

BÖLÜM 50

NÖROFİBROMATOZİS

Selcan ÖZTÜRK¹
Mehmet CANPOLAT²
Sefer KUMANDAŞ³

GİRİŞ

Nörofibromatozis (NF); başta santral sinir sistemi ve periferik sinir sistemi olmak üzere kemik, göz, kas-iskelet sistemi, gastrointestinal ve endokrin sistemi de etkileyebilen multisistemik bir nörokütanöz hastalıktır.¹ Nörofibromatozisin klinik ve genetik olarak farklı formları bulunmaktadır. Nörofibromatozis tip 1 (NF1), Nörofibromatozis Tip 2 (NF2), Schwannomatoz ve Legius en sık bilinenleridir.² Deride sütlü kahverengi (cafe-au-lait) lekeler ve nörofibromlar ayırt edici özellikleridir. 1982 yılında, 7 tip ve ‘başka türlü sınıflandırılamayan’ olgular için sekiz kategoriden oluşan nörofibromatoz sınıflaması önerilirken; son yapılan çalışmalarla, ‘gastrointestinal tip’ Tip 8 ve ‘Nörofibromatozis/Noonan’ Tip 9 olarak kategoriye eklenmiştir.³ Nörofibromatozisler, klinik bulguların heterojenitesine bağlı olarak, 9 farklı forma ayrılmıştır.^{3,4}

NÖROFİBROMATOZİS TİP 1

Nörofibromatozis tip 1 (NF1; OMIM#162200); 19.yüzyılda tanımlanan ve VonRecklinghausen hastalığı veya periferal nörofibromatoz olarak bilinen nörokütanöz hastalıktır.⁵ İnsidansı her

canlı doğumda 1/2600 ile 1/3000 arasında değişir.⁶ Otozomal dominant kalıtlıdır.⁶ NF1, tüm nörofibromatozis olgularının %96’sını oluşturmaktadır.⁷ Olgular arasında etnik ve cinsiyet açısından herhangi bir fark yoktur.²

GENETİK

NF1, 17q11.2 kromozomunda bulunan NF1 genindeki kalitsal veya herhangi bir ailevi geçmiş olmaksızın yeni mutasyonlar (denovo) nedeniyle oluşmaktadır.⁸ Hastaların yüzde ellisinde kalitsal mutasyon, diğer yarısında spontan mutasyon vardır.⁷ NF1 genindeki mutasyonlar, aynı aile üyeleri arasında bile farklılık gösterebilmektedir.⁹ Nükleotid değişiklikleri, nokta mutasyonlar, insersiyon veya mikrodeleksyon, splice bölge mutasyonları dahil olmak üzere hemen hemen her türlü mutasyon ve hatta tüm gen delesyonları bile görülebilir.¹⁰ Somatik mutasyonlar da, NF1’in mozaik şecline neden olabilir. Mozaik mutasyonlar daha az şiddetli olmaktadır ve genellikle daha lokalize, tek taraflı lezyonlara neden olmaktadır.¹¹ Hastalık şüphesi olan bireylerin %95’inde mutasyonları tespit eden genetik test mevcuttur.¹² Genetik testler, özellikle sporadik olarak etkilenen küçük çocuklarda teşhis için faydalıdır.¹²

¹ Uzm. Dr., Erciyes Üniversitesi Tip Fakültesi, Çocuk Sağlığı ve Hastalıkları AD., Çocuk Nörolojisi BD., drselcanozturk@gmail.com

² Prof. Dr., Erciyes Üniversitesi Tip Fakültesi, Çocuk Sağlığı ve Hastalıkları AD., Çocuk Nörolojisi BD., mcanpolat@erciyes.edu.tr

³ Prof. Dr., Erciyes Üniversitesi Tip Fakültesi, Çocuk Sağlığı ve Hastalıkları AD., Çocuk Nörolojisi BD., seferkumandas@yahoo.com

Legius sendromu tanısı tanı kriterleri ve genetik testler ile doğrulanmış olguların takibinde beyin ve spinal MRG tetkiki ile izlemde göz muayenesinin rutin olarak yapılması önerilmemektedir.²⁰

