

PATIENT INFORMATION

Unique ID	[Unique ID]	Physician	[Physician]	Sample type	DBS
3billion ID	[3billion ID]	Department	Pediatrics	Collected on	yyyy-mm-dd
DOB* / Sex	yyyy-mm-dd / Female	Institution	[Institution]	Ordered on	yyyy-mm-dd
Ethnicity	Latino/Admixed American			Accessioned on	yyyy-mm-dd

* (YYYY-MM-DD)

CLINICAL INFORMATION

Symptoms	Intellectual disability, Atrial septal defect, Cryptorchidism
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RESULT SUMMARY

Primary findings	No variant reported	Additional findings	No variant reported
Requested gene(s) findings	No variant reported	Secondary findings	No variant reported

PRIMARY FINDINGS

NEGATIVE

No clinically significant variant relevant to the patient's phenotype as provided in the Human Phenotype Ontology (HPO) terms, additional memo and attached documents was identified.

PRIMARY FINDINGS INTERPRETATION

All heterozygous/homozygous/potentially compound heterozygous/hemizygous variants of uncertain significance (VUS) in an autosomal dominant/recessive/X-linked/digenic inherited disease genes associated with the phenotypes provided were reviewed. Autosomal recessive genes with at least one pathogenic/likely pathogenic variant and mitochondrial variants were also carefully reviewed but no clinically significant variants were identified as reportable. However, this does not mean that there is no genetic cause for the disease. The possibility of missing the disease-causing variant due to technical limitations and/or limited genotype-phenotype knowledge cannot be excluded (see below Recommendations #2, #3, and #5). If requested, an automated daily reanalysis will be performed and any updated results will be provided to the medical provider (see below Recommendation #5).

ADDITIONAL FINDINGS

No additional variants were identified, including variants of uncertain significance (VUSs) that could not be reported as primary findings due to limited evidence of pathogenicity, even though they may explain the patient's symptoms; pathogenic, likely pathogenic variants or VUSs that may partially explain the patient's symptoms, regardless of whether they fit the mode of inheritance; or variants associated with the family history provided by the healthcare provider, regardless of the patient's current symptoms.

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REQUESTED GENE FINDINGS

No clinically significant variant was identified in the requested genes. However, 1 variant was identified in the requested genes as below. See the appendix on the last page for the coverage information of the genes requested by the provider.

Congenital disorder of glycosylation, type Id (OMIM: 181270, Autosomal Dominant)						
Gene	Variant	Zygosity	Inheritance	In silico	Allele frequency	Class
ALG3	NM_005787.6:c.62G>T (p.Cys21Phe)	Heterozygous	Unknown	REVEL: 0.30, 3Cnet: 0.00 SpliceAI: 0.02	gnomAD: 39 / 1606074	VUS

SECONDARY FINDINGS

No clinically significant variant was identified in the 84 medically actionable secondary finding genelist recommended to be reported by the American College of Medical Genetics and Genomics (ACMG). However, there is a possibility of missing the disease-causing variant due to the test limitations (see below Recommendations #2, #3, and #5).

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RESOURCES

- Online Mendelian Inheritance in Man®: This report contains information from the Online Mendelian Inheritance in Man® (OMIM®) database, which has been obtained under a license from Johns Hopkins University. This report does not represent the entire, unmodified OMIM® database, which is available in its entirety at <http://omim.org/downloads>.
- gnomAD (genome Aggregation Database): gnomad.broadinstitute.org
- ClinVar (National Center for Biotechnology Information ClinVar Database): ncbi.nlm.nih.gov/clinvar
- HGVS (Human Genome Variation Society): varnomen.hgvs.org
- HGMD (The Human Gene Mutation Database) Professional
- MITOMAP (A human mitochondrial genome database): <https://www.mitomap.org/MITOMAP>

REFERENCES

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3. Elizabeth M et al. Specifications of the ACMG/AMP standards and guidelines for mitochondrial DNA variant interpretation. Hum Mutat. 2020 Dec;41(12):2028-2057.
4. Seo GH et al. Diagnostic yield and clinical utility of whole exome sequencing using an automated variant prioritization system, EVIDENCE. Clin Genet. 2020 Dec;98(6):562-570. PMID: 32901917.
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NOTES

1. Results summary: Results are categorized into positive, inconclusive, and negative. A variant in a known disease gene that would fit the patient's phenotype is reported.

