancer >60 years who do not meet other testing criteria will harbor a highly penetrant P/LP variant associated with breast cancer.

Additional tailoring of testing criteria in patients with breast cancer could be done based on histopathology or the presence of multiple primary breast cancers. An analysis of females >65 years (N = 26,707) from population-based case-control studies showed that 3.42% of females with ER-negative breast cancer and 3.01% of women with triple-negative breast cancer harbored a P/LP variant in a high-penetrance breast cancer susceptibility gene (*BRCA1, BRCA2,* and *PALB2*).[497] Multiple studies also show that individuals with multiple primary breast cancers may be more likely than individuals with a single breast cancer to harbor a P/LP variant associated with breast cancer (7.1%–13.2% vs. 4.2%–9.4%).[366,498,499] For the 2023 Guidelines update, the panel expanded the testing criterion for multiple primary breast cancers (synchronous or metachronous) to apply to all patients with breast cancer regardless of age of initial breast cancer diagnosis, which formerly applied only to patients with breast cancer diagnosed at ages 46 to 50 years.

The panel continues to endorse a risk-stratified approach and does not endorse universal testing of all patients with breast cancer due to limitations of this approach, such as low specificity, shortages in trained genetics health professionals to provide appropriate pre- and post-test genetic counseling, and lack of evidence to support risk management for

genes included in many multi-gene panels. Though all patients with breast cancer should be evaluated to determine the appropriateness of germline genetic testing, testing should ultimately be based on patient characteristics, such as those specified in the *Testing Criteria for High-Penetrance Breast Cancer Susceptibility Genes* in the algorithm.[492]

Probability Models

Decision models developed to estimate the likelihood that a *BRCA1/2* P/LP variant is present include BRCAPRO,[500,501] Penn II,[502] and the Breast and Ovarian Analysis of Disease Incidence and Carrier Estimation Algorithm (BOADICEA).[500] Validated clinical and family history-based models that incorporate PRS are also emerging as precision risk estimation tools.[503-505] A lifetime risk for breast cancer of 20% to 25% or greater as assessed by models based largely on family history has been used in some guidelines to identify females as being at high risk for breast cancer. For example, this risk threshold was used in updates to the American Cancer Society (ACS) guidelines on breast screening, which incorporate MRI.[258,506] Penn II has been validated in families with two or more cases of breast and/or ovarian cancer.[502,507] Therefore, caution should be taken in applying this model to individuals with only one case of breast or ovarian cancer. In addition, this model was developed specifically to evaluate the likelihood of a *BRCA1/2* P/LP variant, and not the appropriateness of multi-gene testing.

If an individual does not meet the criteria for testing for high-penetrance breast and/or ovarian cancer susceptibility genes that are described above, then testing may be considered in those who are determined to have a 2.5% to 5% probability of harboring a *BRCA1/2* P/LP variant, based on probability models validated for *BRCA1/2* (eg, Tyrer-Cuzick, BRCAPro, BOADICEA). However, the panel cautions that model estimates vary substantially, and different thresholds may be applied if other genes are utilized in a specific model. If genes other than *BRCA1/2* are to be included in models that evaluate the threshold for testing, then penetrance, clinical actionability, and phenotypic features of cancers associated with these genes should be taken into account. Models that take these parameters into account to determine eligibility and appropriateness of multi-gene testing should be developed and validated. Subgroup analyses of 1075 carriers of a *BRCA1/2* P/LP variant from the Breast Cancer Prospective Family Study Cohort showed that BRCAPRO underpredicted breast cancer risk, but BOADICEA was well-validated.[508] In 2020, the web-based CanRisk tool was developed to apply BOADICEA for clinical use and is now available. Further development and testing is needed to increase acceptability of the tool by clinicians.[509] Besides *BRCA1/2,* BOADICEA also includes *PALB2*, *CHEK2*, and *ATM*. In 2022, BOADICEA was expanded to also take into account associations between *BARD1*, *RAD51C*, and *RAD51D* with breast cancer risk.[510] PREMMplus has also been developed at an NCCN Member Institution to evaluate the likelihood of a germline mutation in a number of P/LP variants (*APC, BRCA1, BRCA2, CDH1, EPCAM, MLH1, MSH2, MSH6,* biallelic *MUTYH, PMS2, TP53, ATM, BRIP1, CDKN2A, CHEK2, PALB2, PTEN, RAD51C*, and *RAD51D*).[511]

Li-Fraumeni Syndrome

LFS is a rare hereditary cancer syndrome that is frequently associated with germline *TP53* P/LP variants.[90] The classic form of LFS is highly penetrant and characterized by a wide spectrum of neoplasms occurring at a young age and throughout the lifespan. An observational cohort study including 480 carriers with a *TP53* P/LP variant enrolled in National Cancer Institute's (NCI) longitudinal Li-Fraumeni syndrome study showed that LFS is associated with a greater incidence of cancer than the general population (SIR, 23.9; 95% CI, 21.9–26.0), with the highest comparative incidence from childhood to age 30 years.[512] An analysis from the NCI Li-Fraumeni Syndrome Study (N = 286) showed a cumulative lifetime cancer incidence of nearly 100%.[513] Soft tissue sarcomas, osteosarcomas (except

Ewing sarcoma), pre-menopausal breast cancer, adrenocortical tumors, and brain tumors are referred to as the "core" cancers of LFS since they account for the majority of cancers observed in individuals with germline *TP53* P/LP variants. In one study, of 91 carriers of a germline *TP53* P/LP variant, at least one of these cancers was found in one or more members of all families with a germline *TP53* P/LP variant.[514] Certain cancers are strongly associated with LFS, for example, hypodiploid acute lymphoblastic leukemia,[515-517] choroid plexus tumor,[518] and anaplastic rhabdomyosarcoma.[519,520] Beyond the core cancers, LFS has also been associated with other leukemias, colon cancer, gastric cancer, bronchoalveolar and other lung cancers, prostate cancer, melanoma, and other CNS tumors.[90,512,514,521-530] However, it is important to mention that estimations of cancer risks associated with LFS are limited to at least some degree by selection bias since dramatically affected kindreds are more likely to be identified and become the subject of further study. In addition, the majority of data are from LFS cohorts composed of self-identified white individuals.

Given the broad tumor types seen in LFS families, a number of different sets of criteria have been used to help identify individuals who have a high likelihood of having LFS including Classic, Chompret, Eeles and Birch criteria. For the purposes of the NCCN Guidelines, two of these criteria, Classic and Chompret, are used to facilitate the identification of individuals who are candidates for testing for *TP53* P/LP variants.

