Experience in genetic counseling for GBA1 variants in Parkinson's disease

Heijer, J.M. den; Hilten, J.J. van; Kievit, A.J.A.; Bonifati, V.; Groeneveld, G.J.

Movement Disorders
CLINICAL PRACTICE

VIEWPOINT

Experience in Genetic Counseling for *GBA1* Variants in Parkinson's Disease

Jonas M. den Heijer, MD,[1,2] Jacobus J. van Hilten, MD, PhD,[2] Anneke J.A. Kievit, MD, PhD,[3] Vincenzo Bonifati, MD, PhD,[3] and Geert Jan Groeneveld, MD, PhD[1,2,*]

Apart from the GWAS risk loci, variants in the *GBA1* gene are the most common risk factor known to date to develop Parkinson's disease (PD).[1,2] Genetic testing and counseling of *GBA1* variants is not yet part of common clinical practice, but the need for this will likely increase because research into this topic has increased considerably during the past two decades and genetic testing will become more common. Several studies show that patients with PD have a positive attitude toward genetic testing.[3–5]

Genetic counseling is offered to support patients in clarifying gaps of knowledge regarding PD genetics as well as the risks, benefits, and limitations of genetic testing and to support them in their decision-making process.[6] We use a whole-exome sequencing panel of genes associated with movement disorders in familial PD and/or complex PD and/or PD with an early onset, less stricter than formulated in the European guidelines.[7,8] In monogenetic PD, with variants in *SNCA*, *PRKN*, or *PINK1*, it is relatively straightforward to clarify the inheritance pattern, inform relatives about their risk, and discuss the options of predictive and reproductive testing. If a variant is found associated with reduced penetrance such as the founder mutation p.G2019S-mutation in *LRRK2* and especially if the variants are associated with mild differential effects on the risk and expression of PD, such as heterozygous variants in *GBA1*, this is more difficult for the patient and relatives to handle and raises a need for genetic counseling tailored to the nature of the variant. *GBA1* encodes the lysosomal enzyme glucocerebrosidase and is considered one of the most promising potential targets for the development of a disease-modifying drug for PD.[6] In light of these developments, a growing number of patients with PD are being screened for *GBA1* variants.

We recently performed a large-scale full *GBA1* gene screening in 3402 people with PD in the Netherlands.[9] In most populations, 4% to 12% of patients with PD carry a heterozygous *GBA1* variant, and in Ashkenazi Jewish patients with PD this is approximately 20%.[2,10] In our Dutch cohort, a remarkably high prevalence of 15.5% exonic or splice site variants was found. Subsequently, 528 patients with PD carrying a variant in the *GBA1* gene were counseled. In this viewpoint, we provide some background on *GBA1* in PD and share our experience in counseling of people with PD about the risks of a *GBA1* variant.

The *GBA1* gene is primarily known by the lysosomal storage disorder Gaucher's disease (GD) caused by a biallelic damaging variant in this gene. Important to note is that >400 variants in the *GBA1* gene have been reported to be able to cause GD.[11,12] Some variants have been associated with a more severe phenotype of GD (eg, L444P [p.Leu483Pro] is associated with severe types 2 and 3 GD, and N370S [p.Asn409Ser] is associated with the mild type 1 GD), but generally there is a weak genotype–phenotype correlation.[13] Having a heterozygous damaging variant will not cause GD, but it may increase the risk of developing PD. Several variants have been associated with an increased risk in PD that in homozygous state will not cause GD (such as E326K [p.Glu365Lys] and T369M [p.Thr408Met]).[14,15] Within PD, indications of a *GBA1* variant "dose effect" on age at onset and motor and nonmotor symptoms have been described.[9,16,17]

Carriers of *GBA1* variants have an increased risk to develop PD (GBA-PD) with an earlier onset and possibly a faster motor and nonmotor disease progression.[17–22] However, for counseling purposes it is important to acknowledge the existence of large variation in genotype–phenotype correlations and therefore the low predictability for an individual patient. For example, in our cohort the mean (range) of age at diagnosis in noncarriers was 60.6 (27–92) years compared with 56.9 (25–84) years in carriers of *GBA1* variants.

[1]*Centre for Human Drug Research, Leiden, The Netherlands;* [2]*Leiden University Medical Center, Leiden, The Netherlands;* [3]*Department of Clinical Genetics, Erasmus Medical Center, Rotterdam, The Netherlands*

***Correspondence to:** Dr. Geert Jan Groeneveld, Centre for Human Drug Research, Zernikedreef 8, 2333 CL, Leiden, The Netherlands; E-mail: ggroeneveld@chdr.nl
Keywords: genetic risk factor, genetic testing, glucocerebrosidase, heredity, trial.
Relevant disclosures and conflicts of interest are listed at the end of this article.

