

GENETIC SUSCEPTIBILITY TO CANCER

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DISCLOSURES

I HAVE NO CONFLICTS OF INTEREST TO DISCLOSE



OBJECTIVE 1:

Decipher how to identify individuals who are suspicious of having a hereditary cancer gene mutation

OBJECTIVE 2:

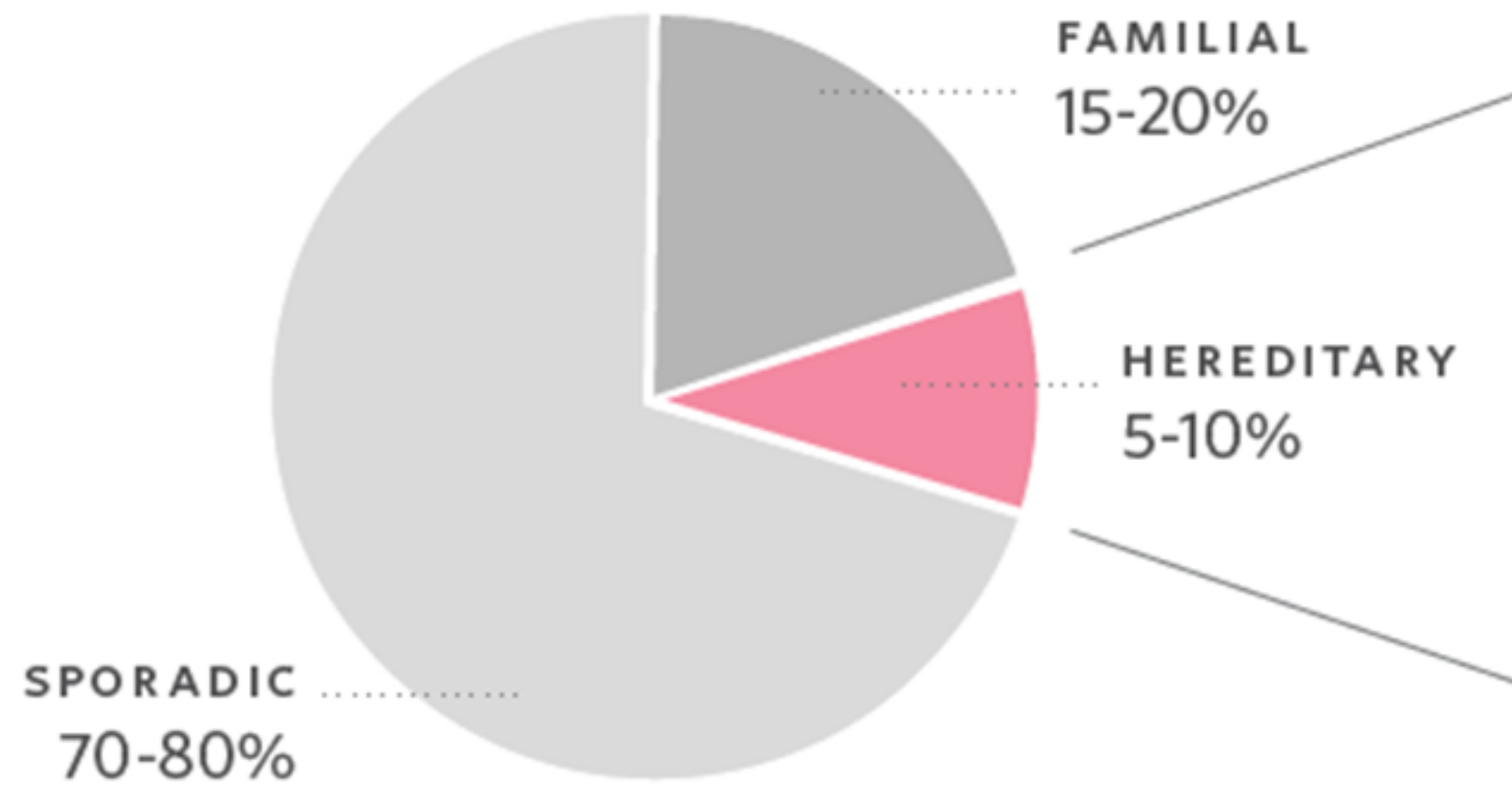
Describe the increased cancer risks associated with hereditary cancer gene mutations

OBJECTIVE 3:

Discuss potential changes to medical management recommendations as a result of an inherited gene mutation



Is it a random (sporadic) cancer or due to an inherited gene mutation?

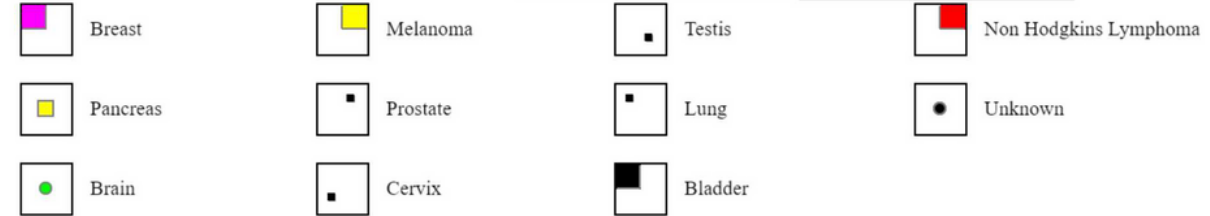


5-10% of all cancer are hereditary

WHO DO WE SUSPECT?



FAMILY HISTORY



CANCER FAMILY HISTORY QUESTIONNAIRE

Personal Information

Patient Name: _____ Date of Birth: _____ Age: _____
 Gender (M/F): _____ Today's Date(MM/DD/YY): _____ Health Care Provider: _____

Instructions: This is a screening tool for cancers that run in families. Please mark (Y) for those that apply to YOU and/or YOUR FAMILY. Next to each statement, please list the relationship(s) to you and age of diagnosis for each cancer in your family.

You and the following close blood relatives should be considered: You, Parents, Brothers, Sisters, Sons, Daughters, Grandparents, Grandchildren, Aunts, Uncles, Nephews, Nieces, Half-Siblings, First-Cousins, Great-Grandparents and Great Grandchildren

YOU and YOUR FAMILY's Cancer History (Please be as thorough and accurate as possible)

	CANCER	YOU AGE OF Diagnosis	PARENTS / SIBLINGS / CHILDREN	AGE OF Diagnosis	RELATIVES on your MOTHER'S SIDE	AGE OF Diagnosis	RELATIVES on your FATHER'S SIDE	AGE OF Diagnosis
<input checked="" type="checkbox"/> Y	EXAMPLE: BREAST CANCER	45	-----	---	Aunt Cousin	45 61	Grandmother	53
<input type="checkbox"/> Y	BREAST CANCER (Female or Male)							
<input type="checkbox"/> Y	OVARIAN CANCER (Peritoneal/Fallopian Tube)							
<input type="checkbox"/> Y	UTERINE (ENDOMETRIAL) CANCER							
<input type="checkbox"/> Y	COLON/RECTAL CANCER							
<input type="checkbox"/> Y	10 or more LIFETIME COLON POLYPS (Specify #)							
<input type="checkbox"/> Y	OTHER CANCER(S) (Specify cancer type)		Among others, consider the following cancers: Melanoma, Pancreatic, Stomach (Gastric), Brain, Kidney, Bladder, Small bowel, Sarcoma, Thyroid, Prostate					

Y N Are you of Ashkenazi Jewish descent?
 Y N Are you concerned about your personal and/or family history of cancer?
 Y N Have you or anyone in your family had genetic testing for a hereditary cancer syndrome? (Please explain/include a copy of result if possible)

Hereditary Cancer Red Flags (To be completed with your healthcare provider - Check all that apply)

Hereditary Breast and Ovarian Cancer Syndrome - Red Flags*

- Personal and/or family history¹ of:**
- Breast cancer diagnosed before age 50
 - Ovarian cancer
 - Two primary breast cancers
 - Male breast cancer
 - Triple Negative Breast Cancer
 - Ashkenazi Jewish ancestry with an HBOC-associated cancer¹⁵
 - Three or more HBOC-associated cancers at any age¹⁵
 - A previously identified HBOC syndrome mutation in the family

¹Close blood relatives include first-, second-, or third-degree in the maternal or paternal lineage

¹⁵In the same individual or on the same side of the family
¹⁵HBOC-associated cancers include breast (including DCIS), ovarian, pancreatic, and aggressive prostate cancer

Lynch Syndrome - Red Flags*

- An individual with any of the following:**
- Colorectal or endometrial cancer before age 50
 - MSI High histology before age 60¹⁶
 - Abnormal MSI/IHC tumor test result (colorectal/endometrial)
 - Two or more Lynch syndrome cancers¹⁷ at any age
 - Lynch syndrome cancer¹⁷ with one or more relatives with a Lynch syndrome cancer¹⁸
 - A previously identified Lynch syndrome or MAP syndrome mutation in the family

- An individual with any of the following family histories:**
- A first- or second-degree relative with colorectal or endometrial cancer before age 50
 - Two or more relatives with a Lynch syndrome cancer¹⁷, one before the age of 50¹⁸
 - Three or more relatives with a Lynch syndrome cancer¹⁷ at any age¹⁸
 - A previously identified Lynch syndrome or MAP syndrome mutation in the family

¹⁶MSI High histology includes: Mucinous, signet ring, tumor infiltrating lymphocytes, Crohn's-like lymphocytic reaction, or medullary growth pattern

¹⁷Lynch syndrome-associated cancers include colorectal, endometrial, gastric, ovarian, ureter/renal pelvis, biliary tract, small bowel, pancreas, brain, sebaceous adenomas

¹⁸Cancer history should be on the same side of the family

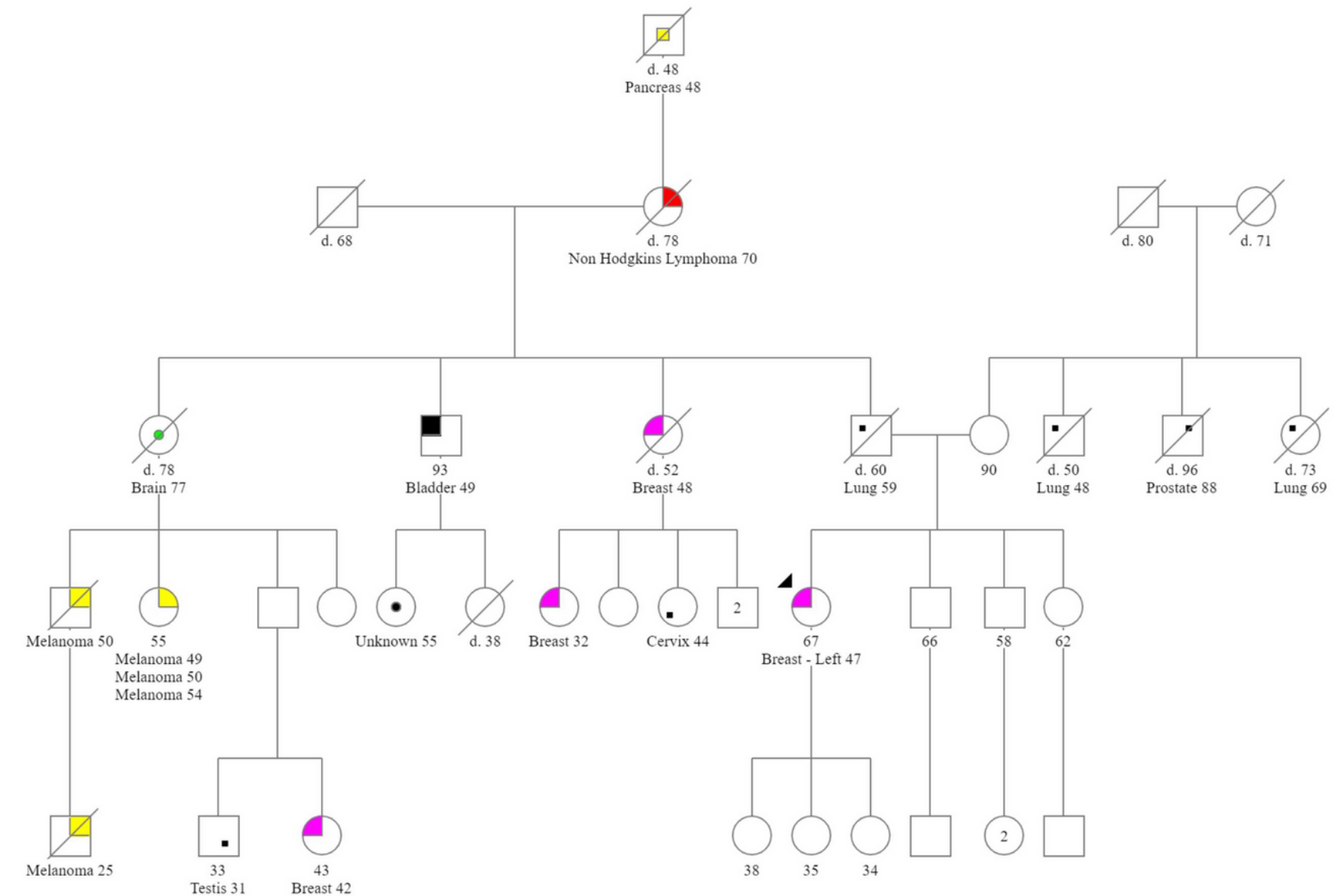
*Assessment criteria are based on medical society guidelines. For individual medical society guidelines, go to www.MyriadPro.com

Cancer Risk Assessment Review (To be completed after discussion with healthcare provider)