KAYNAKLAR

1. Kresak J, Walsh M. Neurofibromatosis: A Review of NF1, NF2, and Schwannomatosis. *J Pediatr Genet.* 2016;05(02):098-104. doi:10.1055/s-0036-1579766
2. Farschtschi S, Mautner V-F, McLean ACL, Schulz A, Friedrich RE, Rosahl SK. The Neurofibromatoses. *Dtsch Arztebl Int.* 2020;117(20):354-360. doi:10.3238/arztebl.2020.0354
3. Ruggieri M. The different forms of neurofibromatosis. *Child's Nerv Syst.* 1999;15(6-7):295-308. doi:10.1007/s003810050398
4. Riccardi VM. Neurofibromatosis: clinical heterogeneity. *Curr Probl Cancer.* 1982;7(2):1-34. doi:10.1016/s0147-0272(82)80016-0
5. Hirbe AC, Gutmann DH. Neurofibromatosis type 1: A multidisciplinary approach to care. *Lancet Neurol.* 2014;13(8):834-843. doi:10.1016/S1474-4422(14)70063-8
6. Evans DG, Howard E, Giblin C, et al. Birth incidence and prevalence of tumor-prone syndromes: estimates from a UK family genetic register service. *Am J Med Genet A.* 2010;152A(2):327-332. doi:10.1002/ajmg.a.33139
7. Le C, Bedocs PM. Neurofibromatosis. In: Neurofibromatosis. StatPearls Publishing LLC.; 2021. https://www.ncbi.nlm.nih.gov/books/NBK459329/#_NBK459329_pubdet
8. Thiele EA KB. Phacomatoses and allied conditions. In: Swaiman's Pediatric Neurology Principles and Practice. 6th ed. Elsevier; 2018:362-372.
9. Boyd KP, Korf BR, Theos A. Neurofibromatosis type 1. *J Am Acad Dermatol.* 2009;61(1):1-6. doi:10.1016/j.jaad.2008.12.051
10. Korf BR. Neurofibromatosis. *Handb Clin Neurol.* 2013;111:333-340. doi:10.1016/B978-0-444-52891-9.00039-7
11. Dunning-Davies BM, Parker APJ. Annual review of children with neurofibromatosis type 1. *Arch Dis Child Educ Pract Ed.* 2016;101(2):102-111. doi:10.1136/archdischild-2014-308084
12. Messiaen LM, Callens T, Mortier G, et al. Exhaustive mutation analysis of the NF1 gene allows identification of 95% of mutations and reveals a high frequency of unusual splicing defects. *Hum Mutat.* 2000;15(6):541-555. doi:10.1002/1098-1004(200006)15:6<541::AID-HUMU6>3.0.CO;2-N
13. Brabbing-Goldstein D, Ben-Shachar S. Ante-natal counseling in phacomatoses. *Child's Nerv Syst ChNS Off J Int Soc Pediatr Neurosurg.* 2020;36(10):2269-2277. doi:10.1007/s00381-020-04776-3
14. Neurofibromatosis type 1. *Nat Rev Dis Prim.* 2017;3(1):17005. doi:10.1038/nrdp.2017.5
15. DeBella K, Szudek J, Friedman JM. Use of the national institutes of health criteria for diagnosis of neurofibromatosis 1 in children. *Pediatrics.* 2000;105(3 Pt 1):608-614. doi:10.1542/peds.105.3.608
16. Wilson BN, John AM, Handler MZ, Schwartz RA. Neurofibromatosis type 1: New developments in genetics and treatment. *J Am Acad Dermatol.* Published online August 2020. doi:10.1016/j.jaad.2020.07.105
17. Wu-Chou YH, Hung TC, Lin YT, et al. Neurofibromatosis 1 Summary Genetic counseling Suggestive Findings. *Gene Rev.* 2000;25(1):33-40.
18. Nunley KS, Gao F, Albers AC, Bayliss SJ, Gutmann DH. Predictive Value of Café au Lait Macules at Initial Consultation in the Diagnosis of Neurofibromatosis Type 1. *Arch Dermatol.* 2009;145(8):883-887. doi:10.1001/archdermatol.2009.169
19. National Institutes of Health Consensus Development Conference Statement: neurofibromatosis. Bethesda, Md., USA, July 13-15, 1987. *Neurofibromatosis.* 1988;1(3):172-178.
20. Anderson S. Café au Lait Macules and Associated Genetic Syndromes. *J Pediatr Heal Care Off Publ Natl Assoc Pediatr Nurse Assoc Pract.* 2020;34(1):71-81. doi:10.1016/j.pedhc.2019.05.001
21. Seminog O, Goldacre M. Risk of benign tumours of nervous system, and of malignant neoplasms, in people with neurofibromatosis: Population-based record-linkage study. *Br J Cancer.* 2012;108. doi:10.1038/bjc.2012.535
22. Ortonne N, Wolkenstein P, Blakeley JO, et al. Cutaneous neurofibromas: Current clinical and pathologic issues. *Neurology.* 2018;91(2 Suppl 1):S5-S13. doi:10.1212/WNL.0000000000005792
23. Walker L, Thompson D, Easton D, et al. A prospective study of neurofibromatosis type 1 cancer incidence in the UK. *Br J Cancer.* 2006;95(2):233-238. doi:10.1038/sj.bjc.6603227
24. Roth TM, Petty EM, Barald KF. The role of steroid hormones in the NF1 phenotype: focus on pregnancy. *Am J Med Genet A.* 2008;146A(12):1624-1633. doi:10.1002/ajmg.a.32301
25. Nguyen R, Kluwe L, Fuensterer C, Kentsch M, Friedrich RE, Mautner V-F. Plexiform neurofibromas in children with neurofibromatosis type 1: frequency and associated clinical deficits. *J Pediatr.* 2011;159(4):652-5.e2. doi:10.1016/j.jpeds.2011.04.008
26. Cunha KSG, Barboza EP, Dias EP, Oliveira FM. Neurofibromatosis type I with periodontal manifestation. A case report and literature review. *Br Dent J.* 2004;196(8):457-460. doi:10.1038/sj.bdj.4811175
27. Higham CS, Dombi E, Rogiers A, et al. The characteristics of 76 atypical neurofibromas as precursors to neurofibromatosis 1 associated malignant peripheral nerve sheath tumors. *Neuro Oncol.* 2018;20(6):818-825. doi:10.1093/neuonc/noy013
28. Ferrari F, Masurel A, Olivier-Faivre L, Vabres P. Juvenile xanthogranuloma and nevus anemicus in the diagnosis of neurofibromatosis type 1. *JAMA dermatology.* 2014;150(1):42-46. doi:10.1001/jamadermatol.2013.6434