Classic LFS criteria include, based on a study by Li and Fraumeni involving 24 LFS kindreds,[531] a member of a kindred with a known *TP53* P/LP variant; a combination of an individual diagnosed at ≤45 years of age with a sarcoma and a first-degree relative diagnosed with cancer at ≤45 years of age; and an additional first- or second-degree relative in the same lineage with cancer diagnosed at <45 years of age or a sarcoma diagnosed at any age (see *Testing Criteria for Li-Fraumeni Syndrome* in the algorithm). Classic LFS criteria have been estimated to have a high positive predictive value (estimated at greater than 50% and in >70% in some studies) as well as a high specificity, although the sensitivity is relatively low (estimated at 40%).[90,514,532] Because individuals with *TP53* P/LP variants are likely to have cancers beyond the LFS core cancers, the classic criteria will miss a significant portion of families.[524,533]

Other groups have broadened the classic LFS criteria to facilitate identification of individuals with LFS.[534,535] For example, criteria for *TP53* testing proposed by Chompret and colleagues recommend testing for patients with multiple primary tumors of at least two "core' tumor types (ie, sarcoma, breast cancer, adrenocortical carcinoma, brain tumors) diagnosed at <36 years of age or patients with adrenocortical carcinoma diagnosed at any age, regardless of family history (see *Testing Criteria for Li-Fraumeni Syndrome* in the algorithm).[535] The Chompret criteria have an estimated positive predictive value of 20% to 35%,[514,535] and, when incorporated as part of *TP53* testing criteria in conjunction with classic LFS criteria, have been shown to improve the sensitivity to 95% (ie, the Chompret criteria added to classic LFS criteria detected 95% of patients with *TP53* P/LP variants).[514] Although not part of the original published criteria set forth by Chompret et al, the panel recommends adopting the 2015 Revised Chompret Criteria, including testing individuals with choroid plexus carcinoma or rhabdomyosarcoma of embryonal anaplastic subtype diagnosed at any age and regardless of family history (for inclusion in criterion 3), based on reports of considerable incidence of *TP53* P/LP variants found in patients with these rare forms of cancer.[514,522,536-538] The panel supports the broader age cut-offs proposed by Tinat et al, based on a study in a large number of families, which detected germline *TP53* P/LP variants in affected individuals with later tumor onsets.[536,538] These age cut-offs are: 1) individual diagnosed with LFS spectrum cancer <46 years of age who also have at least one FDR or SDR diagnosed with a LFS spectrum cancer <56 years of age or with multiple tumors; and 2)

individual with multiple tumors from a LFS spectrum cancer, with the first diagnosed <46 years of age.[538]

Patients with early-onset breast cancer (age of diagnosis ≤30 years) who were assigned female at birth, with or without family history of core tumor types, are another group for whom *TP53* gene P/LP variant testing may be considered.[537] Several studies have investigated the likelihood of a germline *TP53* P/LP variant in this population.[514,536,539-542] Among females <30 years of age with breast cancer and without a family history, the incidence of *TP53* P/LP variants has been reported at 3% to 8%.[514,540,542,543] Some studies have also suggested that amplification of HER2 may arise in conjunction with germline *TP53* P/LP variants.[93,544,545] *TP53* P/LP variants are a common finding across cancer types on tumor-only genomic testing,[546,547] but usually do not warrant consideration of germline testing.[548] A recent analysis showed that the germline conversion rate (GCR, defined as the fraction of patients with a TP53 P/LP variant on tumor-only testing that is determined to be germline on blood or saliva based genetic testing) of *TP53* P/LP variants was only 0.9% for tumors from all age patients and 5.1% for patients age <30.[548] In the absence of paired germline analysis, germline testing should be offered if the personal or family history provides sufficient clinical suspicion of a germline P/LP variant. Consistent with European Society of Medical Oncology (ESMO) recommendations,[549] the Panel also recommends that germline testing be offered to all patients who were diagnosed with any cancer at age <30 years.

Lastly, when *TP53* is included on multigene germline panels, the NCCN testing criteria for LFS are often not met. It has been argued that a spectrum of heritable *TP53*-related cancer syndromes exist.[550] One study described families with TP53 P/LP variants falling into a spectrum from classic LFS to attenuated families who do not meet criteria. These definitions will help future LFS research describe the populations being studied, but at this time LFS management is recommended for all individuals with P/LP TP53 variants regardless of the presentation in the family.[551]

If a *TP53* P/LP variant is found in blood, saliva, or buccal samples, especially in individuals whose personal or family history does not meet LFS criteria, this warrants consideration of testing of an alternative tissue, usually cultured skin fibroblasts, and close relatives to try to distinguish between germline, constitutional mosaicism, and somatic findings, such as CH or tumor contamination of peripheral blood. For patients who have a personal history of cancer, the panel also recommends looking for signs of tumor somatic interference and technical limitations.

A table describing workup and management depending on etiology of *TP53* P/LP variant found on genetic testing was added to the Guidelines for the 2024 update. The intent of this new table was to expand on potentially mosaic *TP53* findings. Prior to publication of this table, the Guidelines did not sufficiently point out the possibility of post-zygotic (somatic or constitutional) mosaicism (PZM) versus abnormal clonal expansions (ACE; including CHIP and clonal cytopenia of undetermined significance [CCUS]) and did not provide adequate guidance regarding how to care for these patients. A review of 84 *TP53*-positive probands identified through multigene testing on blood or saliva from 2012 to 2019 showed constitutional mosaicism in 8.3%.[552] Ancillary tissue testing and cascade testing of children in all PZM and ACE *TP53* P/LP variant carriers is recommended, as this will further facilitate diagnosis and management.[553] In addition, the clinical features that suggest CH versus PZM when a *TP53* P/LP variant is in the range of 30% to 70% variant allele frequency (VAF), in a patient with no prior chemotherapy and no hematologic abnormality, continue to be unknown.

Risk Assessment, Counseling, and Management

Discussions with patients about LFS management should address the limitations of screening for the many cancers associated with this syndrome. It is also important to address the psychosocial and quality-of-life aspects of this syndrome. Given the complexity of LFS management and that LFS is rare, individuals with LFS should be followed at centers with expertise in management of this syndrome. Personal and family history of cancer should be taken into consideration for screening (ie, specific screenings, 5 to 10 years before earliest diagnosis). It is also important for patients' primary care providers and/or pediatricians to be informed about patients' diagnoses of LFS. Patients should be advised about the risk to relatives, and genetic counseling for relatives is recommended.[554] For the 2024 Guidelines update, the panel added a section on pediatric surveillance in LFS.