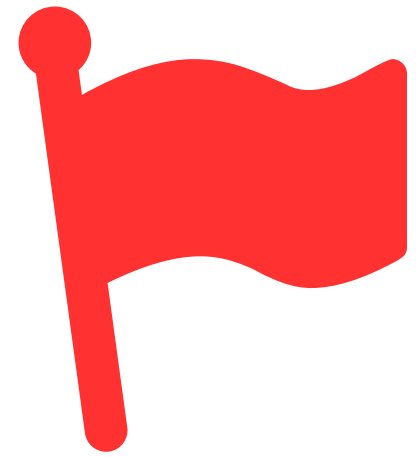
Patient's Signature: _____ Date: _____

Health Care Provider's Signature: _____ Date: _____

For Office Use Only: Patient offered hereditary cancer genetic testing? YES NO ACCEPTED DECLINED
 Follow-up appointment scheduled: YES NO Date of Next Appointment: _____



RED FLAGS



Aggressive cancers

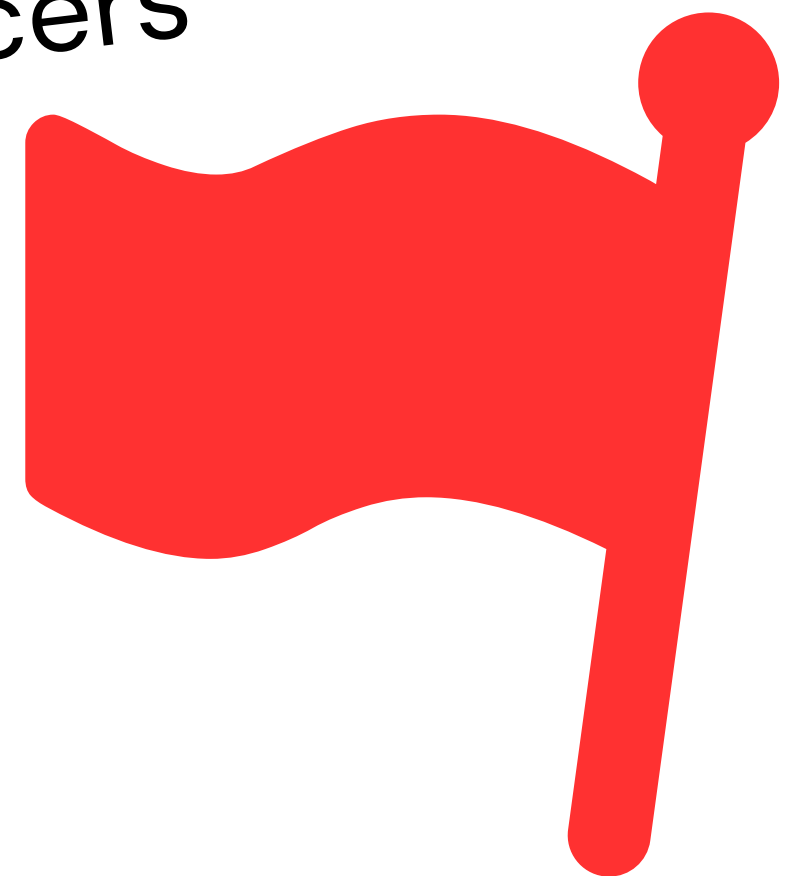
Bilateral cancers

Multiple generations with similar types of cancer

Rare cancers

Individuals with multiple primary cancers

Early onset



ASK MORE QUESTIONS



Previous “negative” genetic testing..What does that mean?

ASK MORE QUESTIONS



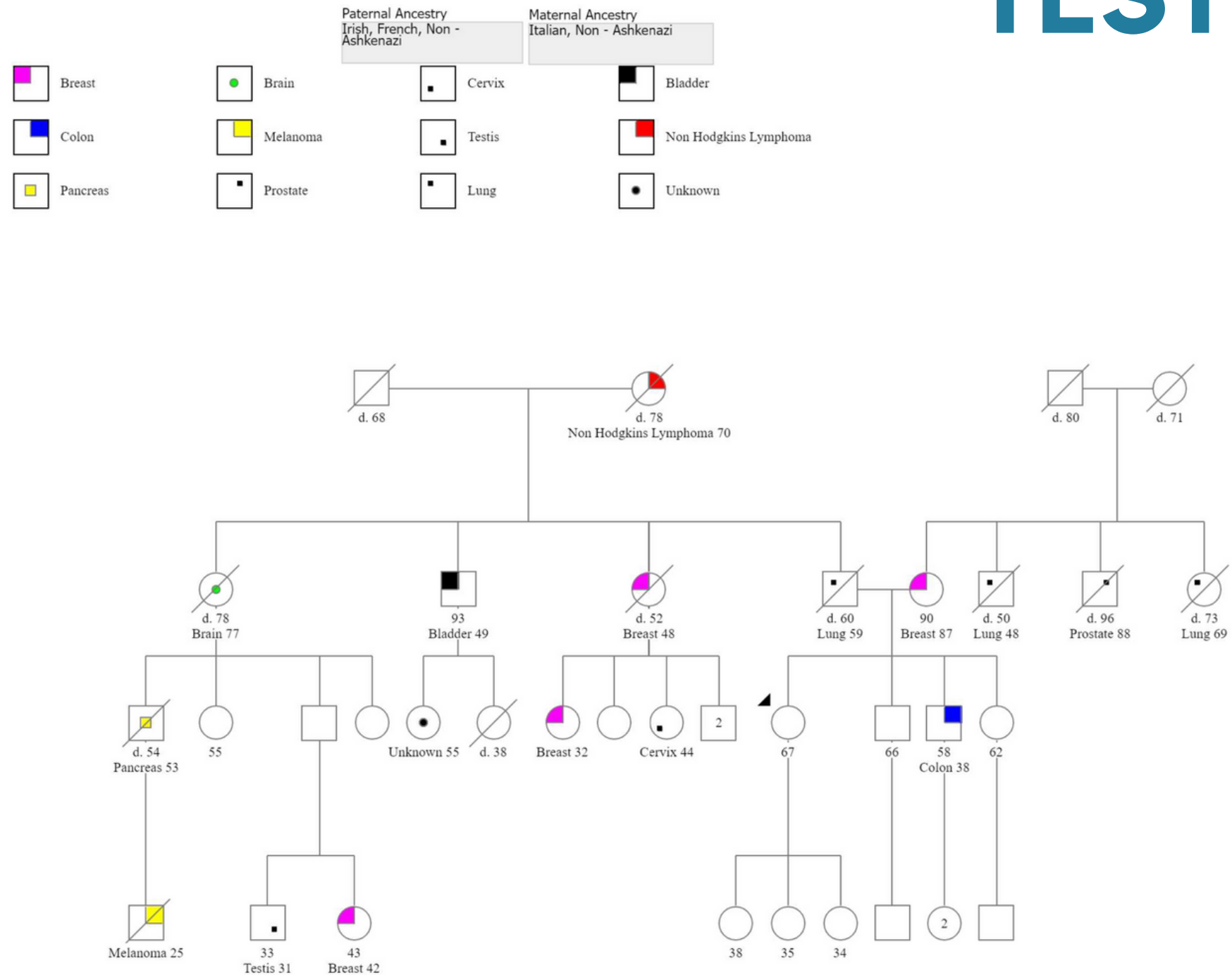
Previous “negative” genetic testing

- **What does that mean?**
- **When was testing performed?**
- **What genes were tested?**
- **What type of testing analysis was used?**

WHO IS MOST INFORMATIVE FAMILY MEMBER TO INITIATE GENETIC TESTING PROCESS?



WHO IS MOST INFORMATIVE FAMILY MEMBER TO INITIATE GENETIC TESTING PROCESS?



**WHAT DOES THIS MEAN FOR
CANCER RISK?**



POSITIVE RESULTS

**HOW DOES THIS INFORMATION
CHANGE MEDICAL MANAGEMENT?**



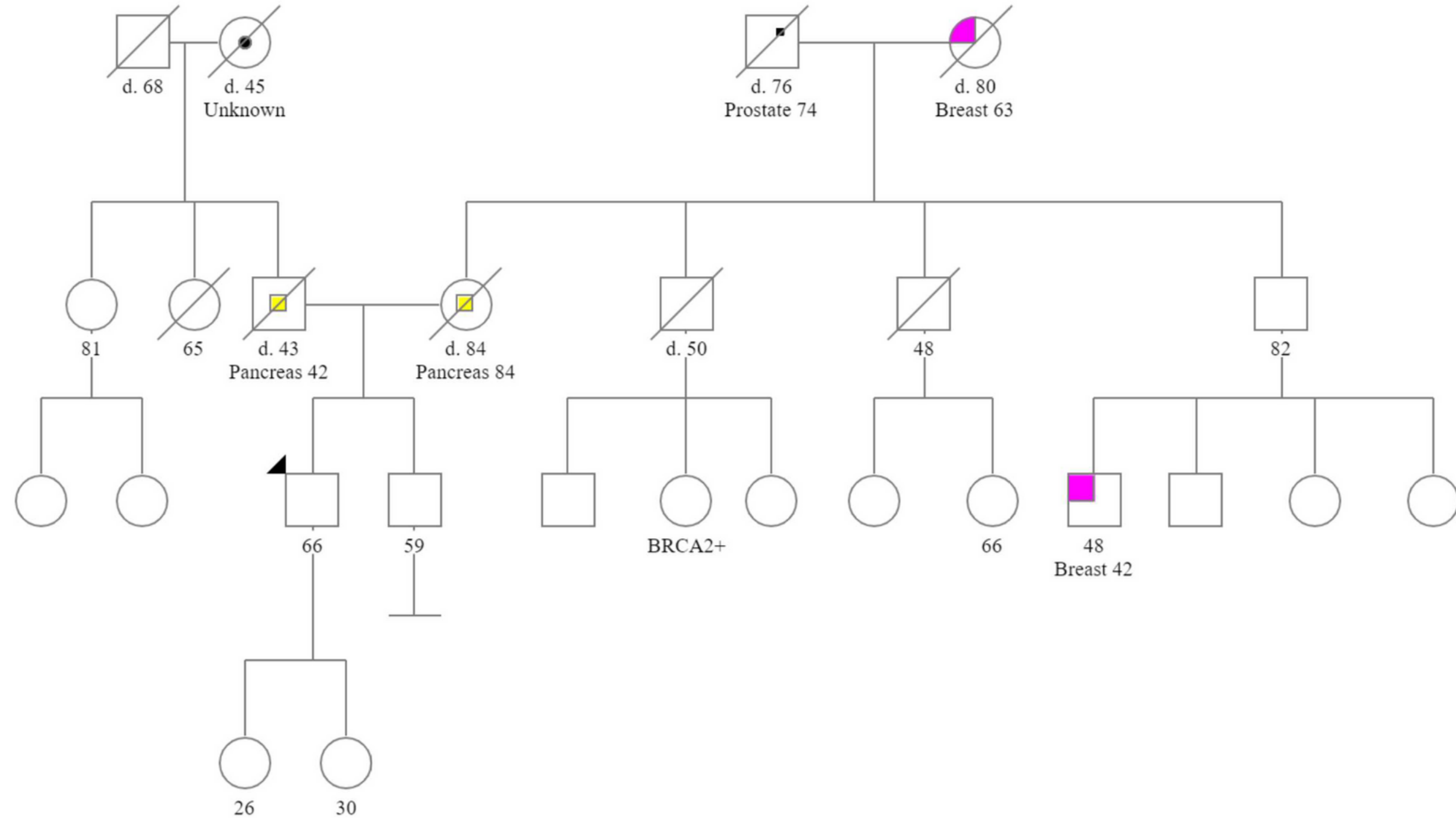
Family 1

Paternal Ancestry
Scottish, Irish, Non -
Ashkenazi

Maternal Ancestry
Scandinavian, German, Non -
Ashkenazi



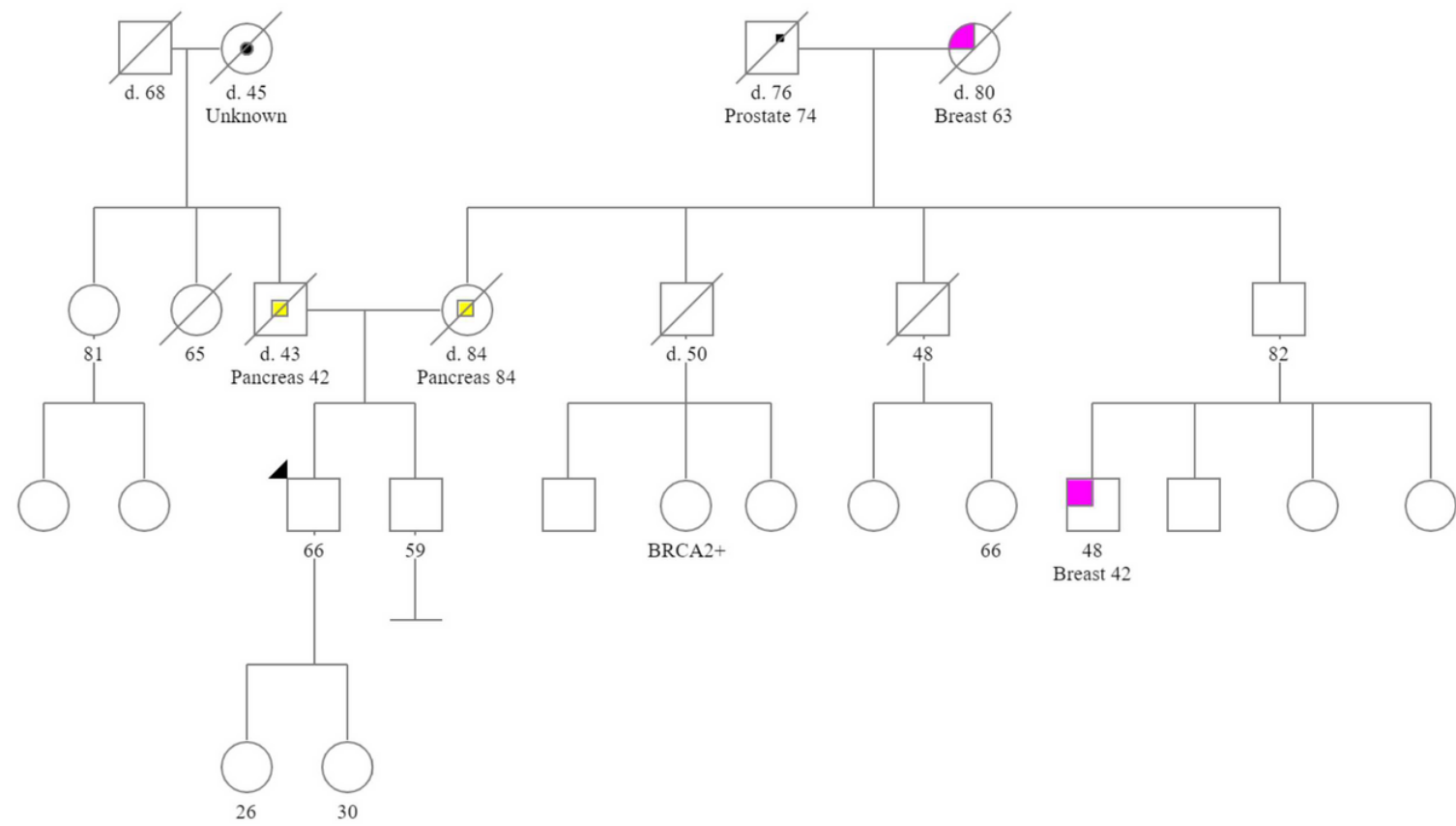
FAMILY 1:



