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Warsaw Syndrome

Synonyms: WABS, Warsaw Breakage Syndrome

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Summary

Clinical characteristics

Warsaw syndrome is characterized by the clinical triad of severe congenital microcephaly, growth restriction, and sensorineural hearing loss due to cochlear hypoplasia. Intellectual disability is typically in the mild-to-moderate range. Severe speech delay is common. Gross and fine motor milestones are usually attained at the usual time, although a few individuals have mild delays. Additional common features include skeletal anomalies and cardiovascular anomalies. Abnormal skin pigmentation and genitourinary malformations have also been reported. Some individuals have had increased chromosome breakage and radial forms on cytogenetic testing of lymphocytes treated with diepoxybutane and mitomycin C.

Diagnosis/testing

The diagnosis of Warsaw syndrome is established in a proband by identification of biallelic pathogenic variants in *DDX11* on molecular genetic testing.

Management

Treatment of manifestations: Supplementary formula and/or gastrostomy tube as needed to optimize nutrition. Treatments for hearing loss include hearing aids, cochlear implantation, auditory brain stem implant; establishing system of communication and hearing habilitation that may include sign language, auditory therapy, speech therapy; educational programs designed for individuals with hearing impairment. Treatment of cardiac anomalies per cardiologist; treatment of genitourinary anomalies per nephrologist and/or urologist; early intervention and psychological evaluations; physical, occupational, and speech therapies.

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Surveillance: Monitor growth, speech development, and educational needs with each visit; there is no consensus regarding tumor screening.

Genetic counseling

Warsaw syndrome is inherited in an autosomal recessive manner. At conception, each sib of an affected individual has a 25% chance of being affected, a 50% chance of being an asymptomatic carrier, and a 25% chance of being unaffected and not a carrier. Carrier testing for at-risk relatives and prenatal testing for pregnancies at increased risk are possible if the *DDX11* pathogenic variants in the family are known.

Diagnosis

Suggestive Findings

Warsaw syndrome **should be suspected** in individuals with a triad of characteristic findings:

- Congenital severe microcephaly
- Prenatal and postnatal growth restriction
- Congenital sensorineural hearing loss due to cochlear abnormalities (e.g., cochlear hypoplasia)

Additional clinical, imaging, and laboratory findings include the following.

Clinical findings

- Intellectual disability and developmental delay
- Skeletal anomalies (e.g., proximal insertion of the thumbs, shortening of the thumbs and the first metacarpals, clinodactyly of the fifth finger, and overlapping toes)
- Abnormal skin pigmentation (e.g., café au lait macules, cutis marmorata, hypo- or hyperpigmentation, livedo reticularis with telangiectasia)
- Congenital cardiovascular malformations (e.g., patent ductus arteriosus, atrial septal defect, ventricular septal defect, tetralogy of Fallot)
- Genitourinary malformations (e.g., hypoplastic scrotum, cryptorchidism, hypospadias, multicystic kidneys)

Imaging findings. Cochlear anomalies on temporal bone imaging (e.g., cochlear hypoplasia)

Laboratory findings

- Increased chromosome breakage and radial forms on cytogenetic testing of lymphocytes treated with diepoxybutane (DEB) and mitomycin C (MMC) in some affected individuals

  Note: (1) The background rate of chromosome breakage in control chromosomes is more variable with MMC; thus, some centers prefer using DEB while other centers use both DEB and MMC.

- Premature chromatid separation (PCS) and premature centromere division (PCD) – separation of the sister chromatids and centromeres during metaphase rather than in anaphase visible on C-banding techniques (Figure 1)

- In many chromosomes, a "railroad track" appearance as a result of the absence of the primary constriction and presence of "puffing" or "repulsion" at the heterochromatic regions around the centromeres and nucleolar organizers.