29. Vaassen P, Rosenbaum T. Nevus Anemicus As an Additional Diagnostic Marker of Neurofibromatosis Type 1 in Childhood. *Neuropediatrics*. 2016;47(3):190-193. doi:10.1055/s-0036-1579786
30. Miraglia E, Moliterni E, Iacovino C, et al. Cutaneous manifestations in neurofibromatosis type 1. *Clin Ter*. 2020;171(5):e371-e377. doi:10.7417/CT.2020.2242
31. Friedrich RE, Nuding MA. Optic Pathway Glioma and Cerebral Focal Abnormal Signal Intensity in Patients with Neurofibromatosis Type 1: Characteristics, Treatment Choices and Follow-up in 134 Affected Individuals and a Brief Review of the Literature. *Anticancer Res*. 2016;36(8):4095-4121.
32. Listernick R, Ferner RE, Piersall L, Sharif S, Gutmann DH, Charrow J. Late-onset optic pathway tumors in children with neurofibromatosis 1. *Neurology*. 2004;63(10):1944-1946. doi:10.1212/01.wnl.0000144341.16830.01
33. Guillamo J-S, Créange A, Kalifa C, et al. Prognostic factors of CNS tumours in Neurofibromatosis 1 (NF1): a retrospective study of 104 patients. *Brain*. 2003;126(Pt 1):152-160. doi:10.1093/brain/awg016
34. Mahdi J, Goyal MS, Griffith J, Morris SM, Gutmann DH. Nonoptic pathway tumors in children with neurofibromatosis type 1. *Neurology*. 2020;95(8):e1052-e1059. doi:10.1212/WNL.0000000000009458
35. Vagge A, Nelson LB, Capris P, Traverso CE. Choroidal Freckling in Pediatric Patients Affected by Neurofibromatosis Type 1. *J Pediatr Ophthalmol Strabismus*. 2016;53(5):271-274. doi:10.3928/01913913-20160719-05
36. Ferrari A, Bisogno G, Macaluso A, et al. Soft-tissue sarcomas in children and adolescents with neurofibromatosis type 1. *Cancer*. 2007;109(7):1406-1412. doi:10.1002/cncr.22533
37. James AW, Shurell E, Singh A, Dry SM, Eilber FC. Malignant Peripheral Nerve Sheath Tumor. *Surg Oncol Clin N Am*. 2016;25(4):789-802. doi:10.1016/j.soc.2016.05.009
38. Pannu AK, Sharma N. Neurofibromatosis type 1 and disseminated malignant peripheral nerve sheath tumor. *QJM*. 2017;110(9):583-584. doi:10.1093/qjmed/hcx071
39. Sung L, Anderson JR, Arndt C, Raney RB, Meyer WH, Pappo AS. Neurofibromatosis in children with rhabdomyosarcoma: A report from the intergroup rhabdomyosarcoma study IV. *J Pediatr*. 2004;144(5):666-668. doi:10.1016/j.jpeds.2004.02.026
40. Ylä-Outinen H, Loponen N, Kallionpää RA, Peltonen S, Peltonen J. Intestinal tumors in neurofibromatosis 1 with special reference to fatal gastrointestinal stromal tumors (GIST). *Mol Genet genomic Med*. 2019;7(9):e927. doi:10.1002/mgg3.927
41. Stewart DR, Sloan JL, Yao L, et al. Diagnosis, management, and complications of glomus tumours of the digits in neurofibromatosis type 1. *J Med Genet*. 2010;47(8):525-532. doi:10.1136/jmg.2009.073965