Category	Explanation
Positive	• AD or XL disease: one heterozygous or hemizygous P/LP variant is identified in a known disease gene. • AR disease: one homozygous P/LP variant or two P/LP (potential) compound heterozygous variants are identified in a known disease gene.
Inconclusive	• AD or XL disease: one heterozygous or hemizygous VUS is identified in a known disease gene. • AR disease: At least two heterozygous or one homozygous VUS are identified in a known disease gene. • AR disease: One heterozygous P/LP variant is identified in a known disease gene. • A P/LP variant(s) are identified in a GUS that has sufficient evidence of being a disease gene.
Negative	• No clinically significant variant that would fit the patient's phenotype well is identified.

Abbreviation: AD; autosomal dominant, AR; autosomal recessive, XL; X-linked, P; Pathogenic, LP; likely pathogenic, VUS; variant of uncertain significance, GUS; gene of uncertain significance.

2. Variant Classification: A variant is classified according to the ACMG guideline (PMID 25741868) using the type of evidence including population data, computational and predictive data, functional data, segregation data, de novo data, and allelic data.

RECOMMENDATIONS

1. Genetic counseling is warranted to review the test results and interpretation.
2. This test can detect single nucleotide variants, small insertions/deletions (<50 bp) and large (>=3 consecutive exons) copy number variants with high accuracy in most of the genomic regions. If low level (<20%) mosaicism variants on autosomes and sex chromosomes, small (<3 consecutive exons) copy number variants (CNVs), structural variants (SVs) including inversions and translocations, or low heteroplasmic level mitochondrial genome variants are suspected, it is recommended to perform other tests specifically designed to detect these types of variants. Variants in regions of high sequence homology, such as pseudogenes, may be difficult to detect. Intronic variants, epigenetic factors, or variants in regulatory regions called by being near coding exons may not be interpretable.
3. The test results are based on the clinical information and family history provided in the test order. If the information provided is incorrect or insufficient, the test may not yield reliable results. If the test results have weak clinical correlations, additional testing may be required at the discretion of your medical provider. Whole exome sequencing test or Sanger sequencing test on the biological parents or other family members is recommended to confirm segregation of the variant(s). For structural variants (SVs), including copy number variants (CNVs), only variants for which the exact breakpoint has been identified can be tested by Sanger sequencing. Low level heteroplasmic (<20%) mitochondrial variants cannot be tested by Sanger sequencing.
4. Variant interpretation is based on currently available scientific and medical information that were publicly available at the time the results were reported. Therefore, the referenced data may not be current at the time of genetic counseling.
5. In case of a negative result with no significant variants reported, it does not rule out the possibility of having a genetic condition. As new clinical/scientific information becomes available, variant classification may change and a new diagnosis can emerge. If the patient has consented to reanalysis, 3billion will perform an automated daily reanalysis using the most recent information and send an updated report to the ordering physician if the results change. The provider may also add new phenotypic information about the patient. To comply with the Korean Bioethics and Safety Act 53 and the operational procedures set forth by 3billion, Inc., specimens will be retained for a maximum period of six months and disposed of without prior notice thereafter. Consequently, any genetic variants identified and reported through reanalysis will not be subject to confirmation by Sanger sequencing unless the patient provides a new specimen.
6. Patient consent for reanalysis is renewed on a 10-year cycle. After 10 years, when a physician renews the patient's consent for reanalysis, the reanalysis period will be extended for another 10 years.