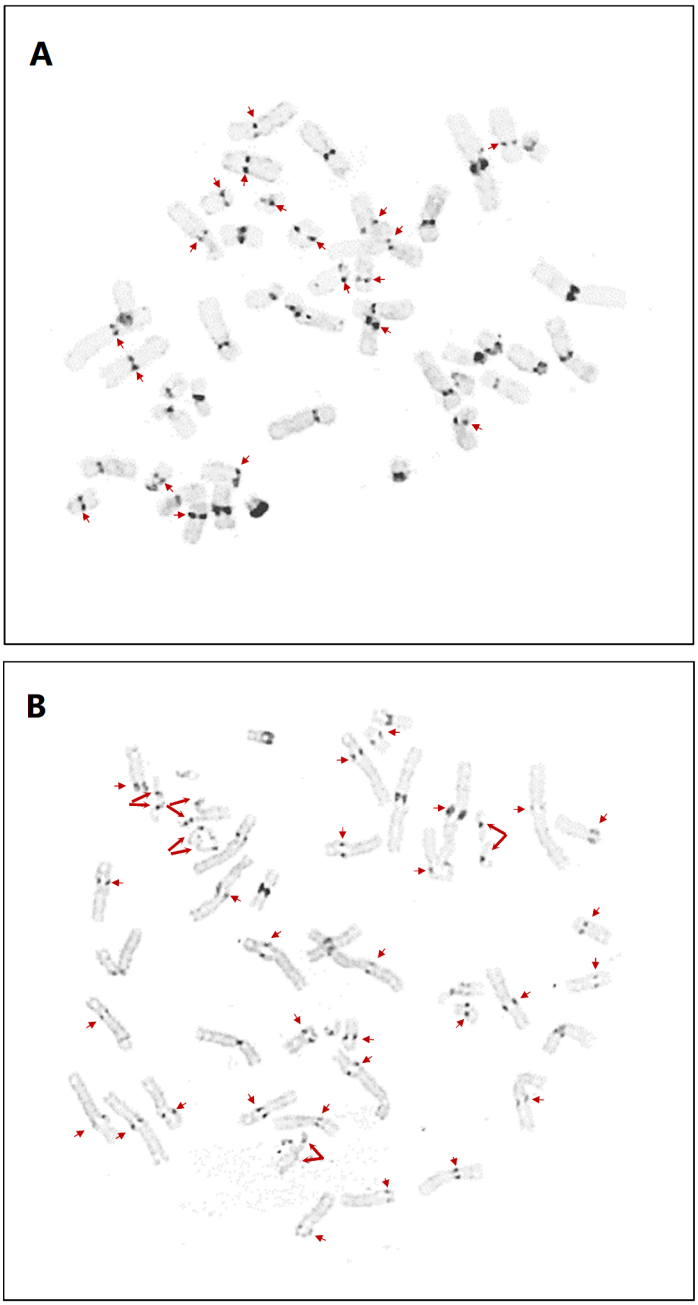

Figure 1. C-banding of metaphase chromosomes in two individuals with Warsaw syndrome. Short arrows show chromosome morphology suggestive of PCD; long arrows show chromosomes with PCS.

A. Representative metaphase from untreated (0 dose) culture

B. Thymidine-synchronized culture

Establishing the Diagnosis

The diagnosis of Warsaw syndrome **is established** in a proband with biallelic pathogenic (or likely pathogenic) variants in *DDX11* by molecular genetic testing (see Table 1).

Note: (1) Per ACMG/AMP variant interpretation guidelines, the terms "pathogenic variants" and "likely pathogenic variants" are synonymous in a clinical setting, meaning that both are considered diagnostic and both can be used for clinical decision making [Richards et al 2015]. Reference to "pathogenic variants" in this section

is understood to include any likely pathogenic variants. (2) Identification of biallelic *DDX11* variants of uncertain significance (or of one known *DDX11* pathogenic variant and one *DDX11* variant of uncertain significance) does not establish or rule out the diagnosis.

Molecular genetic testing approaches can include a combination of **gene-targeted testing** (single-gene testing, multigene panel) and **comprehensive genomic testing** (exome sequencing, exome array, genome sequencing) depending on the phenotype.