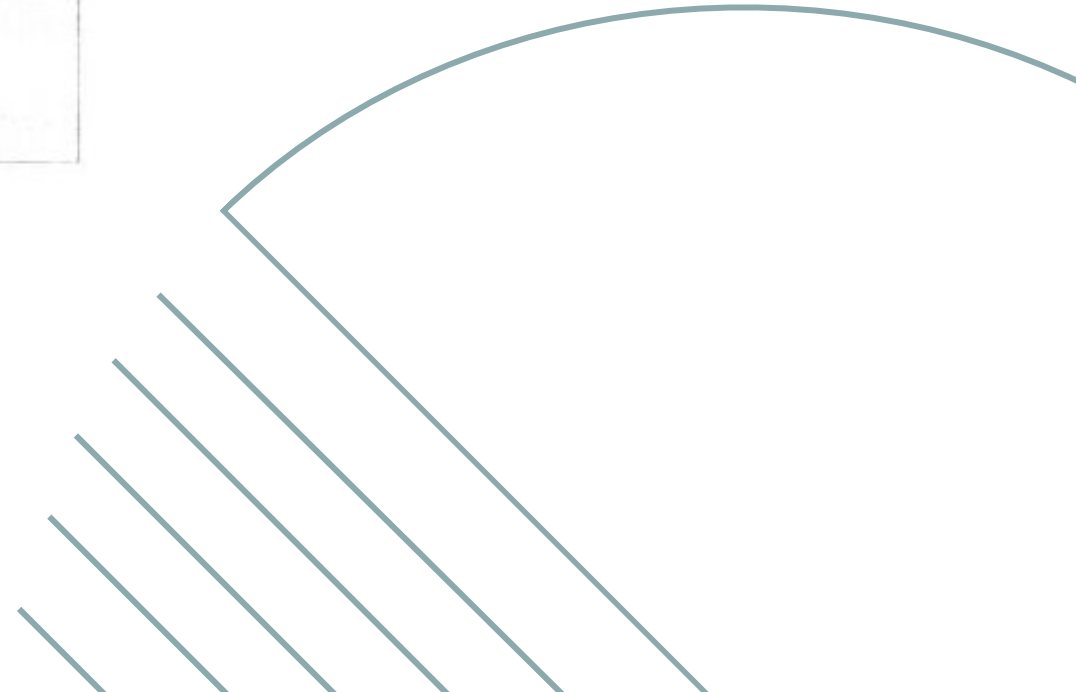
Family 1

Paternal Ancestry
Scottish, Irish, Non - Ashkenazi

Maternal Ancestry
Scandinavian, German, Non - Ashkenazi



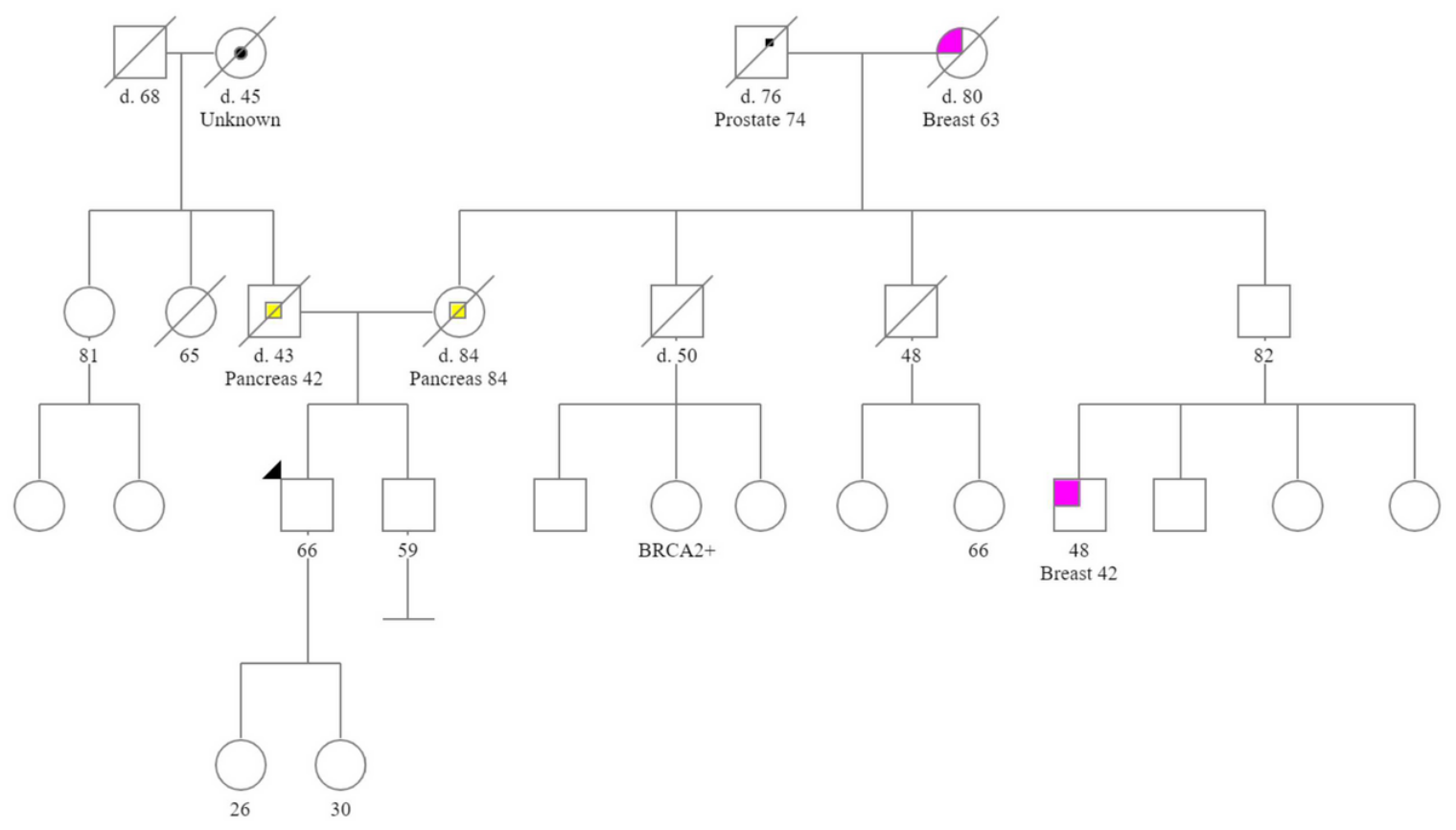
GENE	TRANSCRIPT
APC*	NM_000038.5
ATM*	NM_000051.3
BMPR1A	NM_004329.2
BRCA1	NM_007294.3
BRCA2	NM_000059.3
CDK4	NM_000075.3
CDKN2A (p14ARF)	NM_058195.3
CDKN2A (p16INK4a)	NM_000077.4
EPCAM*	NM_002354.2
FANCC	NM_000136.2
MEN1*	NM_130799.2
MLH1*	NM_000249.3
MSH2*	NM_000251.2
MSH6*	NM_000179.2
NF1*	NM_000267.3
PALB2	NM_024675.3
PALLD	NM_001166110.1
PMS2*	NM_000535.5
SMAD4	NM_005359.5
STK11	NM_000455.4
TP53	NM_000546.5
TSC1*	NM_000368.4
TSC2	NM_000548.3
VHL	NM_000551.3



Family 1

Paternal Ancestry: Scottish, Irish, Non-Ashkenazi
 Maternal Ancestry: Scandinavian, German, Non-Ashkenazi

Breast
 Pancreas
 Prostate
 Unknown



REQUESTED VARIANTS

GENE	VARIANT	ZYGOSITY	VARIANT CLASSIFICATION	RESULT
BRCA2	c.5164_5165del (p.Ser1722Tyrfs*4)	N/A	PATHOGENIC	Not detected

The table above reflects the information for the requested variant(s) as of the date that this report was issued. Please see the result box for a summary of any reportable findings.

+ RESULT: POSITIVE

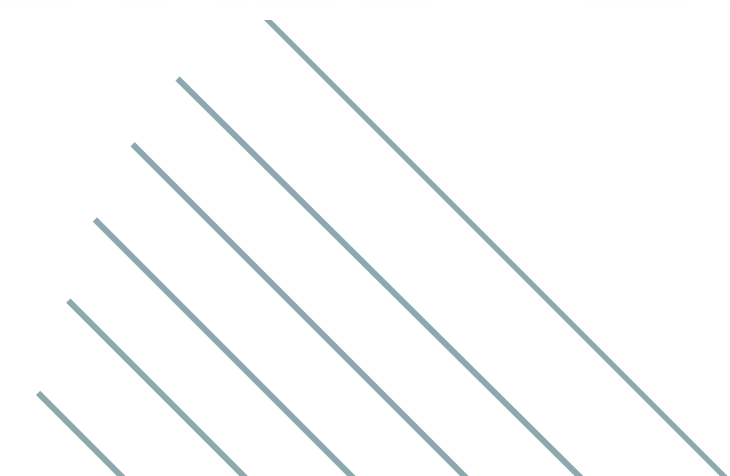
One Pathogenic variant identified in BRCA2. BRCA2 is associated with autosomal dominant hereditary breast and ovarian cancer syndrome and autosomal recessive Fanconi anemia.

Additional Variant(s) of Uncertain Significance identified.

GENE	VARIANT	ZYGOSITY	VARIANT CLASSIFICATION
BRCA2	c.3296C>A (p.Ser1099*)	heterozygous	PATHOGENIC
MSH6	c.3674C>T (p.Thr1225Met)	heterozygous	Uncertain Significance

About this test

This diagnostic test evaluates 23 gene(s) for variants (genetic changes) that are associated with genetic disorders. Diagnostic genetic testing, when combined with family history and other medical results, may provide information to clarify individual risk, support a clinical diagnosis, and assist with the development of a personalized treatment and management strategy.



CANCER RISKS: BRCA1/2

Cancer	General Population Risk	BRCA1/2 Risk
Breast	12%	> 60%
Male Breast	<0.5%	Up to 1.2%
Ovary	1-2%	Up to 58%
Prostate	12-13%	Up to 61%
Pancreas	1-2%	Up to 10%



MEDICAL MANAGEMENT: BRCA1/2

Breast (female)*

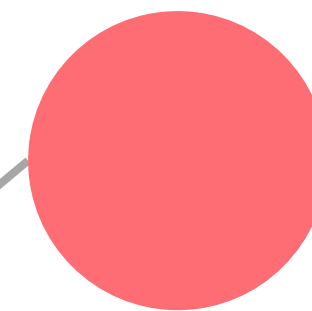
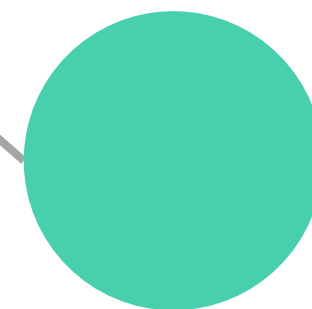
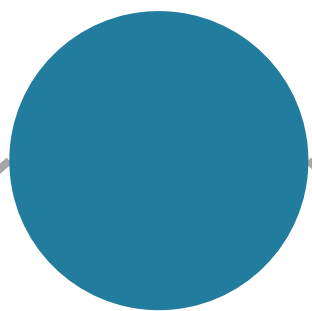
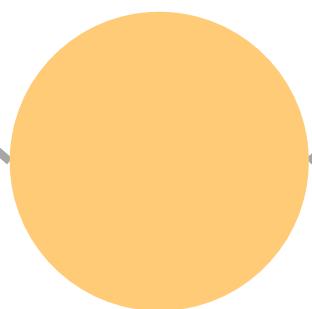
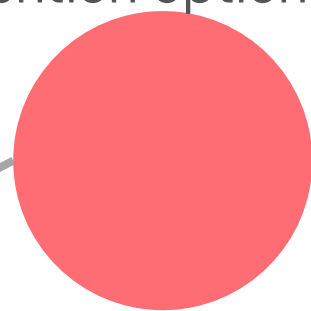
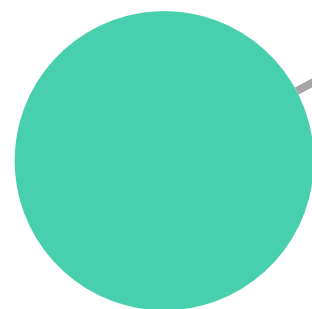
Breast awareness at 18
Clinical breast exam every 6-12 month at 25
Annual breast MRI starting at 25
Annual mammogram starting at 30
Consider risk reducing mastectomy
Chemoprevention options to consider