Received 18 May 2020; revised 22 September 2020; accepted 4 October 2020.
Published online 27 October 2020 in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/mdc3.13098

Motor impairment scores are generally worse in GBA-PD compared with idiopathic PD, but the structurally large standard deviations make an individualized prediction impossible.[17,18,21]

Similarly for cognitive decline, this is generally worse in GBA-PD compared with idiopathic PD. A meta-analysis shows an OR of 2.40 (95% confidence interval, 1.71–3.38) for developing PD dementia in *GBA1* variant carriers compared with idiopathic PD.[22] Nevertheless, between-patient variability is again high, making it impossible to individually predict cognitive decline.[20,21,23]

The risk of PD in those who carry a *GBA1* variant is increased by an estimated overall 2- to 7-fold. Heterozygous and homozygous (potential GD) carriers have similar ORs.[24] Higher ORs have been reported for specific variants, but these are usually based on studies with a small number of carriers.[2,10,25,26] To our knowledge, no extended families have been reported with PD in multiple relatives with a *GBA1* variant as a possible high-penetrance (monogenic) causative factor, making any larger estimated risks unlikely.

Penetrance of *GBA1* is age dependent and estimated to be between 1% and 14% at 60 years of age and 10% to 30% at approximately 80 years of age.[24,27–29] The higher end of these ranges is reported in subjects with familial PD and therefore possibly an overestimation as a result of an additional genetic burden in these familial cases.[30] The lower end of these ranges is based on parents of patients with GD, which are obligate *GBA1* variant carriers, but do not necessarily carry any other genetic risk factors for PD other than *GBA1*.[24,29] A recent study in unselected patients with PD (so both patients with and without a positive PD family history) showed an intermediate penetrance of 10.0% at 60 years and 19.4% at 80 years.[28] Penetrance was higher in carriers compared with noncarriers, but no statistically significant difference was found between carriers of mild (eg, N370S) and severe (eg, L444P) GD-associated variants.[24,27,28] All in all, most people with a homozygous or heterozygous variant will never develop PD.[24,31,32]

To account for the "dose effect" of different *GBA1* variants, the following 3 categories were defined for counseling patients with PD: (1) low-risk variants, if the allele has been reported in PD, but not as GD causing; (2) moderate-risk variants, if the allele has been reported in at least a single GD case either in a homozygous state or in a compound heterozygous state with other GD-associated variants; or (3) unknown variants, if a variant was not reported previously. A further "dose effect" within all variants previously reported in GD (here moderate-risk variants) seems plausible, but sample sizes are generally very small for these (>400!) different variants, and therefore these cannot currently be differentiated reliably for personalized counseling.

When counseling a *GBA1* variant, it is important to provide a relevant context. For example, for a moderate-risk variant case, "Of people of 60 years and older, approximately 1% will develop PD. With a *GBA1* variant, there would be an approximate 2%–7% risk of developing PD at this age. This also means there is a 93%–98% chance of *not* having developed PD at this age." The age-specific incidence rate of PD of course increases beyond the age of 60 years.[33] *GBA1* can therefore be seen as a modifier of the PD risk, or risk factor in PD, and play a role in the complex disease etiology as such.

Considering the low absolute increase in risk of developing PD, the inability to predict disease progression, and the current lack of therapeutic consequences, we deemed it appropriate to primarily counsel the patients with PD by phone and provide similar written information by mail. Patients had the opportunity to request a meeting in person. Only sporadically a patient returned a phone call for additional questions.

A transcript was created for the 3 *GBA1* categories (Table S1, box 2A,B,C). Prior to presenting the transcript, it is advisable to give a brief simplified explanation of genetic principles (Table S1, box 1). The primary concern of carriers in our study was often related to the consequences for their children. There is of course a 50% chance of inheriting the *GBA1* variant, but it is important to stress that the risks attributed to *GBA1* are very small so that presymptomatic testing for the *GBA1* variant is, in our view, not justified.

So far, the clinical relevance of having a *GBA1* variant is very limited for an individual. However, a study on deep brain stimulation is worth mentioning in which at 7.5 years after deep brain stimulation, 6 of 10 (60%) *GBA1* variant carriers had severe cognitive impairment compared with 1 of 16 (6%) in noncarriers.[34] This finding needs validation in a larger cohort, but this could be relevant for deep brain stimulation decision-making. Furthermore, the prospect of possibly being eligible for a clinical trial based on carrying a *GBA1* variant may be relevant for an individual as well.

Perhaps when genotype–phenotype correlations will have been elucidated further in future larger cohorts a variant-specific counseling can be tailored further.

In conclusion, the increasing amount of genetic testing being performed in PD creates an exciting time in which hopefully important steps are being made toward a personalized disease-modifying treatment. Accompanying this development, we should not forget to adequately inform patients about these findings and their clinical context and to bring nuance when appropriate.