Breast screening in adults with LFS includes clinical examination, breast imaging (MRI and mammogram, as indicated), and breast awareness. Although there are no data regarding risk reduction surgery, individuals with LFS who were assigned female at birth have increased breast cancer risk that warrants consideration of RRM. Given the high risk of contralateral breast cancer in LFS, the option of contralateral RRM should be discussed with patients diagnosed with breast cancer.[555] Counseling for risk-reducing surgeries may include discussion of extent of cancer risk reduction/protection, risks associated with surgeries, degree of age-specific cancer risk, reconstructive options, and competing risks from other cancers. Family history and life expectancy should also be considered.

Use of a screening protocol that includes MRI may improve early cancer detection in individuals with LFS.[554,556] Whole-body MRI for screening of cancers associated with LFS continues to be evaluated in multiple international trials. Use of whole-body MRI is appealing due to its wide anatomic coverage, lack of radiation and the potential to reduce the number of imaging studies that a patient undergoes.[557] A meta-analysis including 578 individuals with *TP53* P/LP variants across 13 prospective cohorts showed that baseline whole-body MRI identified cancer in 7% of the sample, with 83% of the cancers being localized and able to treat with curative intent.[558] In a prospective observational study, a clinical surveillance protocol for carriers of a *TP53* P/LP variant from families affected by LFS was incorporated.[559] Eleven-year follow-up of this study, which included 89 carriers of a *TP53* P/LP variant, showed that this surveillance protocol may be beneficial, with 84% (16 of 19) of patients who were diagnosed with cancer while under surveillance being alive at final follow-up, compared to 49% (21 of 43) of patients who were not being surveilled and were diagnosed with cancer due on symptoms (P = .012).[560] Five-year OS was greater for patients undergoing surveillance (88.8%) compared to patients not undergoing surveillance (59.6%; P = .013). Based on these study results, the panel recommends annual whole-body MRI.[554] It is important to note that, to date, data on the effectiveness of whole-body MRI have come from centers performing a high volume of these cancer screenings. Also, whole-body MRI protocols may vary. The Panel acknowledges that this surveillance method may not be uniformly available or affordable. Patients who do not have access to whole-body MRI should be encouraged to enroll in clinical trials and to work with their clinicians to develop an alternative screening program based on available cancer screening approaches. The panel also acknowledges that whole-body MRI screening of all individuals with LFS may result in false positives and overdiagnosis.[558,561] Further, the utility of whole-body MRI has not been evaluated in individuals with a *TP53* P/LP variant who do not have a classic family history of LFS, a group that is increasingly being identified through multi-gene testing. The brain may be examined as part of whole-body MRI or as a separate exam.

In addition to whole body MRI, the panel recommends additional screening modalities for certain cancers. Individuals assigned female at

birth should begin breast cancer screening with annual clinical breast exam and breast MRI at age 20 and the addition of annual mammogram at age 30. The panel recommends colonoscopy and upper endoscopy every 2 to 5 years starting at 25 years or younger in the context of prior abdominal radiation or family history. Dermatological exams are recommended. Finally, prostate cancer screening with PSA is recommended beginning at age 40.

Many of the other cancers associated with germline *TP53* P/LP variants do not lend themselves to early detection. Thus, additional recommendations for adults with LFS are general and include comprehensive physical examinations (including neurologic examination) every 6 to 12 months, especially when there is a high index of suspicion for second malignancies in cancer survivors and rare cancers. Clinicians should address screening limitations for other cancers associated with LFS. Screening methods for other LFS-associated cancers include periodic colonoscopy and upper endoscopy, dermatologic examination, and PSA. Education regarding signs and symptoms of cancer is important. Cancer screening in LFS should take into account prior treatment with radiation therapy.

Individuals with a *TP53* P/LP variant are at increased risk of second malignant neoplasms.[537,562] Radiosensitivity in individuals with a *TP53* P/LP variant is not significantly different than in the general population,[563,564] but carriers seem to be more susceptible to radioresistance.[518,564,565] Though use of therapeutic RT should generally be avoided in individuals with a *TP53* P/LP variant, clinical decision-making should take into account the availability of other curative treatment options.

There is little evidence regarding care of *TP53* P/LP variant carriers with PZM or hypomorphic variants. Until there are more data on these carriers, they should be cared for as LFS, as opposed to patients with *TP53* CH, which should not be managed as LFS. Instead, given *TP53* mutation is considered a high-risk clinical feature in CH, patients with *TP53* CH may be referred to hematology expertise.[566,567]

Cowden Syndrome/*PTEN* Hamartoma Tumor Syndrome

The spectrum of disorders resulting from germline P/LP variants in *PTEN*[568] are referred to as PHTS. The spectrum of PHTS includes Cowden syndrome, Bannayan-Riley-Ruvalcaba syndrome (BRRS), adult Lhermitte-Duclos disease (LDD), Proteus-like syndrome,[89,569,570] and autism spectrum disorders with macrocephaly.[89,570,571] Cowden syndrome is rare, with an incidence of 1 in 200,000, although it is likely to be underestimated due to difficulties associated with making a clinical diagnosis of the disease.[572,573] Cowden syndrome is an autosomal dominant disorder, and most cases are associated with germline *PTEN* P/LP variants, though one study found that germline *KILLIN* methylation may also be associated with this syndrome.[574] The frequency of germline *PTEN* P/LP variant in Cowden syndrome cases is high, at approximately 80%.[575]

Hamartomas (benign tumors resulting from an overgrowth of normal tissue) are a common manifestation of the PHTS syndromes. Cowden syndrome is associated with multiple hamartomatous and/or cancerous lesions in various organs and tissues, including the skin, mucous membranes, breast, thyroid, endometrium, and brain.[89,576] However, it has been suggested that patients with other PHTS diagnoses associated with *PTEN* P/LP variants should be assumed to have Cowden syndrome-associated cancer risks.