42. Ferner RE, Huson SM, Thomas N, et al. Guidelines for the diagnosis and management of individuals with neurofibromatosis 1. *J Med Genet*. 2007;44(2):81-88. doi:10.1136/jmg.2006.045906
43. Sharif S, Moran A, Huson SM, et al. Women with neurofibromatosis 1 are at a moderately increased risk of developing breast cancer and should be considered for early screening. *J Med Genet*. 2007;44(8):481-484. doi:10.1136/jmg.2007.049346
44. Delucia TA, Yohay K, Widmann RF. Orthopaedic aspects of neurofibromatosis: update. *Curr Opin Pediatr*. 2011;23(1):46-52. doi:10.1097/MOP.0b013e32834230ce
45. Kang E, Yoon HM, Lee BH. Neurofibromatosis type I: points to be considered by general pediatricians. *Clin Exp Pediatr*. 2021;64(4):149-156. doi:10.3345/cep.2020.00871
46. Elefteriou F, Kolanczyk M, Schindeler A, et al. Skeletal abnormalities in neurofibromatosis type 1: approaches to therapeutic options. *Am J Med Genet A*. 2009;149A(10):2327-2338. doi:10.1002/ajmg.a.33045
47. Tucker T, Schnabel C, Hartmann M, et al. Bone health and fracture rate in individuals with neurofibromatosis 1 (NF1). *J Med Genet*. 2009;46(4):259-265. doi:10.1136/jmg.2008.061895
48. Heervä E, Leinonen P, Kuorilehto T, et al. Neurofibromatosis 1-related osteopenia often progresses to osteoporosis in 12 years. *Calcif Tissue Int*. 2013;92(1):23-27. doi:10.1007/s00223-012-9661-y
49. Crawford AH, Herrera-Soto J. Scoliosis Associated with Neurofibromatosis. *Orthop Clin North Am*. 2007;38(4):553-562. doi:10.1016/j.ocl.2007.03.008
50. Hsieh H-Y, Wu T, Wang C-J, Chin S-C, Chen Y-R. Neurological complications involving the central nervous system in neurofibromatosis type 1. *Acta Neurol Taiwan*. 2007;16(2):68-73.
51. Nix JS, Blakeley J, Rodriguez FJ. An update on the central nervous system manifestations of neurofibromatosis type 1. *Acta Neuropathol*. 2020;139(4):625-641. doi:10.1007/s00401-019-02002-2
52. Summers MA, Quinlan KG, Payne JM, Little DG, North KN, Schindeler A. Skeletal muscle and motor deficits in Neurofibromatosis Type 1. *J Musculoskeletal Neuronal Interact*. 2015;15(2):161-170.
53. North KN, Riccardi V, Samango-Sprouse C, et al. Consensus statement from the NF1 Cognitive Disorders Task Force. *Neurology*. Published online 1997;481121-481127.
54. Lehtonen A, Howie E, Trump D, Huson SM. Behaviour in children with neurofibromatosis type 1: cognition, executive function, attention, emotion, and social competence. *Dev Med Child Neurol*. 2013;55(2):111-125. doi:10.1111/j.1469-8749.2012.04399.x
55. Cohen JS, Levy HP, Sloan J, Dariotis J, Biesecker BB. Depression among adults with neurofibromatosis type 1: prevalence and impact on quality of life. *Clin Genet*. 2015;88(5):425-430. doi:10.1111/cge.12551

