Mutations in the Human Homologue of the Drosophila patched Gene in Caucasian and African-American Neviod Basal Cell Carcinoma Syndrome Patients

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Abstract

The nevoid basal cell carcinoma syndrome (NBCCS), or Gorlin syndrome, is a multisystem autosomal dominant disorder. The salient features of this syndrome include multiple basal cell carcinomas, palmar and/or plantar pits, odontogenic keratocysts, skeletal and developmental anomalies, and ectopic calcification. Other features include such tumors as ovarian fibromas and medulloblastomas. There is extensive interfamilial as well as intrafamilial variability with respect to the manifestation and severity of the phenotype. Alterations in the human homologue (PTCH) of the Drosophila segment polarity gene patched have been identified in NBCCS patients as well as tumors associated with this syndrome. We report several mutations in this gene in NBCCS patients and present the clinical phenotypes of the individuals in whom these mutations were identified.

Introduction

NBCCS3 (Online Mendelian Inheritance in Man number 109400), or Gorlin syndrome, is an autosomal dominant disorder characterized primarily by multiple BCCs, developmental and skeletal anomalies, plantar and/or palmar pits, odontogenic keratocysts, and ectopic calcification (1, 2). The NBCCS locus was mapped to human chromosome 9q22.3 by linkage analysis (3–5). Familial as well as sporadic forms of BCCs showed loss of heterozygosity of marker alleles in this genomic region, suggesting that the gene functions as a tumor suppressor (4, 5). Similar loss of heterozygosity is also exhibited by tumors such as ovarian fibromas and medulloblastomas that are less common features in NBCCS (6, 7). The human homologue (PTCH) of the Drosophila segment polarity gene patched (ptc) has now been identified as the gene for NBCCS (8–10). The human patched gene consists of at least 23 exons and spans approximately 34 kb (9). We screened 59 unrelated NBCCS patients for mutations in PTCH (23 exons) and have thus far identified deletions, insertions, splice site alterations, and nonsense and missense mutations distributed throughout the gene. Mutations have been detected in both Caucasian and African-American NBCCS families and appear to be unique to the families screened.

Materials and Methods

Patient DNA samples used in this study were obtained from the National Cancer Institute (Bethesda, MD) and New Haven, CT, NBCCS collections. Cell lines from NBCCS patients deposited in the NIGMS human genetic mutant cell repository were also utilized in this analysis. The patients were examined by medical geneticists and other specialists. Criteria for diagnosis of NBCCS (Gorlin syndrome) included the presence of at least two major features of the syndrome such as multiple BCCs or onset of one BCC before the age of 20, pits of palms and/or soles, jaw cysts, calcification of the falx cerebri, and having a first-degree relative with NBCCS. Tumor DNA was obtained from patients when available.

Primers were designed (Table 1) to amplify entire exons to screen the coding regions of the gene. Patient DNA samples (100 ng) were screened for mutations occurring within exons by radiolabeled (α-32P)dCTP PCR amplification followed by simultaneous SSCP and heteroduplex analysis (11–13). DNA samples were amplified in PCR buffer (0.6 mM dNTPs, 1.5 mM MgCl2, final concentration) and [α-32P]dCTP for 35 cycles (94°C for 30 s, 57°C for 30 s, and 72°C for 30 s). Amplified products were diluted 1:3 in stop solution, denatured for 8 min at 94°C, and chilled briefly on ice before loading onto 8% acrylamide: Bis gel (2.6% cross-linking) in 1× Tris-borate EDTA buffer. Gels were run at 70 W for 2–3 h at 4°C and then dried and exposed to X-ray film for 4–12 h. Heteroduplexes were identified from the double-stranded DNA at the bottom of the gels, and SSCPs were identified from the upper single-stranded region. PCR products with SSCP or heteroduplex variants were analyzed further by treatment with shrimp alkaline phosphatase and exonuclease (United States Biochemical Corp.) and cycle sequenced with AmpliTaq FS (Perkin-Elmer Corp.). The sequence was analyzed on an Applied Biosystems model 373A DNA sequencer.