The lifetime risk for breast cancer for females diagnosed with Cowden syndrome/PHTS has been estimated at 40% to 60%, with an average age of 38 to 50 years at diagnosis.[89,577] Some studies (as discussed above) have reported a higher cumulative lifetime risk for breast cancer (77%–

85%) in individuals with Cowden syndrome/PHTS or *PTEN* P/LP variants.[578-581] A large European cohort study estimated lifetime risk for breast cancer in females as 54.3% to 75.8%.[582] There have been only two cases of breast cancer reported in males with Cowden syndrome/PHTS.[577] Although many females with Cowden syndrome/PHTS experience benign breast disease,[89] there is no evidence that the rate is higher than in the general population.[577]

Thyroid disease, including benign multinodular goiter, adenomatous nodules, and follicular adenomas, has been reported to occur in approximately 30% to 68% of adults with *PTEN* P/LP variants,[570,583] and the lifetime risk for thyroid cancer (follicular or papillary) has been estimated at 3% to 16.5%.[89,582,584] However, data tend to be aggregated, so it is difficult to calculate rates for multinodular goiter versus solitary nodules.[577] A retrospective chart review of 47 children with *PTEN* P/LP variants showed that 26% had abnormal thyroid imaging.[585] The youngest reported case of thyroid cancer in a child with Cowden syndrome/PHTS was at age 7.[586]

Macrocephaly (defined as head circumference greater than the 97th percentile)[587] is a common finding in patients with Cowden syndrome/PHTS. It has been estimated that approximately 80% to 100% of individuals with this syndrome will exhibit this clinical finding.[577] Adult LDD and autism spectrum disorder characterized by macrocephaly are strongly associated with Cowden syndrome/PHTS.[569,575,579,588] A rare, slow-growing, benign hamartomatous lesion of the brain, LDD, is a dysplastic gangliocytoma of the cerebellum.[89,579] In a multicenter prospective study examining 3042 probands who met clinical criteria for Cowden syndrome/PHTS, 6% met criteria for LDD.[583] In a study of individuals meeting the diagnostic criteria for Cowden syndrome/PHTS, the cumulative lifetime risk for LDD was reported to be 32%.[579] The preponderance of evidence supports a strong association between adult-onset LDD and the presence of a *PTEN* P/LP variant,[575,589] although exceptions have been reported.[590] In addition, there is a relatively large body of evidence to support that 10% to 20% of individuals with autism spectrum disorder and macrocephaly carry germline *PTEN* P/LP variants.[571,591-594]

As in many other hereditary cancer syndromes, affected individuals are more likely to develop bilateral and multifocal cancer in paired organs.[575] Although not well defined, females with Cowden syndrome/PHTS may have a 5% to 22% risk for endometrial cancer.[89,577,582,595] While many females with Cowden syndrome/PHTS may also have uterine fibroids, this risk is not likely to be much greater than in females without Cowden syndrome/PHTS or *PTEN* P/LP variant.[577]

In addition, brain tumors and vascular malformations affecting any organ are occasionally seen in individuals with Cowden syndrome/PHTS, although the risks for developing these conditions are not well defined.[89,577] It is important to note, however, that most of the data on the frequencies of the clinical features of Cowden syndrome/PHTS are from compilations of case reports of relatively young individuals who may have subsequently developed additional signs of the disease (ie, new cancerous lesions), and these data are also likely to be confounded by selection bias.[89] Furthermore, a considerable number of these studies were published prior to the establishment in 1996 of the International Cowden Consortium operational diagnostic criteria for the syndrome, which were based on published data and the expert opinion of individuals representing a group of centers mainly in North America and Europe.[89,596]

Benign skin lesions are experienced by most to all patients with Cowden syndrome/PHTS.[570,576,585] Skin lesions associated with Cowden syndrome/PHTS include trichilemmomas (ie, benign tumors derived from the outer root sheath epithelium of a hair follicle), oral papillomas, mucocutaneous neuromas (hamartoma of the peripheral nerve sheath),

palmoplantar keratoses, penile pigmentation, lipomas and vascular anomalies, and fibromas.[577,585,597] Trichilemmomas associated with Cowden syndrome/PHTS tend to appear on the face, particularly the eyes, mouth, nose, and forehead.[577] Most individuals with Cowden syndrome/PHTS exhibit characteristic mucocutaneous lesions by their twenties, and such lesions have been reported to occur in 99% of individuals with Cowden syndrome/PHTS, showing nearly complete penetrance, although this may be a reflection of selection bias in the cases reported.[163,569] The presence of three or more mucocutaneous neuromas is considered a major diagnostic criterion of Cowden syndrome/PHTS,[577] while the presence of two or more trichilemmomas has been reported to be pathognomonic for Cowden syndrome/PHTS.[598,599] However, since most of the evidence regarding trichilemmomas is from the older literature, it is possible that the association with Cowden syndrome/PHTS is somewhat overestimated.[89] There are reports of individuals with a solitary trichilemmoma who do not have Cowden syndrome/PHTS.[598,599] Nevertheless, due to the strong association between these lesions and Cowden syndrome/PHTS and the difficulty in clinically distinguishing between a trichilemmoma and another mucocutaneous lesion, it is important that a diagnosis of trichilemmoma is histologically confirmed.

It was previously estimated that about half of individuals with Cowden syndrome/PHTS have gastrointestinal polyps.[600] However, this was almost certainly an underestimate.[600,601] In an analysis of 67 *PTEN* P/LP variant carriers undergoing colonoscopy, colorectal polyps were found in 92.5% of patients.[600] About half of the patients undergoing colonoscopy had hyperplastic polyps, and about 25% had polyps that were hamartomatous, ganglioneuromatous, or adenomatous.[600] Adenomatous or hyperplastic polyps were associated with development of colorectal cancer in this sample. Out of 39 carriers of a *PTEN* P/LP variant undergoing esophagogastroduodenoscopy (EGD), upper gastrointestinal polyps were found in 67% of patients.[600] A systematic review of published case series (N = 102) regarding gastrointestinal manifestations in Cowden syndrome/PHTS and component syndromes showed that 92.5% of these patients had polyps, with 64% having 50 or more.[602] Histologies were described as: hyperplastic (44%), adenomatous (40%), hamartomatous (38%), ganglioneuroma (33%), and inflammatory (24.5%). Other studies have also reported ganglioneuromatous polyps (ie, rare, benign peripheral nervous system tumors) in this population.[577,603] A retrospective chart review of 47 children with *PTEN* P/LP variants showed that only 13% had gastrointestinal polyps, but 34% had other gastrointestinal symptoms such as abdominal pain, rectal bleeding, and/or constipation.[585] Early-onset (<50 years of age) colorectal cancer has been reported in 13% of patients with *PTEN* P/LP variant-associated Cowden syndrome/PHTS, suggesting that routine colonoscopy may be warranted in this population.[600] The lifetime risk for colorectal cancer has been estimated as 9% to 16%.[579,580]

Several studies have projected lifetime estimates of cancer risk that are significantly higher than previously estimated. In a study of patients meeting diagnostic criteria for Cowden syndrome/PHTS (N = 211; identified from published literature and records from a single institution), the cumulative lifetime risk for any cancer was 89%.[579] *PTEN* P/LP variants had been identified in 97 of 105 patients (92%) who underwent testing. The cumulative lifetime cancer risks for all patients (n = 210) were 81% for female breast cancer, 21% for thyroid cancer, 19% for endometrial cancer, 15% for renal cancer, and 16% for colorectal cancer.[579] In a prospective study that evaluated genotype-phenotype associations between *PTEN* P/LP variants and cancer risks,[580] deleterious germline P/LP variants in *PTEN* were identified in 368 patients. Calculation of age-adjusted SIRs using cancer incidence data from the SEER database showed elevated SIRs among individuals with *PTEN* P/LP variants for breast cancer (25), thyroid cancer (51), endometrial cancer (43), colorectal cancer (10), renal cancer (31), and melanoma (8.5). The estimated cumulative lifetime cancer risks were 85% for breast,