Prostate*

Prostate cancer screening at 40

Melanoma

Annual full-body skin examination
Minimizing ultraviolet (UV) exposure



Breast (male)*

Self-breast exam at age 35
Annual clinical breast exam at 35
For BRCA2: Annual mammogram at 50

Ovaries*

Consider risk reducing bilateral salpingo-oophorectomy
Chemoprevention options to consider

Pancreas*

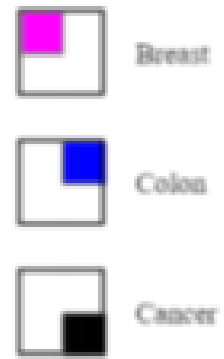
Annual MRI/MRCP and/or EUS starting at age 50 if family history of PDAC in FDR/SDR

*Consider PARP inhibitor in cancer treatment plan

NCCN



FAMILY 2:



Paternal Ancestry
Swedish, Austrian,
Hungarian

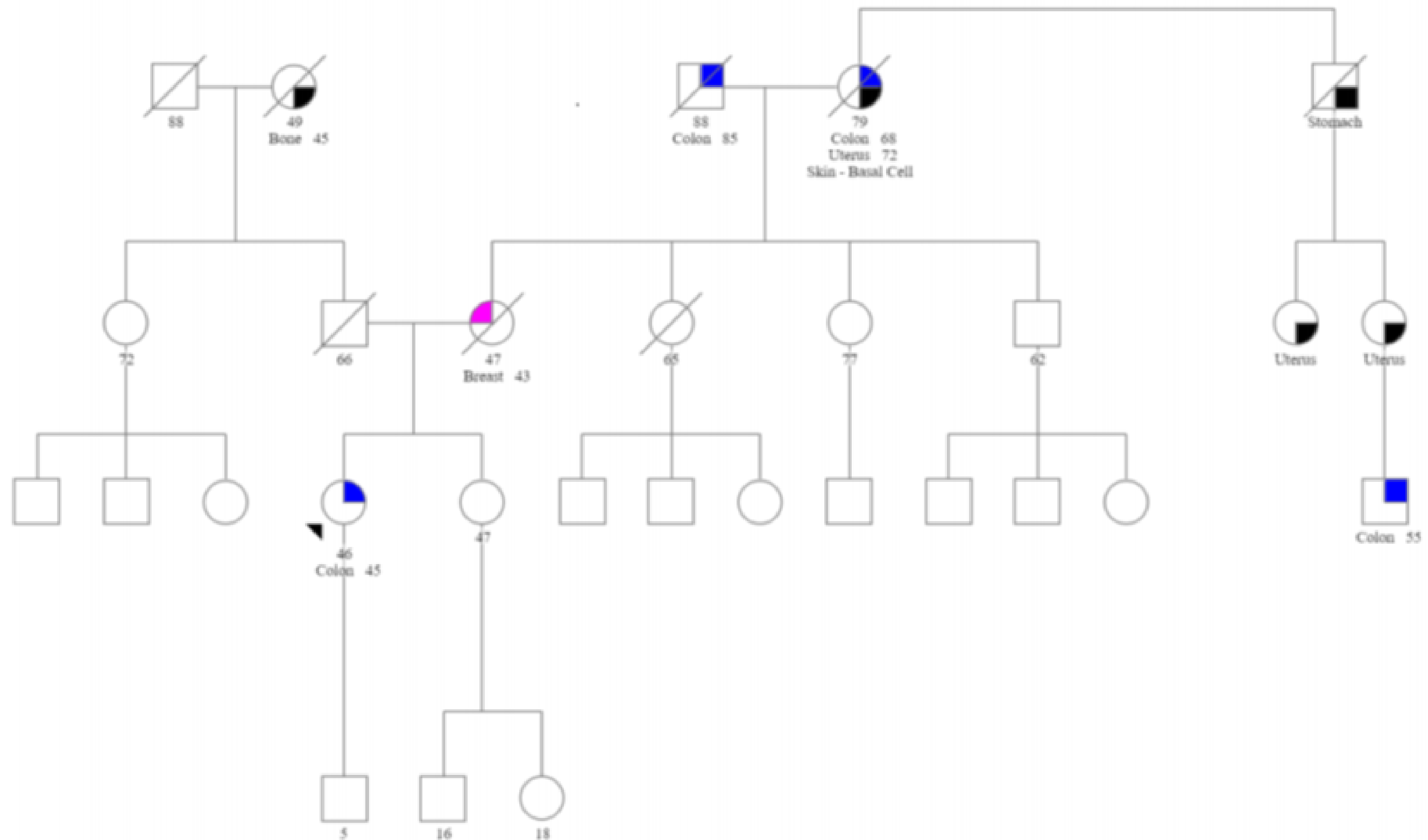
Maternal Ancestry
German, Russian

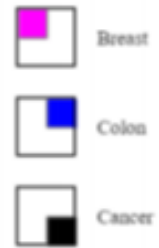
FHQ Final Comments

Paternal Ashkenazi
No

Maternal Ashkenazi
No

[Empty box for FHQ Final Comments]





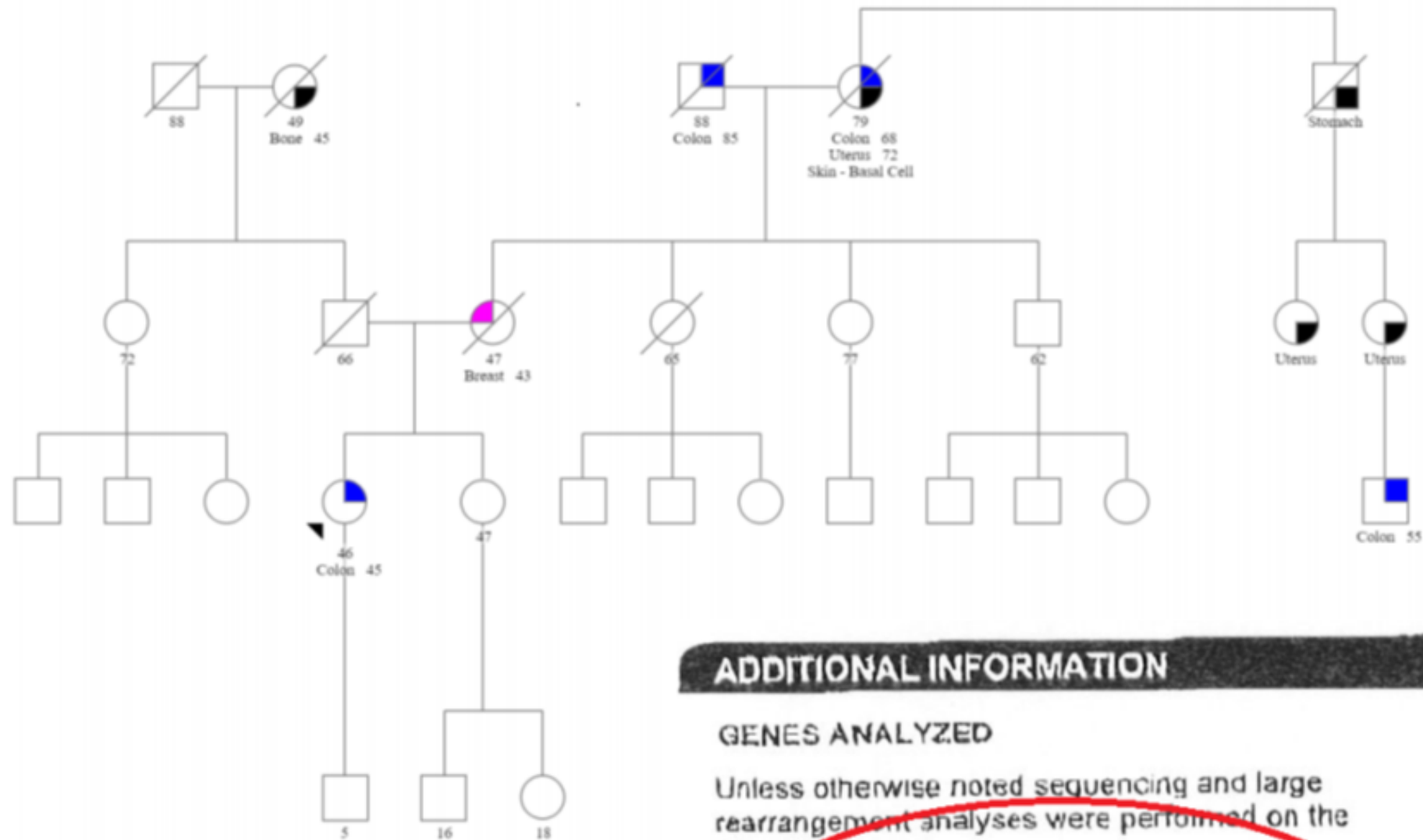
Paternal Ancestry
Swedish, Austrian,
Hungarian

Maternal Ancestry
German, Russian

FHQ Final Comments

Paternal Ashkenazi
No

Maternal Ashkenazi
No



ADDITIONAL INFORMATION

GENES ANALYZED

Unless otherwise noted sequencing and large rearrangement analyses were performed on the following genes:

APC, ATM, BARD1, BMPR1A, BRCA1, BRCA2, BRIP1, CDH1, CDK4, CDKN2A, CHEK2, EPCAM (large rearrangement only), MLH1, MSH2, MSH6, MUTYH, NBN, PALB2, PMS2, PTEN, RAD51C, RAD51D, SMAD4, STK11, TP53. Sequencing was performed for select regions of *POLE* and *POLD1* and large rearrangement analysis was performed for select regions of *GREM1* (see technical specifications).

** Other genes not analyzed with this test may also be associated with cancer.

Indication for Testing: It is our understanding that this individual was identified for testing due to a personal or family history suggestive of a hereditary predisposition for cancer.

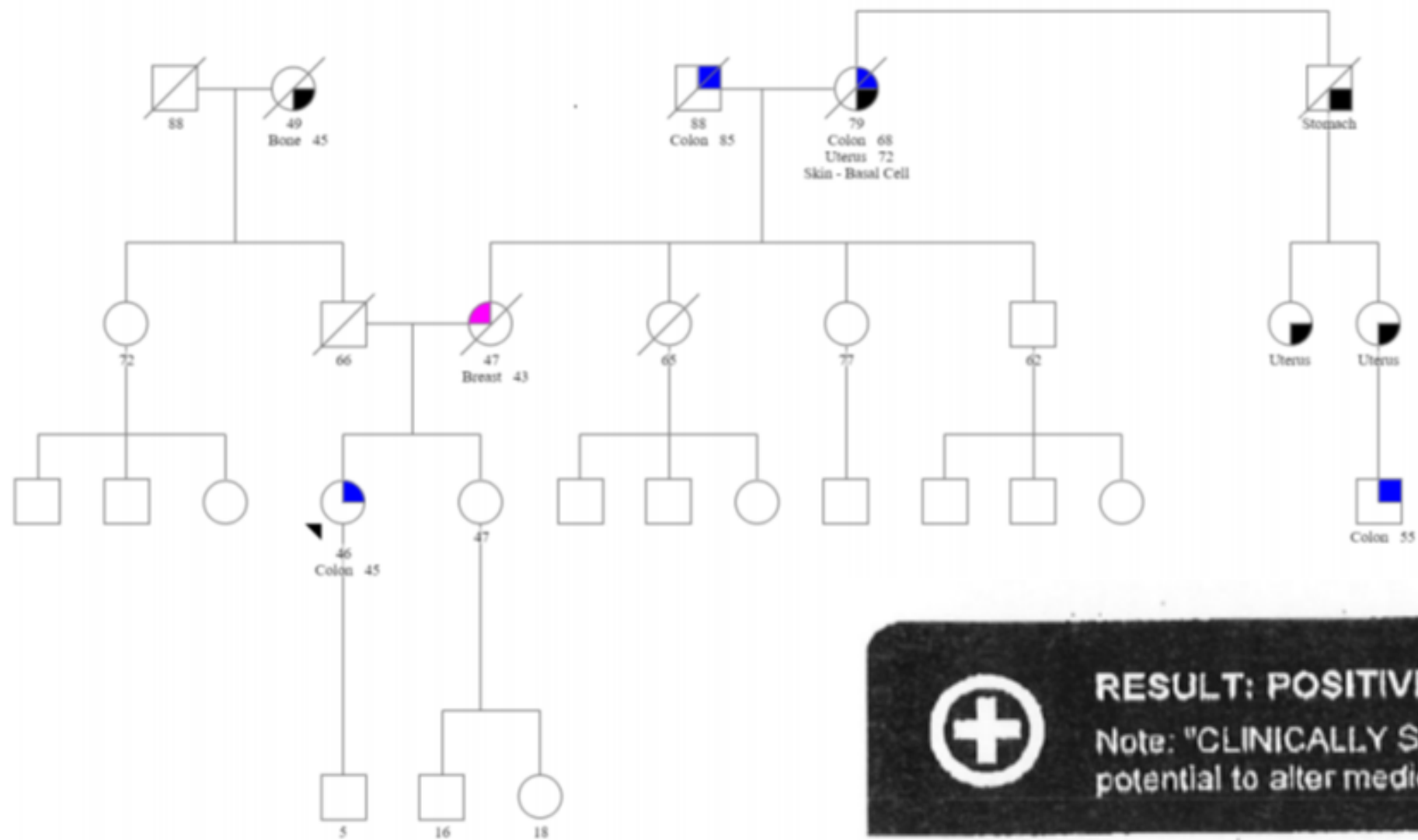
Associated Cancer Risks and Clinical Management: Please see the "myRisk Management Tool" associated with this report for a summary of cancer risk and professional society medical management guidelines that may be useful in developing a plan for this patient based on test results and reported personal/family history, if applicable. Testing of other family members may assist in the interpretation of this patient's test result.