Gene-targeted testing requires that the clinician determine which gene(s) are likely involved, whereas genomic testing does not. Because the phenotype of Warsaw syndrome is broad, individuals with the distinctive findings described in Suggestive Findings are likely to be diagnosed using gene-targeted testing (see Option 1), whereas those in whom the diagnosis of Warsaw syndrome has not been considered are more likely to be diagnosed using genomic testing (see Option 2).

Option 1

When the phenotypic and laboratory findings suggest the diagnosis of Warsaw syndrome, molecular genetic testing approaches can include **single-gene testing** or use of a **multigene panel**:

- **Single-gene testing.** Sequence analysis of *DDX11* detects small intragenic deletions/insertions and missense, nonsense, and splice site variants; typically, exon or whole-gene deletions/duplications are not detected. Perform sequence analysis first. If only one or no pathogenic variant is found, perform gene-targeted deletion/duplication analysis to detect intragenic deletions or duplications.

  Note: Analysis of *DDX11* is complicated by the presence of at least 16 highly homologous pseudogenes (e.g., *DDX11L1*, *DDX11L2*).

- **A multigene panel** that includes *DDX11* and other genes of interest (see Differential Diagnosis) is most likely to identify the genetic cause of the condition while limiting identification of variants of uncertain significance and pathogenic variants in genes that do not explain the underlying phenotype. Note: (1) The genes included in the panel and the diagnostic sensitivity of the testing used for each gene vary by laboratory and are likely to change over time. (2) Some multigene panels may include genes not associated with the condition discussed in this *GeneReview*. Of note, given the rarity of Warsaw syndrome, some panels for microcephaly and/or hearing loss may not include this gene. (3) In some laboratories, panel options may include a custom laboratory-designed panel and/or custom phenotype-focused exome analysis that includes genes specified by the clinician. (4) Methods used in a panel may include sequence analysis, deletion/duplication analysis, and/or other non-sequencing-based tests.

  For an introduction to multigene panels click here. More detailed information for clinicians ordering genetic tests can be found here.

Option 2

When the diagnosis of Warsaw syndrome is not considered because an individual has atypical phenotypic features, **comprehensive genomic testing** (which does not require the clinician to determine which gene[s] are likely involved) is the best option. **Exome sequencing** or **genome sequencing** are most commonly used.

If exome sequencing is not diagnostic, **exome array** (when clinically available) may be considered to detect (multi)exon deletions or duplications that cannot be detected by sequence analysis. Note: To date such variants have not been identified as a cause of Warsaw syndrome.

Note: Analysis of *DDX11* is complicated by the presence of at least 16 highly homologous pseudogenes (e.g., *DDX11L1*, *DDX11L2*). Sequence for all exons of the gene may not be obtained by genomic testing.

For an introduction to comprehensive genomic testing click here. More detailed information for clinicians ordering genomic testing can be found here.

Table 1. Molecular Genetic Testing Used in Warsaw Syndrome

Gene [1]	Method	Proportion of Pathogenic Variants [2] Detectable by Method
DDX11	Sequence analysis [3]	14/14 individuals [4]
	Gene-targeted deletion/duplication analysis [5]	Unknown, none reported

1. See Table A. Genes and Databases for chromosome locus and protein.
2. See Molecular Genetics for information on allelic variants detected in this gene.
3. Sequence analysis detects variants that are benign, likely benign, of uncertain significance, likely pathogenic, or pathogenic. Variants may include small intragenic deletions/insertions and missense, nonsense, and splice site variants; typically, exon or whole-gene deletions/duplications are not detected. For issues to consider in interpretation of sequence analysis results, click here.
4. van der Lelij et al [2010], Capo-Chichi et al [2013], Bailey et al [2015], Eppley et al [2017], Alkhunaizi et al [2018], Bottega et al [2019]
5. Gene-targeted deletion/duplication analysis detects intragenic deletions or duplications. Methods used may include a range of techniques such as quantitative PCR, long-range PCR, multiplex ligation-dependent probe amplification (MLPA), and a gene-targeted microarray designed to detect single-exon deletions or duplications.