35% for thyroid, 28% for endometrial, 9% for colorectal, 34% for renal, and 6% for melanoma.[580] In another study in individuals with PHTS found to have deleterious germline *PTEN* P/LP variants (N = 154; detailed information available in n = 146), age- and gender-adjusted SIRs were elevated for female breast cancer (39), endometrial cancer (49), female thyroid cancer (43), male thyroid cancer (199.5), female melanoma (28), and male melanoma (39).[578] The cumulative lifetime risks in these individuals were 77% for female breast cancer and 38% for thyroid cancer. The cumulative lifetime risk for any cancer was 85% overall, and females with Cowden syndrome/PHTS were found to have a 2-fold greater cancer risk compared with males with Cowden syndrome/PHTS.[578] It is important to note, however, that all three of these studies suffer from significant ascertainment biases, in that patients were usually selected for *PTEN* testing based on the presence of these malignancies, which would inflate the projected lifetime cancer estimates. An observational study of 180 patients with *PTEN* P/LP variants used Kaplan-Meier methods to estimate that female carriers (n = 99) have an 87% cumulative risk of developing any cancer and/or LDD by 60 years of age, while male carriers have a cumulative risk of 56%.[604]

The BRRS variant of Cowden syndrome/PHTS has been characterized by the presence of multiple lipomas, gastrointestinal hamartomatous polyps, macrocephaly, hemangiomas, developmental delay, and pigmented macules on the glans penis,[605] although formal diagnostic criteria have not been established for this syndrome. *PTEN* gene P/LP variants testing in individuals characterized with BRRS have been reported in approximately 60% of these patients.[606] Further, in another study, 10% of patients with BRRS for whom a *PTEN* P/LP variant test was negative were shown to be carriers of large *PTEN* gene deletions.[588]

Risk Assessment, Counseling, and Management

The assessment of individuals suspected of having Cowden syndrome/PHTS incorporates both a history of the benign and malignant conditions associated with the syndrome and a targeted physical examination, including the skin and oral mucosa, breast, and thyroid gland and head circumference (see *Testing Criteria for Cowden Syndrome/PHTS* in the algorithm). The NCCN Guidelines Panel has established a list of criteria to help indicate which individuals are candidates for testing for *PTEN* P/LP variants (see *Testing Criteria for Cowden Syndrome/PHTS* in the algorithm). These criteria are used to assess the need for further risk assessment and genetic testing. When *PTEN* is included on multi-gene panels, these testing criteria do not need to be met. Clinical diagnostic criteria have also been developed to help identify clinical features associated with Cowden syndrome/PHTS (see *Revised Clinical Diagnostic Criteria for PTEN Hamartoma Tumor Syndrome* in the algorithm, and discussed below under *Clinical Diagnostic Criteria*). Patients who meet clinical diagnostic criteria for Cowden syndrome/PHTS as described in this section are candidates for testing for *PTEN* P/LP variants.

Testing Criteria

Testing criteria for Cowden syndrome/PHTS are grouped into three general categories. A patient is considered for testing for *PTEN* P/LP variants based on whether they meet certain criteria or combinations of criteria from these three categories. The first criteria category includes individuals meeting diagnostic criteria for Cowden syndrome[607]: a personal history of BRRS, adult LDD, autism spectrum disorder with macrocephaly, or two or more biopsy-proven trichilemmomas. Any individual presenting with one or more of these diagnoses warrants *PTEN* testing. Previously, some of the criteria from this group have been referred to as “pathognomonic,” although it is unlikely that any of these conditions can stand alone as a definitive diagnostic criterion for Cowden

syndrome/PHTS. Another criterion that can be considered to be sufficient to warrant testing for *PTEN* P/LP variants is a family history that includes the presence of a known *PTEN* P/LP variant.

The next category of criteria represents "major" features associated with Cowden syndrome/PHTS and are described in the Guidelines (see *Testing Criteria for Cowden Syndrome/PHTS* in the algorithm).[570,573,583,587,607] With respect to decisions related to the presence of mucocutaneous lesions, the panel did not consider the available literature to be adequate to accurately specify the number or extent of these lesions required for the condition to be defined as a major criterion for Cowden syndrome/PHTS, and clinical judgment is needed when evaluating such lesions. An individual exhibiting two or more major criteria where one criterion is macrocephaly meets the testing threshold. An individual with three or more major criteria (without macrocephaly) is also considered to meet the threshold for testing. In addition, individuals exhibiting one major criterion with three or more minor criteria (see *Testing Criteria for Cowden Syndrome/PHTS* in the algorithm) also meet the testing threshold; if an individual exhibits two or more major criteria but does not have macrocephaly, then one of the major criteria may be included as one of the three minor criteria to meet the testing threshold.

The final category of criteria represents features with a "minor" association with Cowden syndrome/PHTS.[570,573,583,607] These criteria are described in the Guidelines (see *Testing Criteria for Cowden Syndrome/PHTS* in the algorithm). An individual would need to exhibit four or more minor criteria or as discussed above, three or more minor criteria and one major criterion to meet testing.

Lastly, an individual who has a first-degree relative diagnosed with Cowden syndrome/PHTS or BRRS for whom testing has not been performed would also meet the threshold for *PTEN* testing if the individual meets at least one major criterion or two or more minor criteria. *PTEN* P/LP variants are commonly found in tumor tissue.[608-610] If a *PTEN* variant is detected through tumor profiling and would be classified as P/LP if present in the germline, then germline testing for *PTEN* should be considered.

Clinical Diagnostic Criteria

The frequency of *PTEN* P/LP variant in individuals meeting International Cowden Consortium diagnostic criteria for Cowden syndrome has previously been estimated at about 80%.[577,606] However, evaluation of data based on samples analyzed at a single academic pathology laboratory (N = 802 evaluable) reported a much lower frequency (34%) of *PTEN* P/LP variants among individuals meeting diagnostic criteria[573] for Cowden syndrome.[570] The authors concluded that the current Consortium diagnostic criteria are not as sensitive in identifying individuals with *PTEN* P/LP variants as previously estimated. Since *PTEN* P/LP variants are relatively rare, recommendations regarding Cowden syndrome diagnostic criteria may be based on studies with a small number of patients. Studies with larger samples have their flaws as well, as patients are selected for testing based on the number and magnitude of clinical features, which may lead to overestimation of the features of Cowden syndrome.[577] A review was conducted examining each consortium diagnostic criterion, and revised criteria were proposed that are more stringent and take into account clinical features that are often seen in PHTS.[577] The criteria were designed by focusing on clinical features associated with *PTEN* P/LP variants. The panel recommends using these criteria for clinical diagnosis of PHTS (see *Revised Clinical Diagnostic Criteria for PTEN Hamartoma Tumor Syndrome* in the algorithm).