Analysis Description: The Technical Specifications summary (<https://www.myriadpro.com/documents-and-forms/technical-specifications/>) describes the analysis, method, performance, nomenclature, and interpretive criteria of this test. Current testing technologies are unable to definitively determine whether a variant is germline or somatic in origin, which may significantly impact risk estimates and medical management; therefore, these results should be correlated with this patient's personal and family history. The interpretation of this test may also be impacted if the patient has a hematologic malignancy or an allogeneic bone marrow transplant.

Breast
 Colon
 Cancer

Paternal Ancestry: Swedish, Austrian, Hungarian
 Maternal Ancestry: German, Russian
 Paternal Ashkenazi: No
 Maternal Ashkenazi: No

FHQ Final Comments



RESULT: POSITIVE - CLINICALLY SIGNIFICANT MUTATION IDENTIFIED

Note: "CLINICALLY SIGNIFICANT," as defined in this report, is a genetic change that is associated with the potential to alter medical intervention.

GENE	MUTATION	INTERPRETATION
<i>MSH6</i>	c.4001G>A (p.Arg1334Gln) Heterozygous	High Cancer Risk This patient has Lynch syndrome/Hereditary Non-Polyposis Colorectal Cancer (HNPCC).

DETAILS ABOUT: *MSH6* c.4001G>A (p.Arg1334Gln): NM_000179.2; (aka: R1334Q (4001G>A))

Functional Significance: Suspected Deleterious - Abnormal Protein Production and/or Function

The heterozygous germline *MSH6* mutation c.4001G>A is located at the last nucleotide of exon 9 and is predicted to result in the substitution of glutamine for arginine at amino acid position 1334 of the *MSH6* protein (p.Arg1334Gln). RNA splicing studies demonstrate that the c.4001G>A variant causes skipping of exon 9, resulting in a frameshift in the mRNA and the introduction of a premature termination codon (Myriad internal data).

Clinical Significance: High Cancer Risk

This mutation is associated with increased cancer risk and should be regarded as clinically significant.



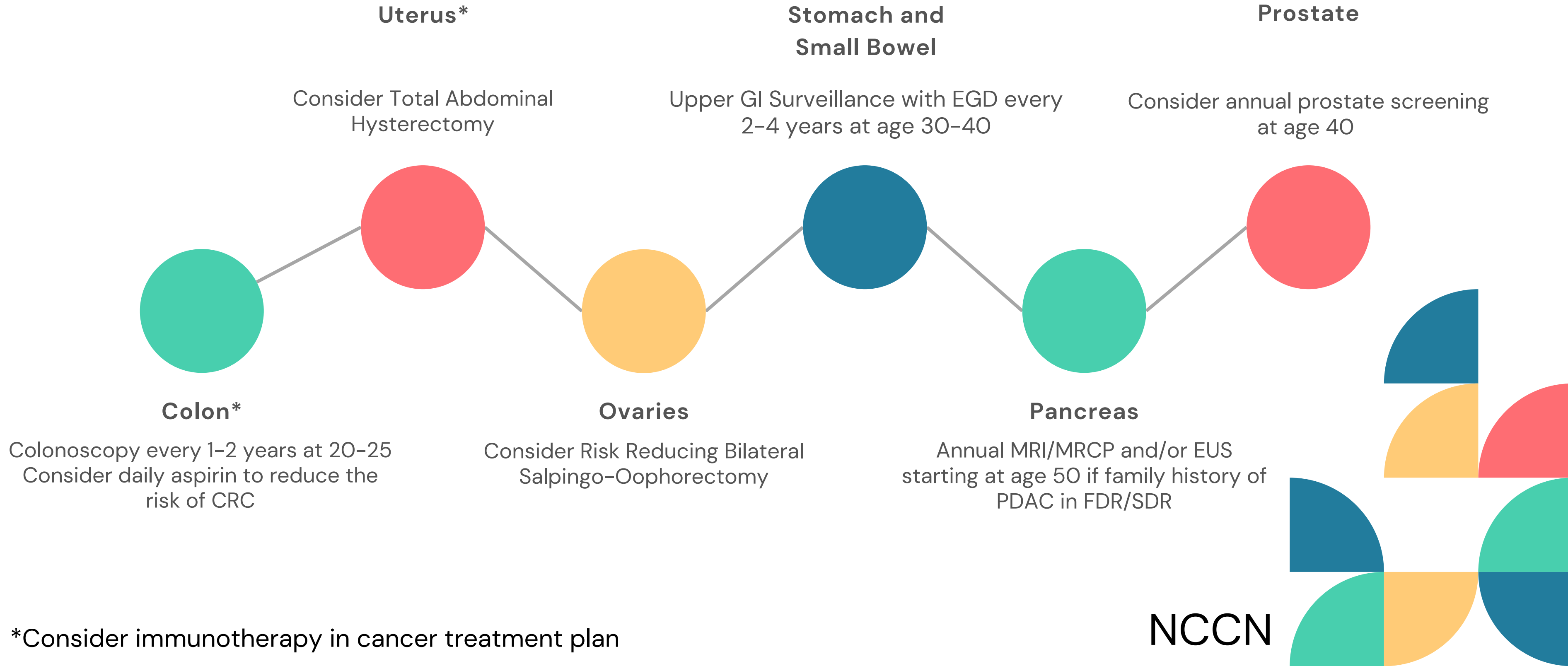
CANCER RISKS: LYNCH SYNDROME

Cancer	General Population Risk	Lynch Syndrome Risk
Colon	4.1%	Up to 61%
Endometrium	3.1%	Up to 57%
Prostate	12.6%	Up to 23.8%
Ovary	1.1%	Up to 38%
Stomach	<1%	Up to 9%
Hepatobiliary tract	<1%	Up to 4%
Bladder	2.3%	Up to 12.8%
Renal Pelvis and/or Ureter	Data unavailable	Up to 28%
Small bowel	<1%	Up to 11%
Brain/CNS	<1%	Up to 7.7%
Pancreas	1.7%	1-6%
Breast	13%	Up to 18.6%

MEDICAL MANAGEMENT: LYNCH SYNDROME

- Consider annual urinalysis starting at age 30–35 y in individuals with family history of urothelial cancer or with a MSH2 gene mutation
- Consider annual physical/neurologic exam starting at age 25–30 y

- Patients should be educated regarding signs and symptoms of neurologic cancer and the importance of prompt reporting of abnormal symptoms to their physicians.
- Consider skin exam every 1–2 years. Age to start surveillance is uncertain and can be individualized.



*Consider immunotherapy in cancer treatment plan

CANCER RISKS: PALB2

Cancer	General Population Risk	PALB2 Risk
Breast	12%	41-60%
Male Breast	<0.5%	0.9%
Ovary	1-2%	3-5%
Pancreas	1-2%	2-5%



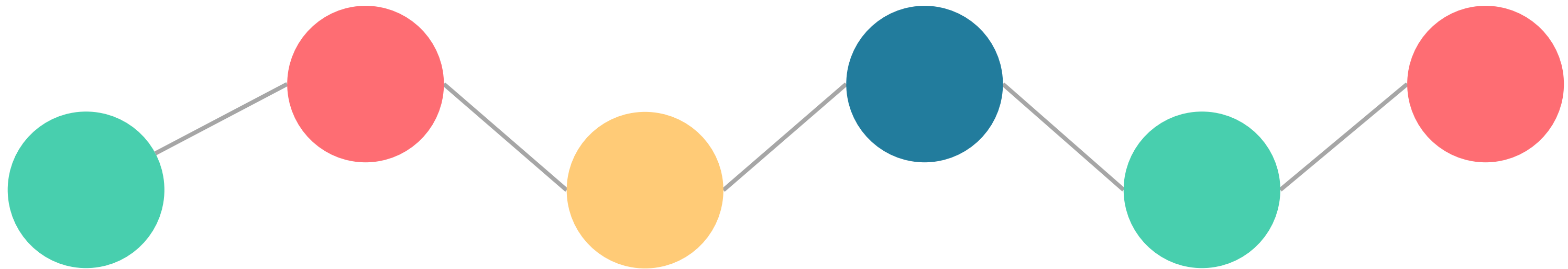
MEDICAL MANAGEMENT: PALB2

Breast (female)

Annual breast MRI starting at 30
Annual mammogram starting at 30
Consider risk reducing mastectomy
Chemoprevention options to consider

Breast (male)

Self-breast exam at age 35
Annual clinical breast exam at 35



Ovaries

Consider risk reducing bilateral salpingo-oophorectomy at 45-50

Pancreas

Annual MRI/MRCP and/or EUS starting at age 50 if family history of PDAC in FDR/SDR

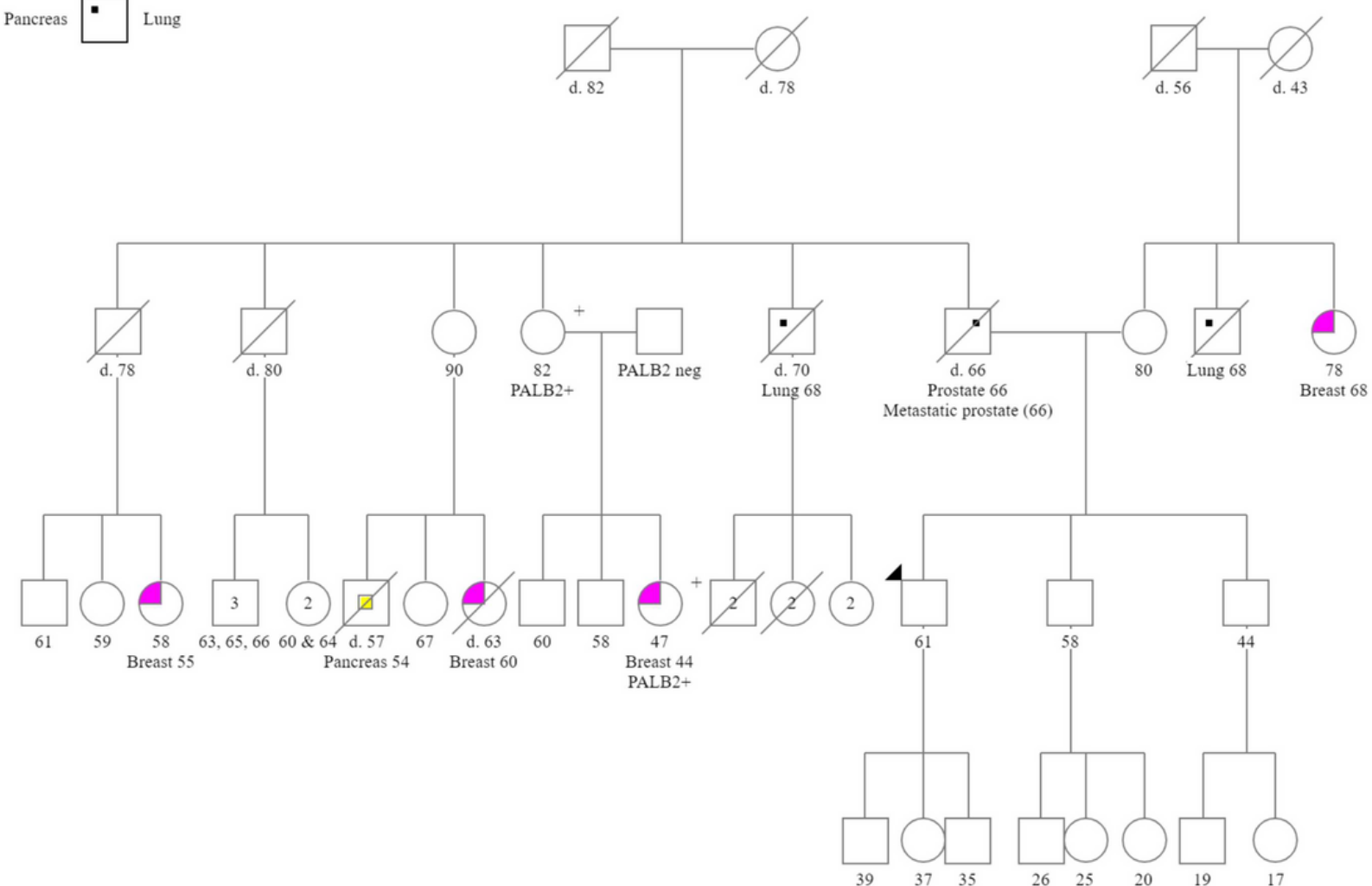
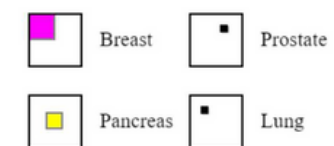
NCCN