Clinical Characteristics

Clinical Description

Warsaw syndrome presents with a clinical triad of severe microcephaly, growth restriction, and hearing loss. Other anomalies have also been described. Fourteen children (8 female, 6 male) have been reported to date.

Microcephaly has a prenatal onset and is reported in all affected individuals. Congenital microcephaly can range from -3.3 to -10 SD for age and sex. Postnatal head growth velocity is slower than average for age and sex. However, there are no reports of a substantial decrease in head growth velocity in childhood.

Prenatal and postnatal growth deficiency. All 14 reported individuals to date had intrauterine growth deficiency with birth weight and height below the third percentile. Postnatal growth deficiency was also reported in all individuals; two individuals had weights between the 50th and 75th percentile later in childhood after they were started on gastric tube feedings [Bailey et al 2015, Alkhunaizi et al 2018].

Congenital sensorineural hearing loss is usually severe; the result of bilateral hypoplasia of the cochlea and the cochlear nerve. Children with Warsaw syndrome usually present early with a failed newborn hearing screen or severe speech disability that is comparable to the degree of sensorineural hearing loss. Expressive language is consistently affected due to the hearing loss; receptive language is also involved but to a lesser degree. Sign language can be learned; however, due to the intellectual disability, this is also limited in some individuals along with receptive language.

Intellectual disability and developmental delay range from mild to moderate and tend to be stable. Behavioral issues such as mild ADHD and aggression were reported in two individuals [Bailey et al 2015, Alkhunaizi et al 2018]; however, affected children usually have good interpersonal skills. Gross and fine motor milestones are usually attained at the usual time although a few individuals have mild delays.

Cardiovascular anomalies are reported in 42% (5/12). These include patent ductus arteriosus (1), small atrial septal defect with large patent ductus arteriosus (1), ventricular septal defect (2), and tetralogy of Fallot (1).

Additional structural brain abnormalities. In addition to cochlear hypoplasia, one individual presented with posterior labyrinthine anomaly with persistent lateral semicircular canal anlage [Alkhunaizi et al 2018]. Two individuals had focal poor sulcation pattern; focal lissencephaly was reported in one of these individuals [Alkhunaizi et al 2018].

Radial ray anomalies include proximal insertion of thumbs, shortened first metacarpals, small radii, and short thumbs.

Manifestations reported in single individuals

- **Limb anomalies** include fifth finger clinodactyly, brachydactyly, small fibula, talipes equino varus, partial syndactyly of toes 2/3, and overlapping toes.
- **Abnormal skin pigmentation** includes café au lait macules, cutis marmorata, hypo- or hyperpigmentation, and livedo reticularis with telangiectasia.
- **Genitourinary malformations** include hypoplastic scrotum, cryptorchidism, hypospadias, and multicystic kidneys.
- **Other findings** include early menarche in two sisters [Eppley et al 2017] and seizure disorder in one individual [Alkhunaizi et al 2018].

Malignancy. *DDX11* is essential for genome maintenance and may act as a tumor suppressor [Parish et al 2006]. The possibility of an increased risk of malignancy in obligate heterozygotes (parents) was raised by van der Lelij et al [2010]; the current authors reported a family that included a mother of the proband with lymphoma and another heterozygous relative with endometrial adenocarcinoma. None of the five affected individuals nor their parents reported by Alkhunaizi et al [2018] had cancer. Therefore, the risk of malignancy in individuals with Warsaw syndrome or heterozygous individuals is not clear.

Genotype-Phenotype Correlations

No genotype-phenotype correlations are known.

Nomenclature

Warsaw breakage syndrome was named for the city of origin of the first reported individual and the elevated level of chromosome breakage similar to Fanconi anemia reported in some affected individuals [van der Lelij et al 2010].

The observation of inconsistent increased level of chromosome breakage in individuals with this disorder led the current authors to suggest changing the name of the condition to Warsaw syndrome [Alkhunaizi et al 2018].