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METHODS

Genomic DNA was extracted from DBS specimen using standard protocol. Exome capture was performed using xGen Exome Research Panel v2, supplemented with xGen human mtDNA panel and xGen Custom Hyb Panel v1 (Integrated DNA Technologies, Coralville, Iowa, USA). Sequencing was performed using NovaSeq X (Illumina, San Diego, CA, USA). In total, 11,458,836,111 bases of sequence were generated and uniquely aligned to a modified version of the Genome Reference Consortium Human Build 38 (GRCh38), in which falsely duplicated regions of chromosome 21 were masked to N's based on the masking file developed in collaboration with the GRC (Genome Reference Consortium) (Nat Biotechnol. 2022;40:672-680) and Revised Cambridge Reference Sequence (rCRS) of the mitochondrial genome, generating 168.58 mean depth-of-coverage within the 34,212,647 bases of the captured region, which is approximately 99.3% of the RefSeq protein coding region. Approximately 99.40% of the targeted bases were covered to a depth of $\geq 20\times$. Despite the insufficient coverage across 0.60% of the bases (see below for details), these metrics are consistent with high quality exome sequencing data and deemed adequate for analysis. Gene or exon level depth-of-coverage (DOC) information is available upon request. In total, 65,500 single nucleotide variants (SNV) and 12,080 small insertions and deletions (INDEL) were identified. Sequencing data analysis and variant interpretation were performed using 3billion's proprietary system, EVIDENCE v4.2 (Clin Genet. 2020;98:562-570). EVIDENCE incorporates bioinformatics pipeline for calling SNV/INDEL based on the GATK best practices (GATK v3.8, Genome Res. 2010;20:1297-303) and Manta (Bioinformatics. 2016;32:1220-2) for calling CNV (copy number variants) based on paired-end information and 3bCNV v23.0818, an internally developed tool, for calling CNV (copy number variants) including aneuploidy based on the DOC information. It also incorporates Mutect2 (Genome Res. 2010;20:1297-303) for calling lower level heteroplasmic SNV/INDEL in the mitochondrial genome, ExpansionHunter v5.0.0 (Bioinformatics. 2019;35:4754-6) for calling repeat expansion variants, MELT v2.2.2 (Genome Res. 2017;27:1916-29) for calling mobile element insertion variants, AutoMap v1.2 (Nat Commun. 2021;12:518) for detecting regions of homozygosity (ROH). Variant Effect Predictor v104.2 (VEP, Ensembl, Genome Biology 2016;17:122) is used for variant annotation. Variants were prioritized based on the guideline recommended by the American College of Medical Genetics and Genomics (ACMG) and the Association for Molecular Pathology (AMP) (Genet Med. 2015;17:405-424, Genet Med. 2020;22:245-257, and Hum Mutat. 2020;41:2028-2057) in the context of the patient's phenotype, relevant family history and previous test results provided by the ordering physician. Only variants deemed clinically significant and relevant to the patient's clinical indications at the time of variant interpretation are reported. Based on internal studies validating the accuracy of the variants called with high quality scores, only low quality variants are confirmed by Sanger sequencing. The raw data files including FASTQ files, VCF files and/or annotated small variant lists are available upon request.

ADDITIONAL MEMO

Ginecoid lipid distribution, microorchidea, normal male karyotype (46, XY), high sexual hormone-binding globulin 23.7nmol/L (normal range 72-220nmom/L), high Bioavailable testosterone 26.5 (0.2 - 3.4), high Free testosterone 2.35pg (0.15-0.6pg), HbA1c: 6.1%

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DISCLAIMER

This test was developed by 3billion in the purpose of identifying single nucleotide variants (SNV), small insertions/deletions (INDEL, <50 bp), large (≥ 3 consecutive exons) copy number variants, mobile element insertion variants and repeat expansion variants within the targeted genomic regions. Repeat expansion detection is possible for the following 18 genes. Repeat expansion number may be underestimated for the starred (*) gene with compromised sensitivity (*AR*, *ARX*, *ATN1*, *ATXN1*, *ATXN2*, *ATXN3*, *ATXN7*, *ATXN8OS**, *CACNA1A*, *COMP*, *FOXL2*, *HOXD13*, *HTT*, *PABPN1*, *PHOX2B*, *PRDM12*, *TBP*, *ZIC2*). Only SNV/INDEL ($>10\%$ heteroplasmic level) are called within the mitochondrial genome. This test is intended for clinical purposes and should not be regarded as investigational or for research. This laboratory is certified under the College of American Pathologists (CAP#:8750906) and Clinical Laboratory Improvement Amendments (CLIA#: 99D2274041) as qualified to perform high complexity clinical laboratory testing. Assay validation and clinical validation were performed following the Korea Institute of Genetic Testing Evaluation and the American College of Medical Genetics and Genomics (ACMG) Technical Standards and Guidelines Section G (<https://www.acmg.net/PDFLibrary/Standards-Guidelines-Clinical-Molecular-Genetics.pdf>). If other types of variants such as translocation, inversion, low-level mosaicism, low heteroplasmic level mitochondrial genome variants, and mitochondrial genome large deletion/duplication are suspected, it is recommended to perform appropriate testing that are designed to detect those types of variants. Also, there are certain exonic regions that are incompletely sequenced due to technical difficulties with amplification, sequencing and alignment. If variants within these regions are suspected, it is recommended to perform alternate testing that are designed to sequence those regions/genes adequately. This report may not be copied or reproduced, except in its totality.

ACCREDITATIONS AND CERTIFICATIONS

CAP License

8750906, AU-ID# 2052626

CLIA ID

99D2274041

This case has been comprehensively reviewed by our clinical team of physicians, geneticists and informaticists.

Report electronically signed by:



Go Hun Seo, M.D, Ph.D.

Chief Medical Officer & Laboratory Director

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APPENDIX. REQUESTED GENE(S) FINDINGS

The requested genes were covered: see below for the coverage information of each gene.

Gene	% bp >=20x	Gene	% bp >=20x
ALG3	100.0	FGFR3	100.0