Screening Recommendations

Cancer is the major health risk associated with Cowden syndrome/PHTS. Therefore, the NCCN Panel has outlined guidelines for prevention and early detection screening of commonly associated cancers with Cowden

syndrome/PHTS. Current medical management recommendations for Cowden syndrome/PHTS include annual physical examinations, starting at 18 years of age (or 5 years before the youngest age of diagnosis of a component cancer in the family).

The recommendations for individuals with Cowden syndrome/PHTS who were assigned female at birth focus on primary and secondary prevention options for breast cancer since this is the most commonly associated cancer in individuals with Cowden syndrome/PHTS based on the available literature. Individuals assigned female at birth should begin regular monthly breast self-examinations at 18 years of age and have a semiannual clinical breast examination beginning at 25 years of age or 5 to 10 years earlier than the earliest known breast cancer in the family (whichever comes first). Individuals assigned female at birth should also have an annual mammogram and breast MRI screening with and without contrast starting at 30 years of age, or 10 years earlier than the earliest known breast cancer in the family (whichever comes first). After 75 years of age, management should be considered on an individual basis. In patients treated for breast cancer who were assigned female at birth and who have not had bilateral mastectomy, mammography and breast MRI screening with contrast should continue as recommended based on age. A single-center retrospective study including 65 females diagnosed with PHTS showed that the yield of breast cancer screening (MRI and mammography) is comparable in this population, compared to other carriers of high-penetrance breast cancer susceptibility genes (eg, *BRCA1/2*).[611]

Although there are no data regarding risk reduction surgery in individuals with Cowden syndrome who were assigned female at birth, the option of RRM and hysterectomy should be discussed. Oophorectomy is not indicated for Cowden syndrome since ovarian cancer risk is not elevated in these patients. Counseling for risk-reducing surgeries may include discussion of extent of cancer risk reduction/protection, risks associated with surgeries, and reproductive options. It is also important to address the psychosocial and quality-of-life aspects of undergoing risk-reducing surgical procedures.

Given that Cowden syndrome is rare, there are no data on screening for endometrial cancer in these patients, though consideration of screening can begin as early as age 35. The panel recommends patient education regarding the symptoms of endometrial cancer including the necessity of a prompt response to symptoms such as abnormal bleeding. Prompt reporting promotes early detection of endometrial cancer. The evaluation of these symptoms should include an endometrial biopsy. Though endometrial cancer screening does not have proven benefit in individuals with Cowden syndrome, endometrial biopsy is highly sensitive and specific as a diagnostic procedure. Therefore, screening through endometrial biopsy every 1 to 2 years may be considered.

Routine TVUS to screen for endometrial cancer in postmenopausal individuals has not been shown to be sufficiently sensitive or specific to warrant a positive recommendation but may be considered at the clinician's discretion. However, TVUS is not recommended as a screening tool in premenopausal individuals due to the wide range of endometrial strip thickness throughout the normal menstrual cycle.

Individuals with Cowden syndrome/PHTS have approximately at least a 3% to 10% lifetime risk of developing thyroid cancer,[89] compared to about 1% in the general population.[612] An annual thyroid ultrasound should be performed, starting at age 7.[613] Children at risk for a *PTEN* P/LP variant (based on a parent's carrier status) whose parents wish to delay genetic testing may also undergo annual thyroid ultrasound, since this is a noninvasive procedure. Colonoscopy is recommended starting at 35 years of age, or earlier if symptomatic. If a close relative was diagnosed with colon cancer before 40 years of age, then colonoscopy screening should

begin 5 to 10 years before the age of the earliest known diagnosis. Colonoscopy should be performed every 5 years or more frequently in cases where the patient is symptomatic or polyps are found. To screen for renal cell carcinoma, renal ultrasound should be considered every 1 to 2 years beginning at 40 years of age. Annual dermatologic examination is recommended. If there are symptoms in children, then assessment of psychomotor abilities should be considered, as well as a brain MRI. Education regarding the signs and symptoms of cancer is important; patients should also be advised about the risk to relatives, and genetic counseling is recommended for at-risk relatives.

No published data exist on the use of prenatal diagnostics/genetic testing for *PTEN* P/LP variants in families with Cowden syndrome. For a general discussion on the topic of reproductive options and counseling considerations, see the Discussion section above on *Reproductive Options* under *Genetic Risk Assessment and Counseling*.

Hereditary Pancreatic Cancer

Pancreatic cancer is thought to have a familial or hereditary component in approximately 10% of cases.[202,203,614-616] Harboring a P/LP variant has been found to be associated with a greater incidence of pancreatic cancer than family history alone (without the presence of an associated germline variant).[617] An analysis of 250 patients with pancreatic cancer who underwent multigene panel testing with a >80 gene panel showed that 15% harbored a P/LP variant.[618] Germline P/LP variants found in pancreatic adenocarcinoma include *BRCA1, BRCA2, CDKN2A,* MMR genes associated with Lynch syndrome (specifically *MSH2, MLH1, MSH6, and EPCAM*), *ATM, PALB2, STK11,* and *TP53*.[92,196,198,200,203,374,375,615,617,619-629] *BRCA2* and *CDKN2A* are generally the most prevalent, with rates in moderate- to high-risk families ranging from 2% to 6% for *BRCA2* and 1.5% to 2.5% for *CDKN2A*.[193,197,202,203] In addition, hereditary pancreatitis, which is associated with increased risk for pancreatic cancer, is associated with the genes *PRSS1* and *SPINK1*.[615] Patients with pancreatic cancer and Ashkenazi Jewish ancestry may have a greater likelihood of testing positive for a *BRCA1/2* P/LP variant, with prevalence of detected P/LP variants in this group ranging from 5.5% to 19%, with P/LP variants being more common for *BRCA2*.[195,196,198,204]

Given the considerable rate of predisposing P/LP variants in patients with pancreatic cancer, as well as the fact that typical clinical factors (eg, young age of onset, family history of cancer) are poorly predictive for identifying carriers of a P/LP variant, universal genetic testing for these individuals is warranted. Given the elevated rates of P/LP variants in pancreatic cancer and that pancreatic cancer risk increases when there is a family history,[630-632] testing of first-degree relatives of patients may be beneficial. However, testing the patient is preferred. Testing of second-degree relatives is generally not recommended but may be considered in select cases. Given that mortality rates for this cancer are high,[633,634] it may be beneficial to family members to test patients near the time of diagnosis, since the option to test the patient may not be available for very long. Family history of pancreatic cancer with unknown histology is often presumed to be exocrine. Detecting a germline P/LP variant can potentially aid in treatment decision-making, particularly regarding systemic therapy options (see *Systemic Therapy Decision-Making* above).