Prevalence

Warsaw syndrome is rare, with 14 individuals reported to date [van der Lelij et al 2010, Capo-Chichi et al 2013, Bailey et al 2015, Eppley et al 2017, Alkhunaizi et al 2018, Bottega et al 2019].

Genetically Related (Allelic) Disorders

No phenotypes other than those discussed in this *GeneReview* are known to be associated with germline pathogenic variants in *DDX11*.

Differential Diagnosis

Table 2. Disorders to Consider in the Differential Diagnosis of Warsaw Syndrome

Differential Disorder	Gene(s)	MOI	Clinical Features of Differential Disorder	
			Overlapping w/Warsaw syndrome	Distinguishing from Warsaw syndrome
Fanconi anemia	21 genes [1]	AR AD XL	• Microcephaly • Short stature • Abnormal skin pigmentation • Skeletal malformations of upper & lower limbs • ↑ chromosome breakage [2]	Progressive bone marrow failure w/ pancytopenia
Nijmegen breakage syndrome	*NBN*	AR	• Microcephaly, progressive • IUGR w/postnatal short stature • Chromosome instability	• Immunodeficiency • Premature ovarian failure in females • High cancer risk in affected persons; intermediate risk in heterozygotes • Inversions & translocations involving chromosomes 7 & 14
Roberts syndrome	*ESCO2*	AR	Cytogenetic findings of PCS	Bilateral symmetric tetraphocomelia or hypomelia
Microcephalic osteodysplastic primordial dwarfism type II	*PCNT*	AR	• Pre- & postnatal growth deficiency • Severe microcephaly • Short stature	• Greater growth deficiency • Extremely short stature • Lack of cochlear hypoplasia • CNS vascular anomalies • Insulin resistance

AD = autosomal dominant; AR = autosomal recessive; CNS = central nervous system; IUGR = intrauterine growth restriction; MOI = mode of inheritance; PCS = premature chromatid separation; XL = X-linked

1. BRCA2, *BRIP1*, *FANCA*, *FANCB*, *FANCC*, *FANCD2*, *FANCE*, *FANCF*, *FANCG*, *FANCI*, *ERCC4*, *FANCL*, *FANCM*, *MAD2L2*, *PALB2*, *RAD51*, *RAD51C*, *RFWD3*, *SLX4*, *UBE2T*, *XRCC*

2. Increased chromosome breakage on cytogenetic testing of lymphocytes with diepoxybutane (DEB) and mitomycin C (MMC)

Management

Evaluations Following Initial Diagnosis

To establish the extent of disease and needs in an individual diagnosed with Warsaw syndrome, the evaluations summarized in Table 3 (if not performed as part of the evaluation that led to the diagnosis) are recommended.

Table 3. Recommended Evaluations Following Initial Diagnosis in Individuals with Warsaw Syndrome

System/Concern	Evaluation	Comment
Constitutional	Assessment of growth parameters	To identify those w/failure to thrive
ENT	ENT referral & audiologic eval incl temporal bone imaging	
Cardiovascular	Cardiology eval w/echocardiogram	To evaluate for congenital cardiac anomalies
Genitourinary	Exam for genitourinary anomalies & renal ultrasound exam	
Other	Assessment of speech development & intellectual abilities	Esp important in toddlers & school-age children
	Consultation w/clinical geneticist &/or genetic counselor	

Treatment of Manifestations

Table 4. Treatment of Manifestations in Individuals with Warsaw Syndrome

Manifestation/ Concern	Treatment
Poor weight gain / Failure to thrive	• Optimize nutritional needs in those w/failure to thrive. • Supplementary formulas &/or gastrostomy tube as needed
Hearing loss	• Hearing aids should be considered in those w/non-profound hearing loss (rarely beneficial if there is complete absence of cochlear nerve). • Cochlear implantation, if cochlear nerve is present • Auditory brain stem implant is an optional treatment. [1] • Establish an appropriate system of communication & hearing habilitation immediately w/diagnosis of hearing loss; may include sign language in addition to auditory & speech therapy. • Offer educational programs designed for those w/hearing impairment.
Cardiac anomalies	Treatment per cardiologist
Genitourinary anomalies	Treatment per nephrologist &/or urologist
Developmental delay	Provide: • Early intervention & psychological evals; • Ongoing PT, OT, & speech therapy to optimize developmental outcomes.