Family 3

Paternal Ancestry
German, Non - Ashkenazi

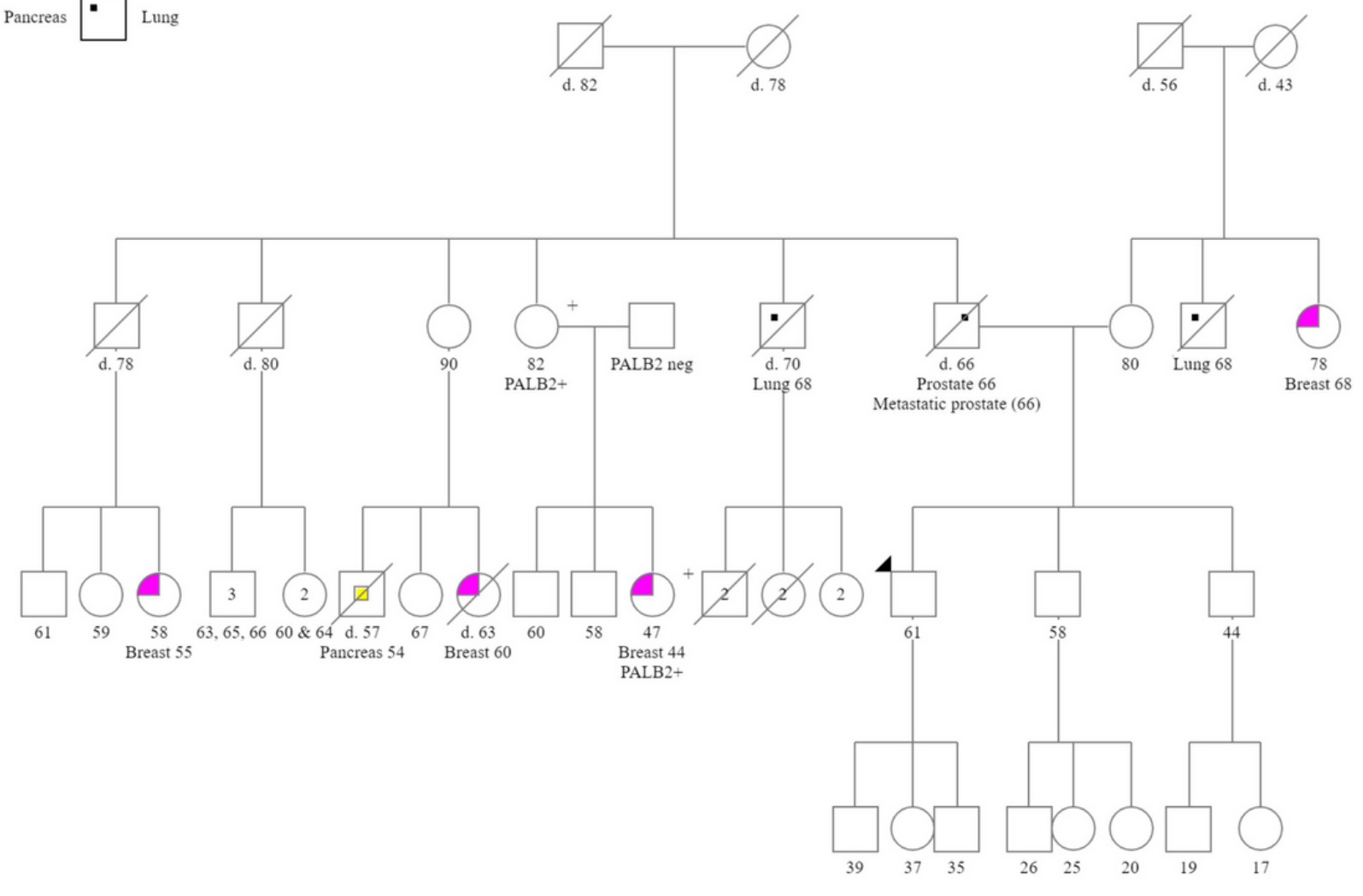
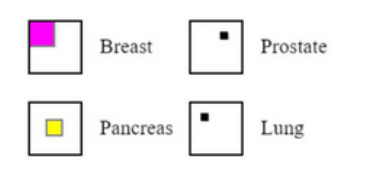
Maternal Ancestry
Italian, Swedish, Bohemian,
Polish, Non - Ashkenazi



No additional pathogenic mutations, variants of unknown significance, or gross deletions or duplications were detected. Genes Analyzed (77 total): ***AIP, ALK, APC, ATM, AXIN2, BAP1, BARD1, BLM, BMPR1A, BRCA1, BRCA2, BRIP1, CDC73, CDH1, CDK4, CDKN1B, CDKN2A, CHEK2, CTNNA1, DICER1, FANCC, FH, FLCN, GALNT12, KIF1B, LZTR1, MAX, MEN1, MET, MLH1, MSH2, MSH3, MSH6, MUTYH, NBN, NF1, NF2, NTHL1, PALB2, PHOX2B, PMS2, POT1, PRKAR1A, PTCH1, PTEN, RAD51C, RAD51D, RB1, RECQL, RET, SDHA, SDHAF2, SDHB, SDHC, SDHD, SMAD4, SMARCA4, SMARCB1, SMARCE1, STK11, SUFU, TMEM127, TP53, TSC1, TSC2, VHL*** and ***XRCC2*** (sequencing and deletion/duplication); ***EGFR, EGLN1, HOXB13, KIT, MITF, PDGFRA, POLD1*** and ***POLE*** (sequencing only); ***EPCAM*** and ***GREM1*** (deletion/duplication only).

Family 3

Paternal Ancestry: German, Non - Ashkenazi
 Maternal Ancestry: Italian, Swedish, Bohemian, Polish, Non - Ashkenazi



RESULTS

ATM Pathogenic Mutation: **c.6679C>T**

SUMMARY

POSITIVE: Pathogenic Mutation Detected

INTERPRETATION

- This individual is heterozygous for the **c.6679C>T (p.R2227C)** pathogenic mutation in the *ATM* gene.
- **Risk estimate:** up to a 4 fold increased risk of female breast cancer and increased lifetime pancreatic and prostate cancer risk.
- The expression and severity of disease for this individual cannot be predicted.
- Genetic testing for pathogenic mutations in family members can be helpful in identifying at-risk individuals.
- Genetic counseling is a recommended option for all individuals undergoing genetic testing.

No additional pathogenic mutations, variants of unknown significance, or gross deletions or duplications were detected. Genes Analyzed (77 total): *AIP, ALK, APC, ATM, AXIN2, BAP1, BARD1, BLM, BMPR1A, BRCA1, BRCA2, BRIP1, CDC73, CDH1, CDK4, CDKN1B, CDKN2A, CHEK2, CTNNA1, DICER1, FANCC, FH, FLCN, GALNT12, KIF1B, LZTR1, MAX, MEN1, MET, MLH1, MSH2, MSH3, MSH6, MUTYH, NBN, NF1, NF2, NTHL1, PALB2, PHOX2B, PMS2, POT1, PRKAR1A, PTCH1, PTEN, RAD51C, RAD51D, RB1, RECQL, RET, SDHA, SDHAF2, SDHB, SDHC, SDHD, SMAD4, SMARCA4, SMARCB1, SMARCE1, STK11, SUFU, TMEM127, TP53, TSC1, TSC2, VHL* and *XRCC2* (sequencing and deletion/duplication); *EGFR, EGLN1, HOXB13, KIT, MITF, PDGFRA, POLD1* and *POLE* (sequencing only); *EPCAM* and *GREM1* (deletion/duplication only).

COMMENT: The *PALB2* c.509_510delGA alteration, which was previously identified in this individual's relative(s), was not detected in this individual's specimen.



CANCER RISKS: ATM

Cancer	General Population Risk	ATM Risk
Breast	12%	20-30%
Ovary	1-2%	2-3%
Prostate	12-13%	Increased
Pancreas	1-2%	5-10



MEDICAL MANAGEMENT: ATM

Breast (female)

Annual breast MRI starting at 30–35
Annual mammogram starting at 40
Chemoprevention options to consider

Prostate*

Consider prostate cancer screening at 40

Ovaries

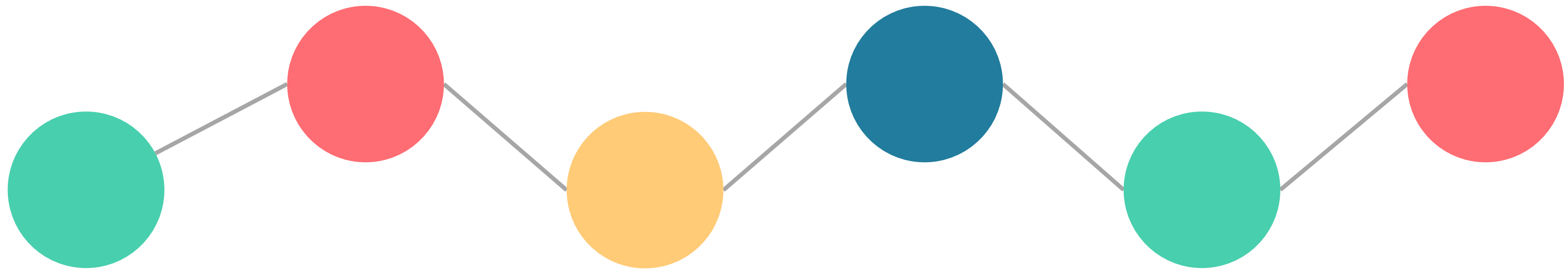
Insufficient evidence for risk reducing bilateral salpingo-oophorectomy. Manage based on family history

Pancreas

Annual MRI/MRCP and/or EUS starting at age 50 if family history of PDAC in FDR/SDR

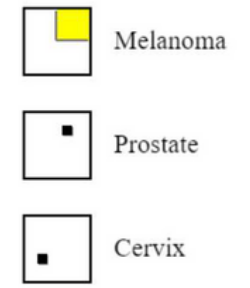
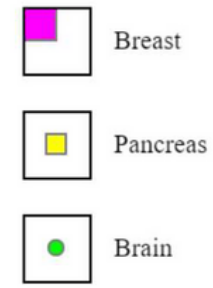
*Consider PARP inhibitor in cancer treatment plan

NCCN

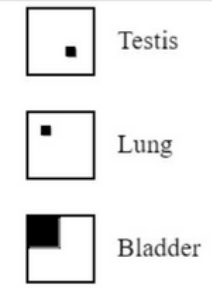


FAMILY 4:

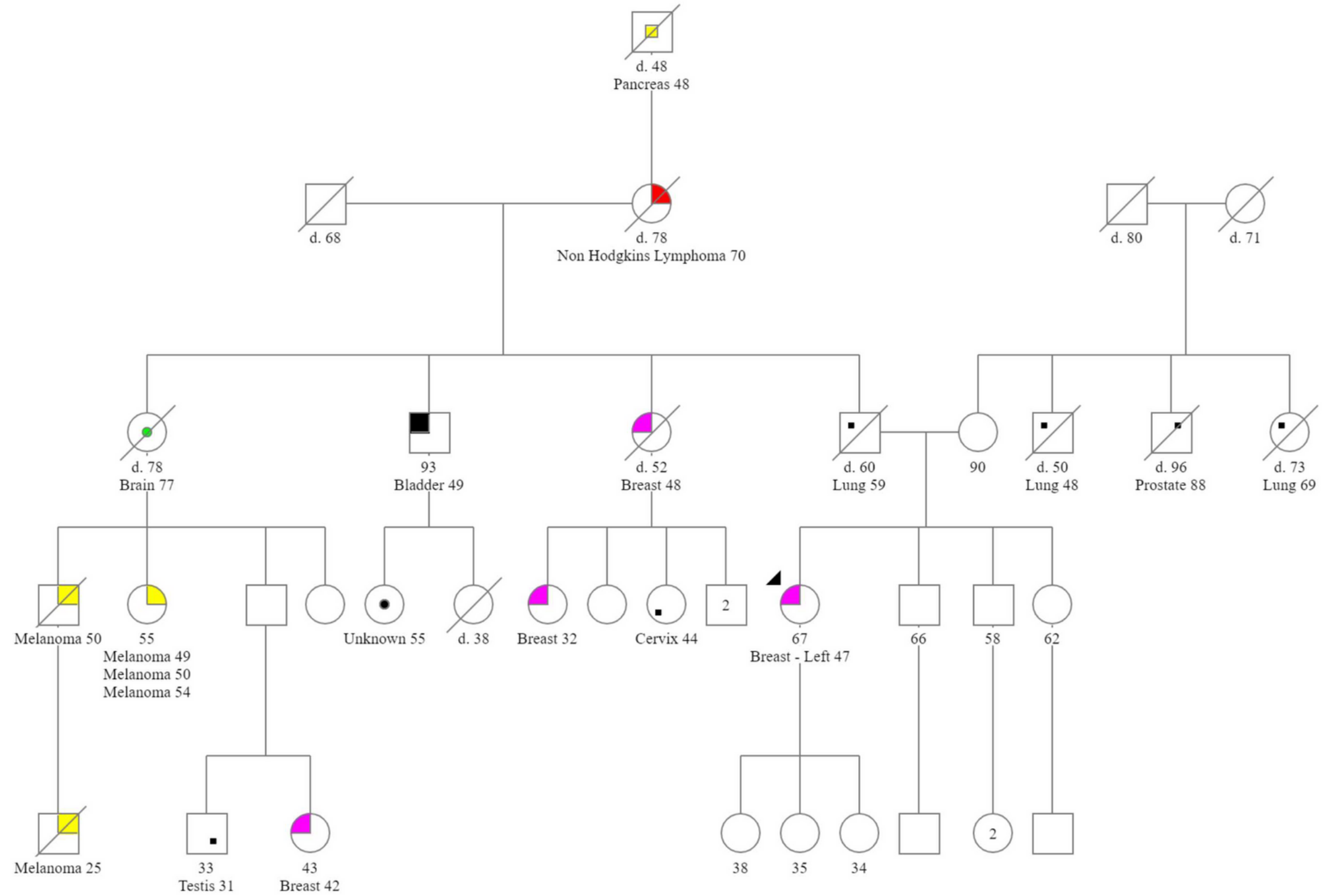
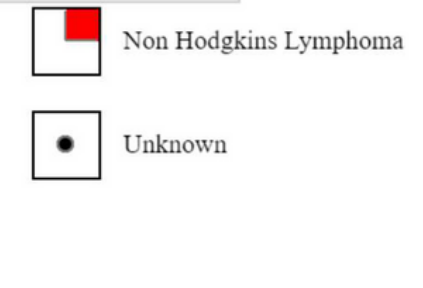
Family 4