Pancreas Screening

Evidence to support screening for pancreatic cancer comes from studies including those who harbor an associated germline P/LP variant and/or those who have a particularly strong family history of pancreatic cancer (at least one first-degree relative and at least one second-degree relative on the same side of the family). The multicenter CAPS5 prospective cohort study, which included 1461 individuals considered high-risk (ie, P/LP carriers of *CDKN2A, STK11, ATM, BRCA1, BRCA2, MSH2, MLH1, MSH6, EPCAM,* or *PALB2*; or family history of ≥1 first-degree and 1 second-

degree relative with pancreatic cancer), evaluated stage at diagnosis and outcome of individuals diagnosed with pancreatic cancer who underwent an annual pancreas imaging surveillance protocol.[632] Out of 10 patients diagnosed with pancreatic cancer, seven were diagnosed with stage I disease. Median OS was significantly greater in patients diagnosed with screening-detected pancreatic cancer, compared to patients diagnosed outside of the surveillance protocol (9.8 years vs. 1.5 years, respectively; HR, 0.13; 95% CI, 0.03–0.50; *P* = .003). An analysis of outcomes from three European centers including 411 asymptomatic individuals showed that pancreatic cancer was detected in 7% of carriers of a *CDKN2A* P/LP variant and less than 1% of those with familial pancreatic cancer.[487] For the carriers of a *CDKN2A* P/LP variant for whom a lesion was detected, 75% were resectable, with a 5-year OS rate of 24%. A prospective study including 347 carriers of a germline *CDKN2A* P/LP variant who participated in a 20-year pancreatic cancer surveillance protocol at a medical center in the Netherlands showed that pancreatic adenocarcinoma was diagnosed in 20.7% by age 70 years.[635] Out of the 36 pancreatic cancers diagnosed, 83.3% were resectable, and 33.3% were diagnosed as stage I. Five-year OS in those who underwent resection was 44.1% (95% CI, 27.2–71.3). In another analysis from six high-volume centers in Italy including 187 high-risk individuals, abnormalities were detected in about 28%.[636] Out of the cysts detected, 62.2% were branch-duct intraductal papillary mucinous neoplasms. Pancreatic adenocarcinomas made up 2.6% of the findings (n = 5). Finally, another analysis including screening of 354 asymptomatic high-risk individuals showed suspicious pancreas lesions in 19%.[637] Out of the lesions detected from screening, 90% were resectable, and the 3-year OS rate was 85% in those with resectable lesions.

The considerable rate of resectable asymptomatic lesions found from routine screening of high-risk individuals demonstrates the potential for downstaging (ie, identification of lesions at an earlier stage). There is also the potential for impact on mortality rates, though long-term studies are needed in this area. Lesions detected through routine screening may not always require resection (eg, sporadic branch-duct intraductal papillary mucinous neoplasms). Although there is much more experience with evaluating and managing pancreatic cysts and other pancreatic imaging abnormalities, determination of the overall risk/benefits of pancreatic surveillance requires further study. Results of surveillance of high-risk individuals performed in tertiary care/high-volume centers under clinical trial settings may not be the same as those performed in routine clinical practice. Data are beginning to better define which screen-detected lesions in high-risk individuals should be considered to be at particularly high risk for neoplastic progression (eg, those with a solid pancreatic mass, those with pancreatic duct abnormalities, those with growing pancreatic cysts[638]), but further data are needed to better define the threshold for surgical intervention in high-risk individuals undergoing pancreatic cancer screening.

With the exception of *CDKN2A* and *STK11*, pancreas cancer screening in individuals who have a P/LP variant associated with increased risk of exocrine pancreatic cancer (ie, *ATM, BRCA1, BRCA2, MSH2, MLH1, MSH6, EPCAM, PALB2, TP53*) is not recommended unless there is additional family history of pancreatic cancer (at least 1 first- or second-degree relative).[639] If family history criteria are met, then pancreas screening may be considered at age 50, or 10 years younger than the earliest pancreatic cancer diagnosis in the family, whichever is earlier.[639] The International Cancer of the Pancreas Screening Consortium recommendations for pancreas screening in individuals with increased risk for hereditary pancreatic cancer do not include carriers of a *TP53* P/LP variant in this group,[639] as there are very limited data on pancreatic cancer screening in these carriers. However, the NCCN Guidelines Panel recommends that pancreatic cancer screening be considered in carriers of a *TP53* P/LP variant, if there is additional family history of pancreatic

cancer (at least 1 first- or second-degree relative), as there is some evidence of a modestly increased risk of pancreatic cancer in these carriers.[200,203]

For carriers of a *CDKN2A* or *STK11* P/LP variant, no additional family history is needed to warrant screening. For carriers of a *CDKN2A* P/LP variant, screening may be considered at age 40, or 10 years younger than the earliest pancreatic cancer diagnosis in the family, whichever is earlier.[639] For carriers of a *STK11* P/LP variant, screening may be considered beginning at ages 30 to 35, or 10 years younger than the earliest pancreatic cancer diagnosis in the family, whichever is earlier.[420,639]

Hereditary pancreatitis is defined by the presence of a causative P/LP variant such as *PRSS1* or *SPINK1*, or a suspicious family history of chronic pancreatitis (two first-degree relatives or three second-degree relatives across two or more generations) without precipitating factors and with a negative workup for other known causes of pancreatitis.[640] Hereditary pancreatitis is associated with increased lifetime risk of exocrine pancreatic cancer.[640-642] The clinical significance of the P/LP variant such as *PRSS1* or *SPINK1* is unclear without a clinical history of pancreatitis. Therefore, germline testing for *PRSS1*, *SPINK1*, and other genes associated with pancreatitis is generally not recommended unless one's personal or family history is suggestive of hereditary pancreatitis.[640] Pancreas cancer screening is recommended in individuals harboring one of these variants only in the presence of a clinical phenotype consistent with hereditary pancreatitis. For individuals meeting these criteria, screening may begin at age 40, or 20 years after onset of pancreatitis, whichever is earlier.[639]

When screening is recommended, it may be done with contrast-enhanced MRI/magnetic resonance cholangiopancreatography (MRCP) and/or endoscopic ultrasound (EUS).[637-639] MRI and EUS have been shown to be superior in detection of subcentimeter pancreatic cysts, compared to CT.[638] Screening at a high-volume center of expertise is recommended, preferably in the context of a research study. In those for whom screening shows potentially concerning features that suggest progression, shorter screening intervals may be indicated.