OT = occupational therapy; PT = physical therapy
1. Freeman & Sennaroglu [2018]

Surveillance

Table 5. Recommended Surveillance for Individuals with Warsaw Syndrome

System/Concern	Evaluation	Frequency
Constitutional	Monitor growth incl height, weight, head circumference, & body mass index.	At each visit
Misc/Other	Monitor speech development & educational needs.	
Malignancy	No consensus for tumor screening [1]	NA

1. Although van der Lelij et al [2010] suggested an increased incidence of malignancies in first-degree relatives of individuals with Warsaw syndrome, to date no affected individuals have developed malignancies and most reported families do not have an increased incidence of malignancies. Thus, it is not known if Warsaw syndrome is associated with an increased incidence of malignancy and if surveillance for malignancies should be recommended.

Evaluation of Relatives at Risk

See Genetic Counseling for issues related to testing of at-risk relatives for genetic counseling purposes.

Therapies Under Investigation

Search ClinicalTrials.gov in the US and EU Clinical Trials Register in Europe for access to information on clinical studies for a wide range of diseases and conditions. Note: There may not be clinical trials for this disorder.

Genetic Counseling

Genetic counseling is the process of providing individuals and families with information on the nature, mode(s) of inheritance, and implications of genetic disorders to help them make informed medical and personal decisions. The following section deals with genetic risk assessment and the use of family history and genetic testing to clarify genetic status for family members; it is not meant to address all personal, cultural, or ethical issues that may arise or to substitute for consultation with a genetics professional. —ED.

Mode of Inheritance

Warsaw syndrome is inherited in an autosomal recessive manner.

Risk to Family Members

Parents of a proband

- The parents of an affected child are obligate heterozygotes (i.e., carriers of one *DDX11* pathogenic variant).
- Heterozygotes (carriers) are asymptomatic and are not at risk of developing the disorder.

Sibs of a proband

- At conception, each sib of an affected individual has a 25% chance of being affected, a 50% chance of being an asymptomatic carrier, and a 25% chance of being unaffected and not a carrier.
- Heterozygotes (carriers) are asymptomatic and are not at risk of developing the disorder.

Offspring of a proband. Unless the reproductive partner of an affected individual also has Warsaw syndrome or is a carrier, offspring will be obligate heterozygotes (carriers) for a pathogenic variant in *DDX11*.

Other family members. Each sib of the proband's parents is at a 50% risk of being a carrier of a *DDX11* pathogenic variant.

Carrier Detection

Carrier testing for at-risk relatives requires prior identification of the *DDX11* pathogenic variants in the family.

Related Genetic Counseling Issues

Family planning

- The optimal time for determination of genetic risk, clarification of carrier status, and discussion of the availability of prenatal/preimplantation genetic testing is before pregnancy.
- It is appropriate to offer genetic counseling (including discussion of potential risks to offspring and reproductive options) to the parents of affected children and young adults who are carriers or are at risk of being carriers.

Prenatal Testing and Preimplantation Genetic Testing

Once the *DDX11* pathogenic variants have been identified in an affected family member, prenatal testing for a pregnancy at increased risk and preimplantation genetic testing are possible.

Differences in perspective may exist among medical professionals and within families regarding the use of prenatal testing. While most centers would consider use of prenatal testing to be a personal decision, discussion of these issues may be helpful.

Resources

GeneReviews staff has selected the following disease-specific and/or umbrella support organizations and/or registries for the benefit of individuals with this disorder and their families. GeneReviews is not responsible for the information provided by other organizations. For information on selection criteria, click here.