Acknowledgments

We would like to thank dr. M. Kriek, clinical geneticist from the LUMC, for her review and advise.

Author Roles

(1) Research project: A. Perform *GBA1* counseling; (2) Manuscript: A. Writing of the First Draft, B. Review and Critique.

J.d.H.: 1A, 2A
J.v.H.: 1A, 2B
A.K.: 1A, 2B
V.B.: 2B
G.J.G.: 1A, 2B

Disclosures

Ethical Compliance Statement: This study was approved by the Independent Ethics Committee of the Foundation 'Evaluation of Ethics in Biomedical Research' (Stichting Beoordeling Ethiek Biomedisch Onderzoek), Assen, The Netherlands. Reference number NL61137.056.17. Written informed consent was obtained from all participants according to the Declaration of Helsinki. We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this work is consistent with those guidelines.

Funding Sources and Conflicts of Interest: No funding is applicable to this article. The authors report no competing interests.

Financial Disclosures of All Authors (for the Preceding 12 Months): J.V.H. reports grants from The Netherlands Organization for Health Research and Development, The Netherlands Organization for Scientific Research, Hoffmann-La-Roche, AbbVie, Lundbeck, Hersenstichting, Stichting Parkinson Fonds, Alkemade-Keuls Foundation, and Centre of Human Drug Research. V.B. discloses intellectual property rights as a coinventor in a patent titled "Role For Low Density Lipoprotein Receptor-Related Protein in Progressive Brain Diseases." He received honoraria from the following: The International Parkinson and Movement Disorder Society; Springer, as Section Editor of *Current Neurology and Neuroscience Reports*; and Elsevier, as co-editor-in-chief of *Parkinsonism & Related Disorders*. He reports grants from the following: Stichting Parkinson Fonds (The Netherlands); Alzheimer Nederland; ZonMw (The Netherlands), under the aegis of the EU Joint Programme Neurodegenerative Disease Research (JPND); and Erasmus MC, Rotterdam. J.M.d.H., A.K., and G.J.G. have no disclosures to report. ■