Cancer Risk Reduction Strategies for Transgender, Non-Binary and Gender Diverse People with Hereditary Cancer Syndromes

Risk reduction strategies for ovarian cancer (including ovarian, fallopian tube, and peritoneal cancer), uterine cancer, prostate cancer, and breast cancer for transgender, non-binary and gender diverse people who have a hereditary predisposition to cancer were added to these Guidelines in 2023. This addition is part of an ongoing NCCN initiative that began in 2020, which states that the Guidelines recommendations should fully address the needs of individuals of all sexual orientations and gender identities. The terms transgender, non-binary and gender diverse include a wide variety of physical and psychological states referring to individuals whose gender identity differs from the biological sex assigned at birth. According to a recent Gallup poll, transgender individuals represent 0.7% of all U.S. adults and 2.1% of those born from 1997 to 2003.[643] A 2022 Pew Research Center survey of U.S. adults showed that 5.1% of individuals younger than age 30 identify as transgender or nonbinary.[644]

Transgender, nonbinary, and gender diverse people encounter many challenges to health care, including stigmatization, discrimination, abuse, and possible higher rates of mortality due to lack of access to appropriate preventive care and guidance.[645] In addition, these individuals face health inequities associated with cancer. Most electronic health data, including SEER data, census data and electronic health records (EHR) do not incorporate gender identity, thus hindering the collection of health data in these populations and denying appropriate screening invitations to these

individuals. A narrative review showed that transgender women may have lower prostate cancer incidence relative to cisgender men,[646] but this analysis was based on only two studies.[647,648] For breast cancer, incidence is greater among transgender women than cisgender men, but lower among transgender men than cisgender women.[646]

Many transgender individuals pursue gender affirming hormonal and/or surgical treatments at some point in their lives, which may impact their cancer risks, though management of their risk is challenging as a result of limited data on the impact of these treatments on cancer risk in transgender individuals. A retrospective cohort study conducted in the Netherlands showed that estrogen therapy may be associated with increased risk of breast cancer in transgender women, compared to cisgender men (SIR, 46.7; 95% CI, 27.2–75.4).[649] However, the incidence of breast cancer in transgender women receiving hormone treatment was not significantly greater than breast cancer incidence in cisgender women (SIR, 0.3; 95% CI, 0.2–0.4). Testosterone, a gender-affirming hormone therapy that may be used by transgender men, has been shown to reduce breast glandular tissue and increase connective tissue in these individuals.[650,651]

There are no prospective data on appropriate prevention and/or screening options for transgender, nonbinary or gender diverse individuals, regardless of whether they are at average risk or hereditary risk. Therefore, recommendations for risk reduction must be made on a case-by-case basis depending on variables involved, which include age, family history, presence of a pathogenic variant in relevant genes, and duration of use of gender-affirming hormone therapy. One way to approach risk reduction choices is to focus on those organs at risk based on biologic sex at birth. Specifically, organs at risk in those assigned female at birth include the ovaries and uterus, while organs at risk in those assigned male at birth include the prostate. Breast cancer risk should be considered elevated regardless of whether assigned male or female at birth. See the NCCN Guidelines for a complete list of cancer risk reduction strategies for transgender individuals with a hereditary risk for these cancers.

Individuals pursuing gender affirming care should be followed at centers of excellence with access to a multidisciplinary team that understands their unique needs and provides a safe and welcoming environment. The team should include surgeons, primary care specialists, oncologists, radiologists, pathologists, endocrinologists, pediatricians, psychologists, genetic counselors, and social workers, all of whom are trained in the appropriate care of the transgender population and can address medical, psychologic, and social care needs. There is a need for formal education in the care of transgender, nonbinary and gender diverse individuals at every level of the health care system. There is also a need for research regarding the impact of gender-affirming hormones and puberty-blocking agents and how they interact with hereditary susceptibility to cancer syndromes so that optimal prevention strategies for these populations may be developed. Finally, a National Registry on the health outcomes of transgender, nonbinary and gender diverse populations is needed to fill the many gaps in the magnitude and management of risks associated with gender-affirming treatment in the setting of hereditary cancer susceptibilities. As in all research involving human participants, care must be taken to preserve the privacy and protection of this vulnerable population.

Table 1. Glossary of Relevant Genetic Terms (from the National Cancer Institute [NCI])

Autosomal dominant
Autosomal dominant inheritance refers to genetic conditions that occur when a P/LP variant is present in one copy of a given gene (ie, the person is heterozygous).

Autosomal recessive
Autosomal recessive inheritance refers to genetic conditions that occur only when P/LP variants are present in both copies of a given gene (ie, the person is homozygous for a P/LP variant, or carries two different variants of the same gene, a state referred to as compound heterozygosity).

de novo mutation
An alteration in a gene that is present for the first time in one family member as a result of a P/LP variant in a germ cell (egg or sperm) of one of the parents, or a P/LP variant that arises in the fertilized egg itself during early embryogenesis. Also called new P/LP variant.

Familial
A phenotype or trait that occurs with greater frequency in a given family than in the general population; familial traits may have a genetic and/or nongenetic etiology.

Family history
The genetic relationships within a family combined with the medical history of individual family members. When represented in diagram form using standardized symbols and terminology, it is usually referred to as a pedigree or family tree.

Founder effect
A P/LP variant observed with high frequency in a population founded by a small ancestral group that was once geographically or culturally isolated, in which one or more of the founders was a carrier of the mutant gene.

Germline
The cells from which eggs or sperm (ie, gametes) are derived.

Kindred
An extended family.

Pedigree
A graphic illustration of family history.

Penetrance
A characteristic of a genotype; it refers to the likelihood that a clinical condition will occur when a particular genotype is present.

Proband
The individual through whom a family with a genetic disorder is ascertained. In males this is called a propositus, and in females it is called a proposita.

Sporadic cancer
This term has two meanings. It is sometimes used to differentiate cancers occurring in people who do not have a germline P/LP variant that confers increased susceptibility to cancer from cancers occurring in people who are known to carry a variant. Cancer developing in people who do not carry a high-risk P/LP variant is referred to as sporadic cancer. The distinction is not absolute, because genetic background may influence the likelihood of cancer even in the absence of a specific predisposing variant. Alternatively, sporadic is also sometimes used to describe cancer occurring in individuals without a family history of cancer.

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