- **National Library of Medicine Genetics Home Reference**
  Warsaw breakage syndrome
- **American Society for Deaf Children**
  Phone: 800-942-2732 (ASDC)
  Email: info@deafchildren.org
  deafchildren.org
- **Human Growth Foundation**
  www.hgfound.org
- **MAGIC Foundation**
  Phone: 800-362-4423
  Email: contactus@magicfoundation.org
  www.magicfoundation.org
- **National Association of the Deaf**
  Phone: 301-587-1788 (Purple/ZVRS); 301-328-1443 (Sorenson); 301-338-6380 (Convo)
  Fax: 301-587-1791
  Email: nad.info@nad.org
  nad.org
- **Restricted Growth Association**
  United Kingdom
  restrictedgrowth.co.uk

Molecular Genetics

Information in the Molecular Genetics and OMIM tables may differ from that elsewhere in the GeneReview: tables may contain more recent information. —ED.

Table A. Warsaw Syndrome: Genes and Databases

Gene	Chromosome Locus	Protein	Locus-Specific Databases	HGMD	ClinVar
DDX11	12p11.21	ATP-dependent DNA helicase DDX11	DDX11 @ LOVD	DDX11	DDX11

Data are compiled from the following standard references: gene from HGNC; chromosome locus from OMIM; protein from UniProt. For a description of databases (Locus Specific, HGMD, ClinVar) to which links are provided, click here.

Table B. OMIM Entries for Warsaw Syndrome (View All in OMIM)

601150	DEAD/H-BOX HELICASE 11; DDX11
613398	WARSAW BREAKAGE SYNDROME; WABS

Introduction. *DDX11* belongs to a family of human DNA helicases (XPD, FANCJ, RTEL1) implicated in genome maintenance and may act as a tumor suppressor [Parish et al 2006]. *DDX11* encodes a superfamily 2 DNA helicase belonging to the iron-sulfur (Fe-S) cluster family of DNA helicase proteins [Hirota & Lahti 2000, Parish et al 2006]. Human Fe-S helicase family genes are implicated in genetic disorders including:

- *DDX11.* Warsaw syndrome (not yet confirmed)
- *ERCC2.* Xeroderma pigmentosum (XP) group D, cerebrooculofacioskeletal syndrome 2, or trichothiodystrophy
- *RTEL1.* Dyskeratosis congenita or Hoyeraal-Hreidarsson syndrome
- *BRIP1.* Fanconi anemia complementation group J

Warsaw syndrome is classified as a cohesinopathy along with Cornelia de Lange syndrome and Roberts syndrome.

DDX11 helicase is an ATP-dependent DNA helicase [Hirota & Lahti 2000, Inoue et al 2007, Bharti et al 2014], which unwinds duplex DNA with a 5'-3' directionality and is essential for the correct assembly of cohesin onto DNA during mitosis [Parish et al 2006]. The DNA-unwinding activity of DDX11 is essential to its in vivo function. All analyzed *DDX11* missense pathogenic variants whose amino acid substitutions are within the catalytic ATPase/helicase domain are either completely or near-completely devoid of helicase activity or are highly unstable in human cells [van der Lelij et al 2010, Capo-Chichi et al 2013, Alkhunaizi et al 2018].

Mechanism of disease causation. Warsaw syndrome occurs through a loss-of-function mechanism.

Gene-specific laboratory considerations. Analysis of *DDX11* is complicated by the presence of at least 16 highly homologous pseudogenes (e.g., *DDX11L1*, *DDX11L2*).

Table 6. Notable *DDX11* Pathogenic Variants

Reference Sequences	DNA Nucleotide Change	Predicted Protein Change	Comment [Reference]
NM_030653.3 NP_085911.2	c.2576T>G	p.Val859Gly	Saudi founder variant [Alkhunaizi et al 2018]

Variants listed in the table have been provided by the authors. *GeneReviews* staff have not independently verified the classification of variants.
GeneReviews follows the standard naming conventions of the Human Genome Variation Society (varnomen.hgvs.org). See Quick Reference for an explanation of nomenclature.

Chapter Notes

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