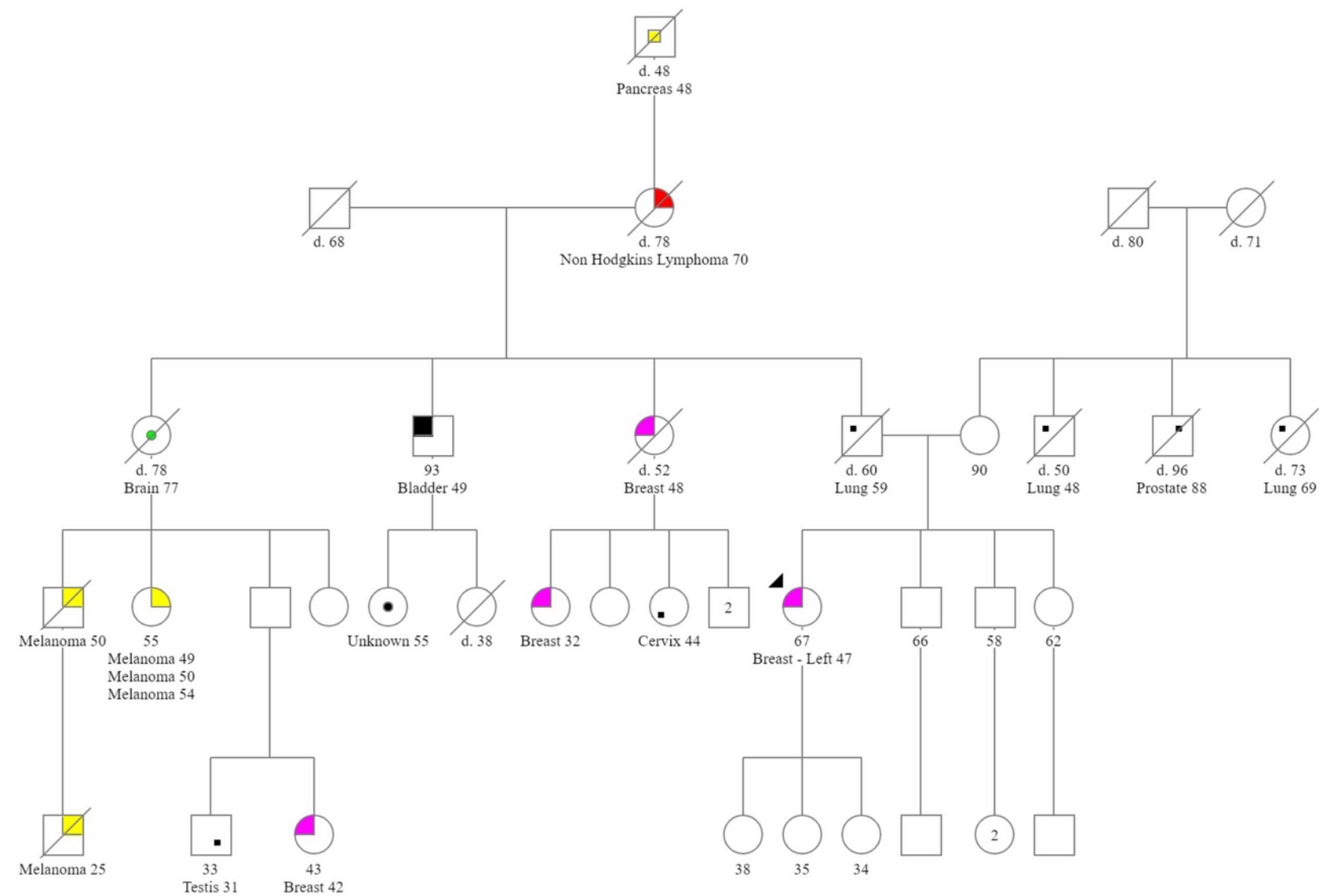
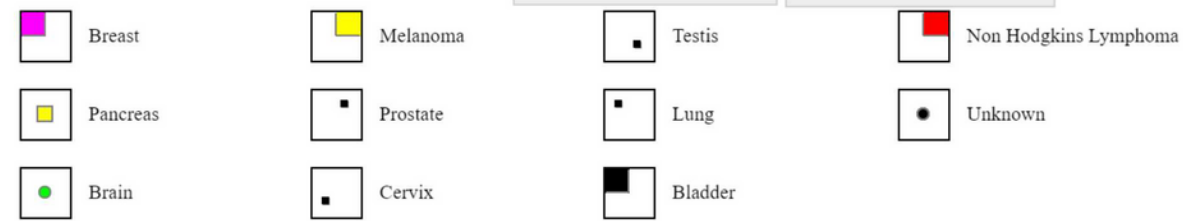
Paternal Ancestry
Irish, French, Non - Ashkenazi



Maternal Ancestry
Italian, Non - Ashkenazi

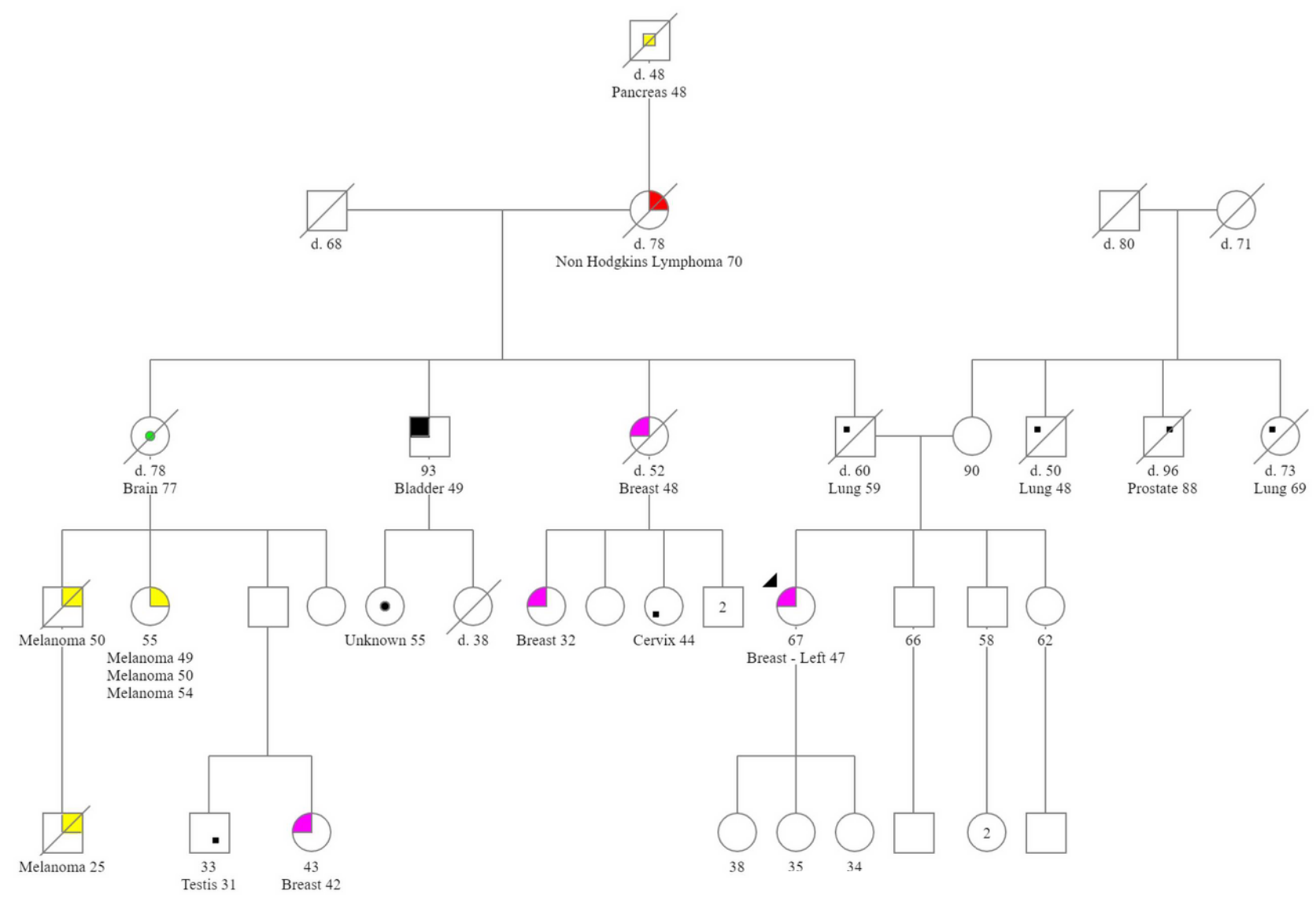
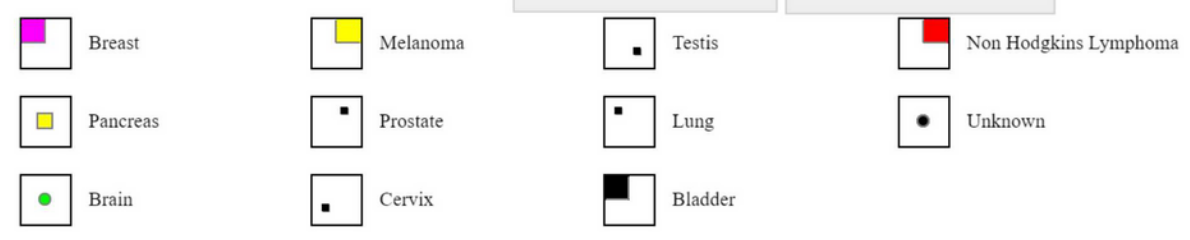


Family 4



No additional pathogenic mutations, variants of unknown significance, or gross deletions or duplications were detected. Genes Analyzed (77 total): ***AIP, ALK, APC, ATM, BAP1, BARD1, BLM, BMPR1A, BRCA1, BRCA2, BRIP1, CDC73, CDH1, CDK4, CDKN1B, CDKN2A, CHEK2, DICER1, FANCC, FH, FLCN, GALNT12, KIF1B, LZTR1, MAX, MEN1, MET, MLH1, MSH2, MSH6, MUTYH, NBN, NF1, NF2, NTHL1, PALB2, PHOX2B, PMS2, POT1, PRKAR1A, PTCH1, PTEN, RAD51C, RAD51D, RB1, RECQL, RET, SDHA, SDHAF2, SDHB, SDHC, SDHD, SMAD4, SMARCA4, SMARCB1, SMARCE1, STK11, SUFU, TMEM127, TP53, TSC1, TSC2, VHL*** and ***XRCC2*** (sequencing and deletion/duplication); ***AXIN2, CTNNA1, EGFR, EGLN1, HOXB13, KIT, MITF, MSH3, PDGFRA, POLD1*** and ***POLE*** (sequencing only); ***EPCAM*** and ***GREM1*** (deletion/duplication only). RNA data is routinely analyzed for use in variant interpretation for all genes.