References

1. Bandres-Ciga S, Diez-Fairen M, Kim JJ, Singleton AB. Genetics of Parkinson's disease: an introspection of its journey towards precision medicine. *Neurobiol Dis* 2020;137:104782.
2. Gan-Or Z, Amshalom I, Kilarski LL, et al. Differential effects of severe vs mild GBA mutations on Parkinson disease. *Neurology* 2015;84(9): 880–887.
3. Falcone DC, Wood EM, Xie SX, Siderowf A, Van Deerlin VM. Genetic testing and Parkinson disease: assessment of patient knowledge, attitudes, and interest. *J Genet Couns* 2011;20(4): 384–395.
4. Gupte M, Alcalay RN, Mejia-Santana H, et al. Interest in genetic testing in Ashkenazi Jewish Parkinson's disease patients and their unaffected relatives. *J Genet Couns* 2015;24(2):238–246.
5. Maloney KA, Alaeddin DS, von Coelln R, et al. Parkinson's disease: patients' knowledge, attitudes, and interest in genetic counseling. *J Genet Couns* 2018;27(5):1200–1209.
6. Resta R, Biesecker BB, Bennett RL, et al. A new definition of genetic counseling: National Society of Genetic Counselors' Task Force report. *J Genet Couns* 2006;15(2):77–83.
7. Berardelli A, Wenning GK, Antonini A, et al. EFNS/MDS-ES/ENS [corrected] recommendations for the diagnosis of Parkinson's disease. *Eur J Neurol* 2013;20(1):16–34.
8. Erasmus MC. Laboratory specialism: clinical genetics laboratory. https://www.erasmusmc.nl/nl-nl/patientenzorg/laboratoriumspecialismen/klinische-genetica. Accessed September 9, 2020.
9. den Heijer JM, Cullen VC, Quadri M, et al. A large-scale full GBA1 gene screening in Parkinson's disease in The Netherlands. *Mov Disord* 2020;35:1667–1674.
10. Ruskey JA, Greenbaum L, Ronciere L, et al. Increased yield of full GBA sequencing in Ashkenazi Jews with Parkinson's disease. *Eur J Med Genet* 2019;62(1):65–69.
11. Stenson PD, Mort M, Ball EV, et al. The human gene mutation database: towards a comprehensive repository of inherited mutation data for medical research, genetic diagnosis and next-generation sequencing studies. *Hum Genet* 2017;136(6):665–677.
12. Hruska KS, LaMarca ME, Scott CR, Sidransky E. Gaucher disease: mutation and polymorphism spectrum in the glucocerebrosidase gene (GBA). *Hum Mutat* 2008;29(5):567–583.
13. Hassan S, Lopez G, Stubblefield BK, Tayebi N, Sidransky E. Alleles with more than one mutation can complicate genotype/phenotype studies in Mendelian disorders: lessons from Gaucher disease. *Mol Genet Metab* 2018;125(1–2):1–3.
14. Huang Y, Deng L, Zhong Y, Yi M. The association between E326K of GBA and the risk of Parkinson's disease. *Parkinsons Dis* 2018;2018:1048084.
15. Mallett V, Ross JP, Alcalay RN, et al. GBA p.T369M substitution in Parkinson disease: polymorphism or association? A meta-analysis. *Neurol Genet* 2016;2(5):e104.
16. Thaler A, Gurevich T, Bar Shira A, et al. A "dose" effect of mutations in the GBA gene on Parkinson's disease phenotype. *Parkinsonism Relat Disord* 2017;36:47–51.
17. Cilia R, Tunesi S, Marotta G, et al. Survival and dementia in GBA-associated Parkinson's disease: the mutation matters. *Ann Neurol* 2016;80 (5):662–673.
18. Davis MY, Johnson CO, Leverenz JB, et al. Association of GBA mutations and the E326K polymorphism with motor and cognitive progression in Parkinson disease. *JAMA Neurol* 2016;73(10):1217–1224.
19. Jesus S, Huertas I, Bernal-Bernal I, et al. GBA variants influence motor and non-motor features of Parkinson's disease. *PLoS One* 2016;11(12): e0167749.
20. Malek N, Weil RS, Bresner C, et al. Features of GBA-associated Parkinson's disease at presentation in the UKtracking Parkinson's study. *J Neurol Neurosurg Psychiatry* 2018;89(7):702–709.
21. Mata IF, Leverenz JB, Weintraub D, et al. GBA variants are associated with a distinct pattern of cognitive deficits in Parkinson's disease. *Mov Disord* 2016;31(1):95–102.
22. Creese B, Bell E, Johar I, Francis P, Ballard C, Aarsland D. Glucocerebrosidase mutations and neuropsychiatric phenotypes in Parkinson's disease and Lewy body dementias: review and meta-analyses. *Am J Med Genet B Neuropsychiatr Genet* 2018;177(2):232–241.
23. Alcalay RN, Caccappolo E, Mejia-Santana H, et al. Cognitive performance of GBA mutation carriers with early-onset PD: the CORE-PD study. *Neurology* 2012;78(18):1434–1440.
24. Alcalay RN, Dinur T, Quinn T, et al. Comparison of Parkinson risk in Ashkenazi Jewish patients with Gaucher disease and GBA heterozygotes. *JAMA Neurol* 2014;71(6):752–757.
25. Lesage S, Anheim M, Condroyer C, et al. Large-scale screening of the Gaucher's disease-related glucocerebrosidase gene in Europeans with Parkinson's disease. *Hum Mol Genet* 2011;20(1):202–210.
26. Sidransky E, Nalls MA, Aasly JO, et al. Multicenter analysis of glucocerebrosidase mutations in Parkinson's disease. *N Engl J Med* 2009; 361(17):1651–1661.
27. Anheim M, Elbaz A, Lesage S, et al. Penetrance of Parkinson disease in glucocerebrosidase gene mutation carriers. *Neurology* 2012;78(6):417–420.
28. Balestrino R, Tunesi S, Tesei S, Lopiano L, Zecchinelli AL, Goldwurm S. Penetrance of glucocerebrosidase (GBA) mutations in Parkinson's disease: a Kin cohort study [published online ahead of print Ausgust 7, 2020]. *Mov Disord*. https://doi.org/10.1002/mds.28200.
29. Rana HQ, Balwani M, Bier L, Alcalay RN. Age-specific Parkinson disease risk in GBA mutation carriers: information for genetic counseling. *Genet Med* 2013;15(2):146–149.
30. Sidransky E, Hart PS. Penetrance of PD in glucocerebrosidase gene mutation carriers. *Neurology* 2012;79(1):106–107.
31. Rana AQ, Siddiqui I, Yousuf MS. Challenges in diagnosis of young onset Parkinson's disease. *J Neurol Sci* 2012;323(1–2):113–116.

32. Sidransky E. Heterozygosity for a Mendelian disorder as a risk factor for complex disease. *Clin Genet* 2006;70(4):275–282.

33. Pringsheim T, Jette N, Frolkis A, Steeves TD. The prevalence of Parkinson's disease: a systematic review and meta-analysis. *Mov Disord* 2014;29(13):1583–1590.

34. Lythe V, Athauda D, Foley J, et al. GBA-associated Parkinson's disease: progression in a deep brain stimulation cohort. *J Parkinsons Dis* 2017;7(4): 635–644.

Supporting Information

Supporting information may be found in the online version of this article.

Table S1 Boxes with general advice and transcripts for GBA-PD counseling.