56. Friedman JM, Arbiser J, Epstein JA, et al. Cardiovascular disease in neurofibromatosis 1: Report of the NF1 Cardiovascular Task Force. *Genet Med.* 2002;4(3):105-111. doi:10.1097/00125817-200205000-00002
57. Riccardi VM. Type 1 neurofibromatosis and the pediatric patient. *Curr Probl Pediatr.* 1992;22(2):66-106. doi:10.1016/0045-9380(92)90053-2
58. Oderich GS, Sullivan TM, Bower TC, et al. Vascular abnormalities in patients with neurofibromatosis syndrome type I: clinical spectrum, management, and results. *J Vasc Surg.* 2007;46(3):475-484. doi:10.1016/j.jvs.2007.03.055
59. Malav IC, Kothari SS. Renal artery stenosis due to neurofibromatosis. *Ann Pediatr Cardiol.* 2009;2(2):167-169. doi:10.4103/0974-2069.58323
60. Murphy ES, Xie H, Merchant TE, Yu JS, Chao ST, Suh JH. Review of cranial radiotherapy-induced vasculopathy. *J Neurooncol.* 2015;122(3):421-429. doi:10.1007/s11060-015-1732-2
61. Ejerskov C, Krogh K, Ostergaard JR, Joensson I, Haagerup A. Gastrointestinal Symptoms in Children and Adolescents With Neurofibromatosis Type 1. *J Pediatr Gastroenterol Nutr.* 2018;66(6):872-875. doi:10.1097/MPG.0000000000001860
62. Gill DS, Hyman SL, Steinberg A, North KN. Age-related findings on MRI in neurofibromatosis type 1. *Pediatr Radiol.* 2006;36(10):1048-1056. doi:10.1007/s00247-006-0267-2
63. Sabol Z, Rešić B, Juraški RG, et al. Clinical sensitivity and specificity of multiple T2-hyperintensities on brain magnetic resonance imaging in diagnosis of neurofibromatosis type 1 in children: Diagnostic accuracy study. *Croat Med J.* 2011;52(4):488-496. doi:10.3325/cmj.2011.52.488
64. Payne JM, Pickering T, Porter M, et al. Longitudinal assessment of cognition and T2-hyperintensities in NF1: an 18-year study. *Am J Med Genet A.* 2014;164A(3):661-665. doi:10.1002/ajmg.a.36338
65. D'Arco F, D'Amico A, Caranci F, Di Paolo N, Melis D, Brunetti A. Cerebrovascular stenosis in neurofibromatosis type 1 and utility of magnetic resonance angiography: our experience and literature review. *Radiol Med.* 2014;119(6):415-421. doi:10.1007/s11547-013-0358-8
66. Miller DT, Freedenberg D, Schorry E, Ullrich NJ, Viskochil D, Korf BR. Health Supervision for Children With Neurofibromatosis Type 1. *Pediatrics.* 2019;143(5). doi:10.1542/peds.2019-0660
67. Korf, BR, Lobbous M ML. Neurofibromatosis type 1(NF1): Pathogenesis, clinical features, and diagnosis. Up to Date. Published online 2021.
68. Yarar C. Nörofibromatozlar. *Türkiye Klin.* 2021;1(978-625-401-263-1):101-113.
69. Ferner RE, Gutmann DH. Neurofibromatosis type 1 (NF1): diagnosis and management. *Handb Clin Neurol.* 2013;115:939-955. doi:10.1016/B978-0-444-52902-2.00053-9
70. Roberts AE, Allanson JE, Tartaglia M, Gelb BD. Noonan syndrome. *Lancet (London, England).* 2013;381(9863):333-342. doi:10.1016/S0140-6736(12)61023-X