Results and Discussion

A PCR-based screening strategy was used for rapid, large-scale identification of variants that were then characterized by sequence analysis and restriction endonuclease digests where appropriate as described in the previous section. Besides the three mutations described previously (9), we found eight additional mutations in eight exons. Table 2 shows these results (four insertions, four substitutions, one deletion, one deletion + substitution, and one splice site alteration, each unique to the DNA sample in which it was identified) and the associated phenotypes in patients for whom confirmed clinical data were available. Although several of these mutations occurred in highly conserved regions of the gene (Fig. 1), the mutations identified thus far appear to be distributed randomly throughout the gene.

The predominant type of mutation that we have characterized disrupts the coding region with small insertions or substitutions. One putative splice site variant replaces the G at the +1 position of the splice donor site of exon 16. Alterations in the gene that would not predict truncation of the protein product included a missense mutation.

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2 The abbreviations used are: NBCCS, nevoid basal cell carcinoma syndrome; BCC, basal cell carcinoma; PTCH, human homologue of Drosophila patched gene; SSCP, single-strand conformation polymorphism; NIGMS, National Institute of General Medical Science.

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in codon 509 of kindreds NBCCS 5 and 6 and a 3-bp deletion, ΔQ815 (deletion of glutamine residue), in kindred NBCCS 9. None of these alterations were found in 72 unrelated normal Caucasian chromosomes (data not shown). In kindred NBCCS 11, a S1132Y (serine-to-tyrosine substitution) mutation was observed in all of the eight affected family members but in none of the unaffected individuals. Additional genetic and functional data should provide insights into the mechanisms by which these alterations disrupt the function of the PTCH gene.

The previously reported 2000insC mutation (9) was identified in an 8-year-old female patient with severe clinical manifestations of the disorder, including multiple BCCs, hypertelorism, and bifid ribs. She was ascertained at the age of 5 years because of a medulloblastoma and is presumed to be a new mutation, because her parents are not symptomatic for the disease. This patient also has mild mental retardation. Although mental retardation is not observed commonly in NBCCS, previous studies suggested that contiguous genes might be responsible for this feature (14). The observations that PTCH is expressed in both fetal and adult brain tissue and that dysgenesis of the corpus callosum is observed in many NBCCS patients (15) suggest that this gene may play a critical role in the development of the nervous system. Although malformations of the corpus callosum itself are not usually associated with retardation, other related variations in brain morphology or biochemistry might be correlated with abnormal cerebral function. The functional role of the 2000insC mutation and this region of the gene in normal developmental processes and its possible contribution to clinical features marginally associated with NBCCS remains to be assessed.

Two different missense alterations within the same codon, G509V
and G509R were identified in a Caucasian and an African-American family, respectively. In the Caucasian family, segregation of G509V was concordant with disease status. The proband, an affected parent, and an affected sibling had this mutation, whereas the unaffected individuals in this family did not. In the African-American family, however, G509R was shared by the proband and his unaffected parent (father; Fig. 2). This alteration was not present in any of 84 unrelated, normal African-American chromosomes (data not shown). DNA extracted from a medulloblastoma sample from the proband demonstrated loss of the “normal” (wild-type) paternal allele but retention of the maternal (affected) allele. This is consistent with the two-hit model of neoplastic transformation wherein both copies of the normal allele are lost by one of several mechanisms that include loss of the wild-type allele and retention of the mutant allele as observed in this case (16). It is interesting to note that the proband displays a more severe phenotype than his mother, whose mutation remains to be identified (17). It is possible that the paternal G509R allele contributes to severity of disease in the proband. It is also likely that this amino acid substitution is neutral with respect to the functional aspect of the protein and therefore exerts no effect on the clinical phenotype seen in this patient. Given the considerable intrafamilial variability seen in NBCCS kindreds (15, 18) with regard to the spectrum of clinical manifestations and their severity, other genetic and/or environmental factors may contribute to the disease phenotype in this patient.

In this study, we have identified and characterized eight new PTCH mutations in NBCCS, each unique to the patient/kindred analyzed. We have also presented all available clinical data on the patients in whose DNA these mutations were found. Considering the complexity and variability of the NBCCS phenotype, molecular analysis of mutations will undoubtedly provide valuable clues regarding basic mechanisms contributing to the clinical phenotype. These clinical and molecular features will, however, have to be assessed in conjunction with other modifying factors such as ethnicity, genetic background of the patients, and interaction with environmental factors such as exposure to UV and X radiation. Combined data from many sources to evaluate genotype-phenotype correlations and gene-environment interactions will help elucidate the factors that confer predisposition to NBCCS and the role of the PTCH mutations underlying this disorder.

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References