Family 4

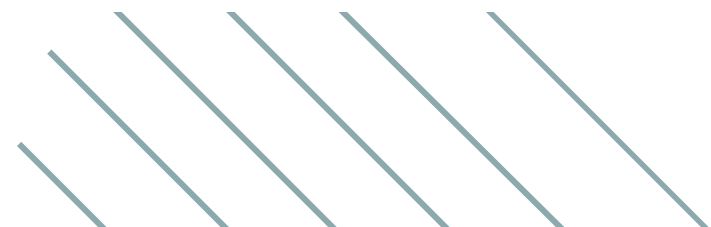


RESULTS

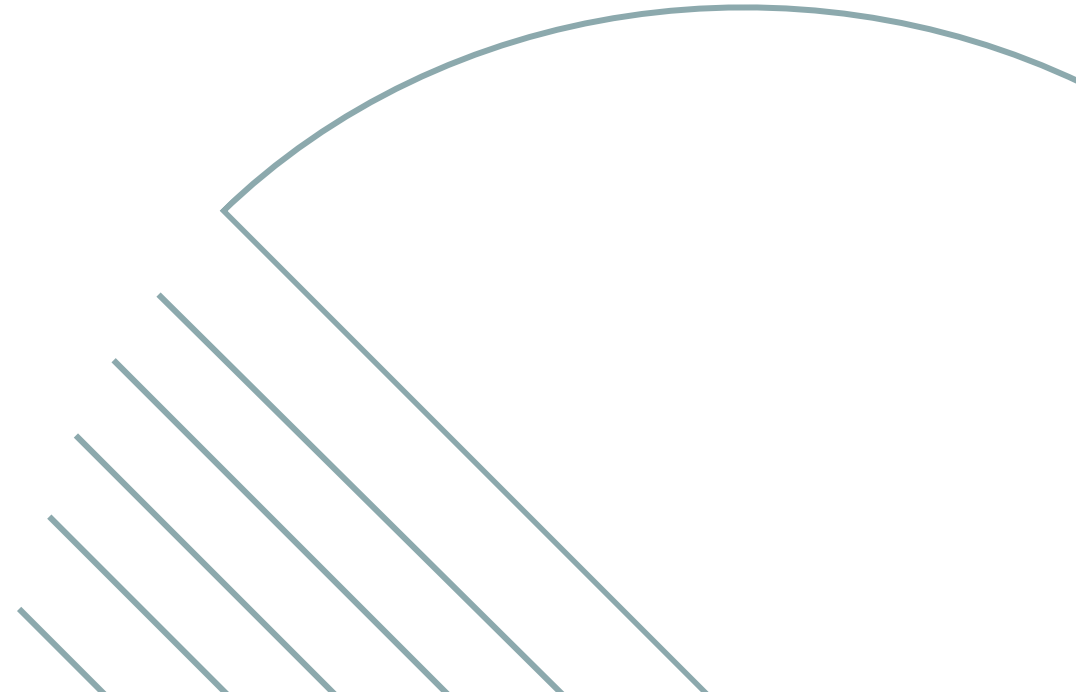
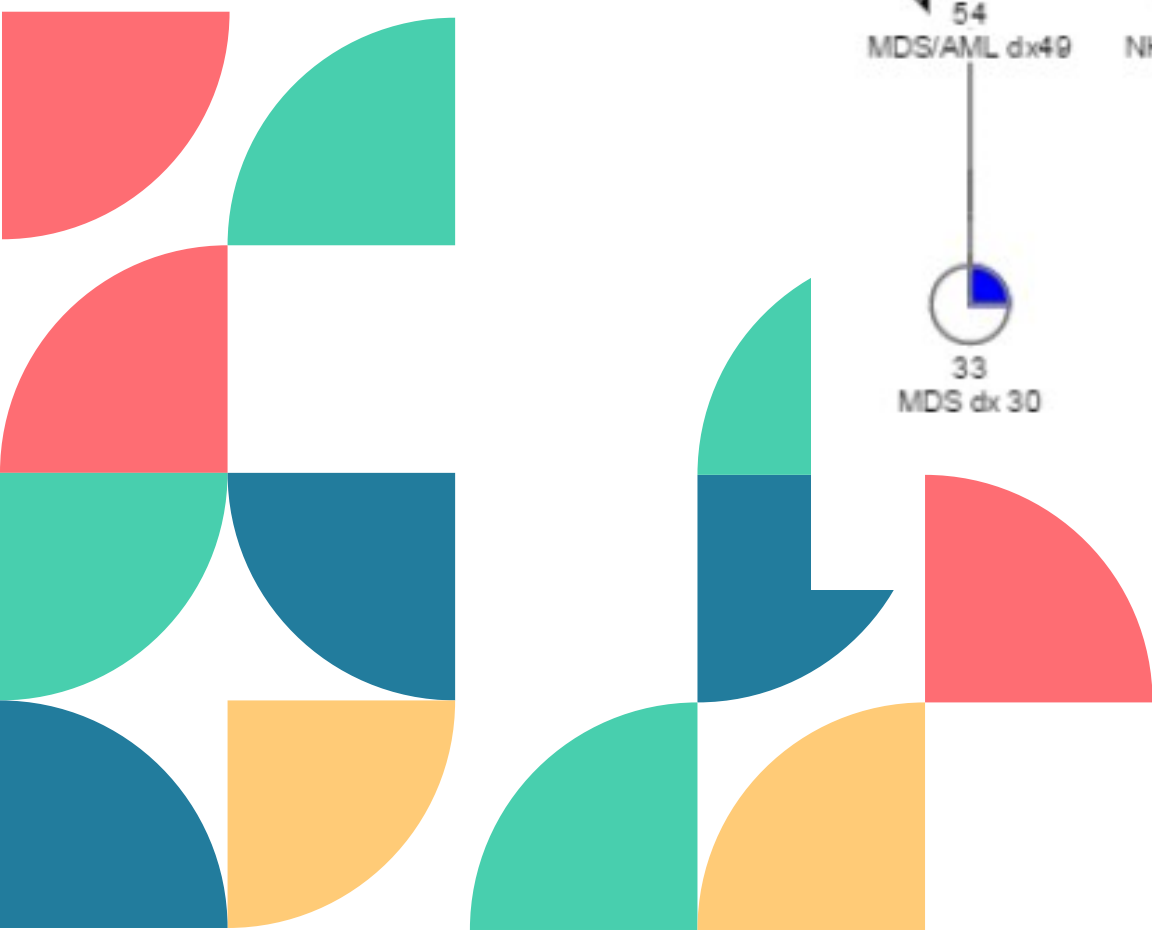
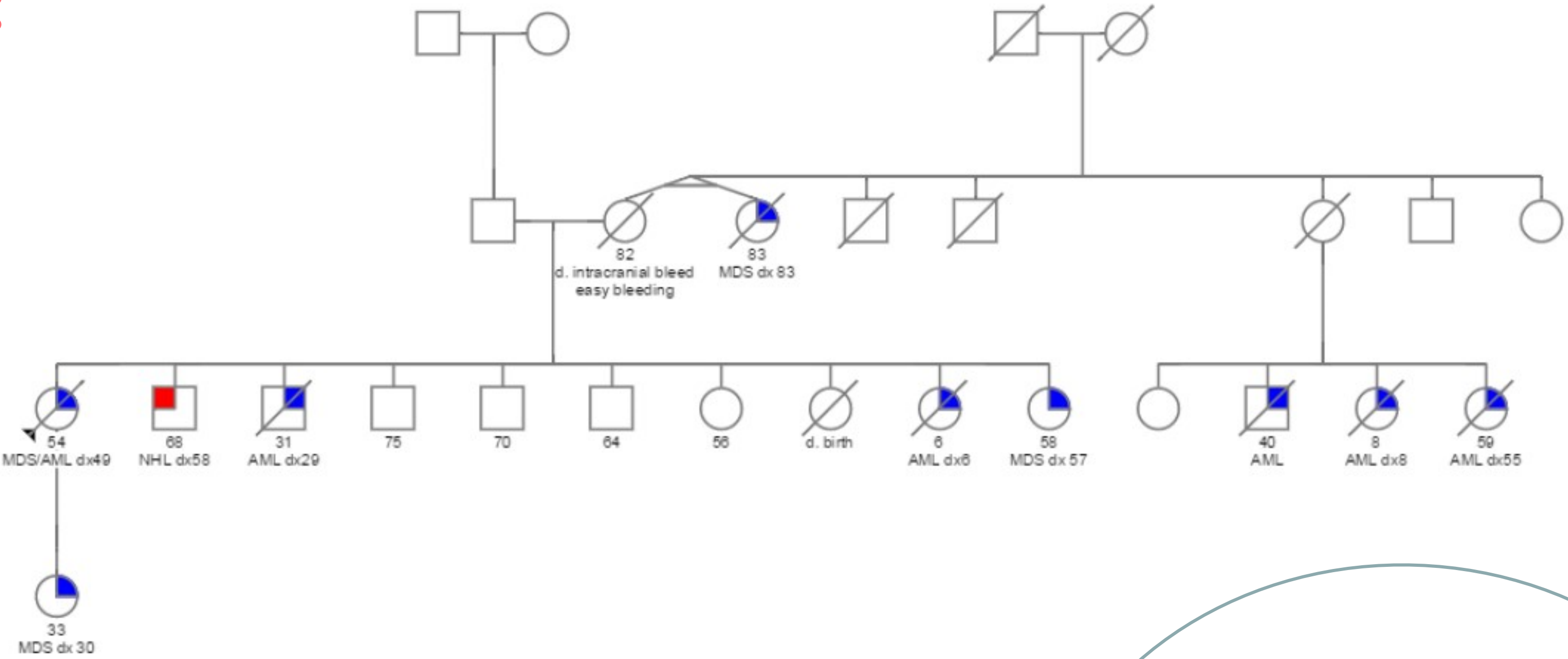
ATM Pathogenic Mutation: p.R1875*

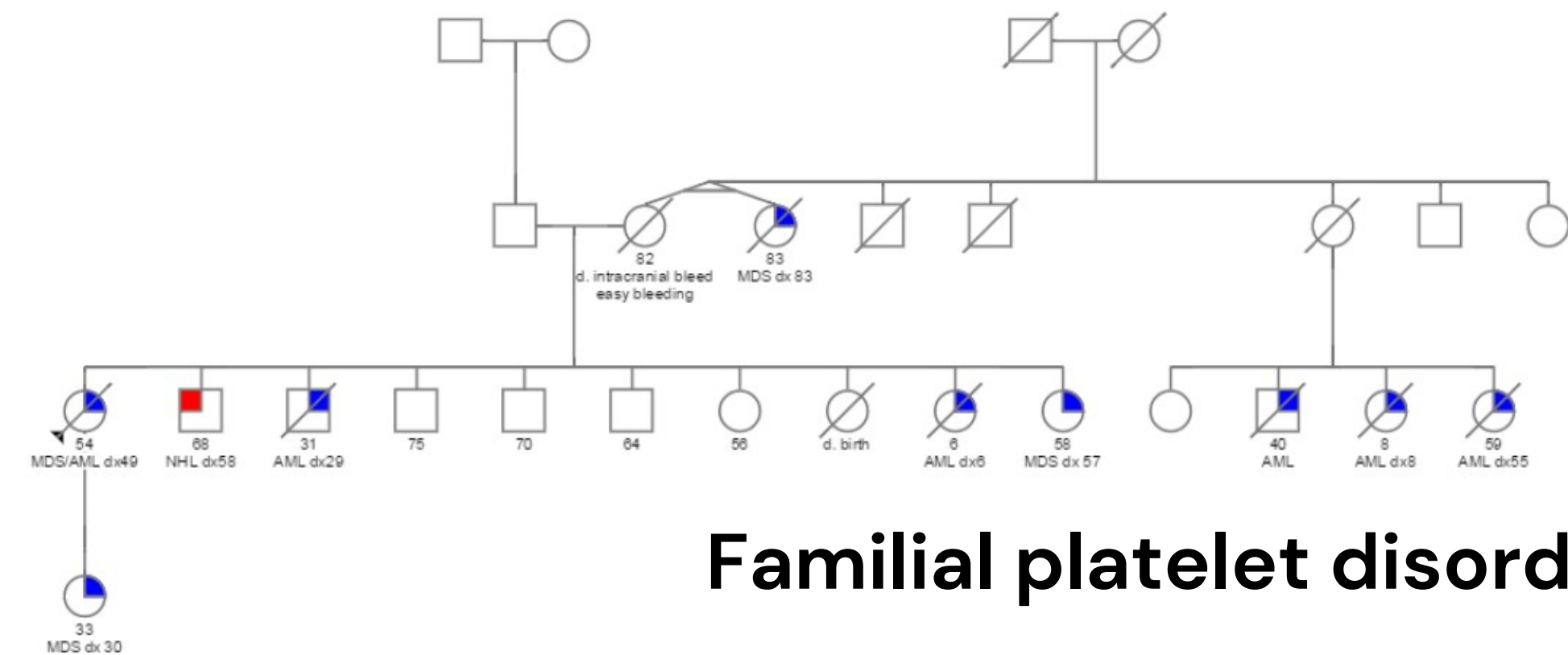
SUMMARY

POSITIVE: Pathogenic Mutation Detected



FAMILY 5:





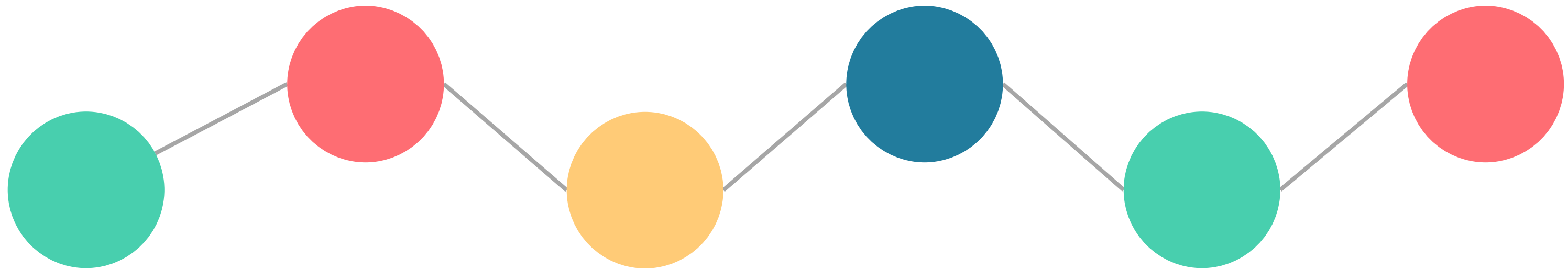
Familial platelet disorder with associated myeloid malignancy

- Gene: *RUNX1*
- 99% patients have thrombocytopenia and abnormal platelet function
- Increased risk for MDS, AML, T-ALL: 20–60% lifetime risk
- Typical age of onset of AML/MDS is 20–40y
- Skin manifestations such as eczema and psoriasis

MEDICAL MANAGEMENT: RUNX1

Clinical examination for signs/symptoms of neoplasm every six to 12 months

Bone marrow examination if constitutional symptoms and/or abnormalities on complete blood count are identified



Complete blood count with differential every three to four months

Skin exam as needed

SUMMARY

- Hereditary cancer gene mutations confer risk for cancer
- Changes to medical management may be indicated once a mutation is identified
- Identifying at risk individuals also allows us to identify other at risk family members
- **Prevention and early detection** of cancer is key in improving patient outcomes

GENETIC RISK ASSESSMENT

**Nebraska Medicine
Hereditary Cancer Clinic
402-559-3602**

**Nebraska Medicine
Cancer Risk & Prevention
Clinic
402-559-5600**



The background features four decorative geometric patterns in the corners. The top-left corner has a series of parallel lines radiating from a point. The top-right corner has a cluster of overlapping semi-circles in yellow, red, teal, and blue. The bottom-left corner has a cluster of overlapping semi-circles in red, teal, and blue. The bottom-right corner has a series of parallel lines radiating from a point, mirroring the top-left pattern.

THANK YOU