71. Tartaglia M, Gelb BD, Zenker M. Noonan syndrome and clinically related disorders. *Best Pract Res Clin Endocrinol Metab.* 2011;25(1):161-179. doi:10.1016/j.beem.2010.09.002
72. Evans DGR, Baser ME, McGaughran J, Sharif S, Howard E, Moran A. Malignant peripheral nerve sheath tumours in neurofibromatosis 1. *J Med Genet.* 2002;39(5):311-314. doi:10.1136/jmg.39.5.311
73. Lion-François L, Gueyffier F, Mercier C, et al. The effect of methylphenidate on neurofibromatosis type 1: a randomised, double-blind, placebo-controlled, crossover trial. *Orphanet J Rare Dis.* 2014;9:142. doi:10.1186/s13023-014-0142-4
74. Ardern-Holmes S, Fisher G, North K. Neurofibromatosis Type 2. *J Child Neurol.* 2017;32(1):9-22. doi:10.1177/0883073816666736
75. Ruggieri M, Huson SM. The clinical and diagnostic implications of mosaicism in the neurofibromatoses. *Neurology.* 2001;56(11):1433-1443. doi:10.1212/WNL.56.11.1433
76. Evans DGR, Moran A, King A, Saeed S, Gurusinghe N, Ramsden R. Incidence of vestibular schwannoma and neurofibromatosis 2 in the North West of England over a 10-year period: higher incidence than previously thought. *Otol Neurotol Off Publ Am Otol Soc Am Neurotol Soc [and] Eur Acad Otol Neurotol.* 2005;26(1):93-97. doi:10.1097/00129492-200501000-00016
77. Evans DGR. Neurofibromatosis type 2 (NF2): a clinical and molecular review. *Orphanet J Rare Dis.* 2009;4:16. doi:10.1186/1750-1172-4-16
78. Hexter A, Jones A, Joe H, et al. Clinical and molecular predictors of mortality in neurofibromatosis 2: a UK national analysis of 1192 patients. *J Med Genet.* 2015;52(10):699-705. doi:10.1136/jmedgenet-2015-103290
79. Asthagiri AR, Parry DM, Butman JA, et al. Neurofibromatosis type 2. *Lancet (London, England).* 2009;373(9679):1974-1986. doi:10.1016/S0140-6736(09)60259-2
80. Schulz A, Zoch A, Morrison H. A neuronal function of the tumor suppressor protein merlin. *Acta Neuropathol Commun.* 2014;2(1):1-10. doi:10.1186/s40478-014-0082-1
81. Evans DGR. Neurofibromatosis 2 [Bilateral acoustic neurofibromatosis, central neurofibromatosis, NF2, neurofibromatosis type II]. *Genet Med.* 2009;11(9):599-610. doi:10.1097/GIM.0b013e-3181ac9a27
82. Evans DGR, Baser ME, O'Reilly B, et al. Management of the patient and family with neurofibromatosis 2: a consensus conference statement. *Br J Neurosurg.* 2005;19(1):5-12. doi:10.1080/02688690500081206
83. Gugel I, Grimm F, Zipfel J, et al. Age at Onset and Presenting Symptoms of Neurofibromatosis Type 2 as Prognostic Factors for Clinical Course of Vestibular Schwannomas. *Cancers (Basel).* 2020;12(9). doi:10.3390/cancers12092355
84. Lin AL, Gutmann DH. Advances in the treatment of neurofibromatosis-associated tumours. *Nat Rev Clin Oncol.* 2013;10(11):616-624. doi:10.1038/nrcalinonc.2013.144

85. Bendon CL, Furniss D, Giele HP. Comparison of outcomes of peripheral nerve schwannoma excision in neurofibromatosis type 2 patients and non-neurofibromatosis type 2 patients: A case control study. *J Plast Reconstr Aesthet Surg.* 2015;68(9):1199-1203. doi:10.1016/j.bjps.2015.05.026
86. Evans DG, Birch JM, Ramsden RT. Paediatric presentation of type 2 neurofibromatosis. *Arch Dis Child.* 1999;81(6):496-499. doi:10.1136/adc.81.6.496
87. MacCollin M, Mautner V. The Diagnosis and Management of Neurofibromatosis 2 in Childhood. 1998;5(93):243-252.
88. Sperfeld AD, Hein C, Schröder JM, Ludolph AC, Hanemann CO. Occurrence and characterization of peripheral nerve involvement in neurofibromatosis type 2. *Brain.* 2002;125(Pt 5):996-1004. doi:10.1093/brain/awf115
89. Bouzas EA, Freidlin V, Parry DM, Eldridge R, Kaiser-Kupfer MI. Lens opacities in neurofibromatosis 2: further significant correlations. *Br J Ophthalmol.* 1993;77(6):354-357. doi:10.1136/bjo.77.6.354
90. Rosser BT. Neurocutaneous Disorders. 2018;(February):96-129.
91. Goutagny S, Kalamarides M. Meningiomas and neurofibromatosis. *J Neurooncol.* 2010;99(3):341-347. doi:10.1007/s11060-010-0339-x
92. Slattery WH 3rd, Fisher LM, Hitselberger W, Friedman RA, Brackmann DE. Hearing preservation surgery for neurofibromatosis Type 2-related vestibular schwannoma in pediatric patients. *J Neurosurg.* 2007;106(4 Suppl):255-260. doi:10.3171/ped.2007.106.4.255
93. Neff BA, Wiet RM, Lasak JM, et al. Cochlear implantation in the neurofibromatosis type 2 patient: long-term follow-up. *Laryngoscope.* 2007;117(6):1069-1072. doi:10.1097/MLG.0b013e31804b1ae7
94. Renzi S, Michaeli O, Salvador H, et al. Bevacizumab for NF2-associated vestibular schwannomas of childhood and adolescence. *Pediatr Blood Cancer.* 2020;67(5):e28228. doi:10.1002/pbc.28228
95. Morris KA, Golding JF, Axon PR, et al. Bevacizumab in neurofibromatosis type 2 (NF2) related vestibular schwannomas: a nationally coordinated approach to delivery and prospective evaluation. *Neuro-oncology Pract.* 2016;3(4):281-289. doi:10.1093/nop/npv065
96. Lu-Emerson C, Plotkin SR. The neurofibromatoses. Part 2: NF2 and schwannomatosis. *Rev Neurol Dis.* 2009;6(3):E81-6.
97. Merker VL, Esparza S, Smith MJ, Stemmer-Rachamimov A, Plotkin SR. Clinical features of schwannomatosis: a retrospective analysis of 87 patients. *Oncologist.* 2012;17(10):1317-1322. doi:10.1634/theoncologist.2012-0162
98. Evans DG, Bowers NL, Tobi S, et al. Schwannomatosis: a genetic and epidemiological study. *J Neurol Neurosurg Psychiatry.* 2018;89(11):1215-1219. doi:10.1136/jnnp-2018-318538
99. Plotkin SR, Wick A. Neurofibromatosis and Schwannomatosis. *Semin Neurol.* 2018;38(1):73-85. doi:10.1055/s-0038-1627471
100. Koontz NA, Wiens AL, Agarwal A, Hingtgen CM, Emerson RE, Mosier KM. Schwannomatosis: the overlooked neurofibromatosis? *AJR Am J Roentgenol.* 2013;200(6):W646-53. doi:10.2214/AJR.12.8577
101. Hilton DA, Hanemann CO. Schwannomas and their pathogenesis. *Brain Pathol.* 2014;24(3):205-220. doi:10.1111/bpa.12125
102. Lin J, Martel W. Cross-sectional imaging of peripheral nerve sheath tumors: characteristic signs on CT, MR imaging, and sonography. *AJR Am J Roentgenol.* 2001;176(1):75-82. doi:10.2214/ajr.176.1.1760075
103. Brems H, Legius E. Legius syndrome, an Update. Molecular pathology of mutations in SPRED1. *Keio J Med.* 2013;62(4):107-112. doi:10.2302/kjm.2013-0002-re
104. Brems H, Pasman E, Van Minkelen R, et al. Review and update of SPRED1 mutations causing Legius syndrome. *Hum Mutat.* 2012;33(11):1538-1546. doi:10.1002/humu.22152
105. Evans DG, Bowers N, Burkitt-Wright E, et al. Comprehensive RNA Analysis of the NF1 Gene in Classically Affected NF1 Affected Individuals Meeting NIH Criteria has High Sensitivity and Mutation Negative Testing is Reassuring in Isolated Cases With Pigmentary Features Only. *EBioMedicine.* 2016;7:212-220. doi:10.1016/j.ebiom.2016.04.005
106. Denayer E, Legius E. Legius syndrome and its relationship with neurofibromatosis type 1. *Acta Derm Venereol.* 2020;100(100-year theme Genodermatoses):161-167. doi:10.2340/00015555-3429