Several kindreds having germline BAP1 mutations with a propensity for uveal and cutaneous melanomas and other internal malignancies have been described in an autosomal dominant tumor predisposition syndrome. However, clinically atypical moles have not been previously recognized as a component of this syndrome, to our knowledge. We describe the first kindred to date with a germline mutation in BAP1 associated with multiple cutaneous melanomas and classic dysplastic nevus syndrome.

**OBSERVATIONS** We describe a 53-year-old man who was initially seen in 2003 with dysplastic nevus syndrome, multiple atypical melanocytic proliferations showing loss of immunostaining for BAP1, and 7 cutaneous melanomas. Germline testing was performed in the proband, his 16-year-old son, and his 13-year-old daughter, revealing a germline mutation in the BAP1 gene (c.592G>T, p.Glu198X) in the proband and in his 16-year-old son. CDKN2A and CDK4 genes were wild type. No members of this kindred reported a history of uveal melanoma.

**CONCLUSIONS AND RELEVANCE** To our knowledge, this is the first report of a patient with multiple melanomas, dysplastic nevus syndrome, and an inactivating germline BAP1 mutation. The coexistence of dysplastic nevus syndrome and a BAP1 germline mutation extends the spectrum of the BAP1 tumor predisposition syndrome and may confer a greater risk for cutaneous melanomas.

**Figure 1**

Report of Cases

During the last 10 years, the pigmented lesion clinic in the Department of Dermatology at Northwestern University followed a man who was initially seen in 2003 at age 43 years with numerous clinically atypical nevi (Figure 1). His personal his-
tory included 7 cutaneous melanomas. One was a nodular melanoma, and 6 were SSMs with typical intraepidermal changes of melanoma, including extensive pagetoid and lentiginous growth (Figure 2). All 6 SSMs were reviewed by our histopathologist (P.G.), while the nodular melanoma was part of his medical history and was not available for our review. In all 6 SSMs, the cells were epithelioid but lacked spitzoid cytomorphology. The patient also had several biopsy specimens of dysplastic nevi (Figure 1) and 13 biopsy specimens of classic BDTs (Figure 3). BAP1 (C-4, 1:400; Santa Cruz Biotechnology) and BRAF V600E (VE1, 1:100; Spring Bioscience) immunostains were performed in the SSMs and in 6 BDTs on an autostainer (Leica BOND-MAX; Leica Biosystems) using a kit (DS990, Polymer Refine Red Detection; Leica Biosystems). All 6 SSMs were negative for immunostaining for BRAF V600E. Two SSMs were also evaluated for BRAF (OMIM 164757) mutation using a test (cobas 4800 BRAF V600; Roche), and were both negative. All 6 cases also showed loss of nuclear immunostaining for BRAF V600E mutation, with 3 positive and 3 negative results. One of these negative cases was tested using the mutation test (cobas 4800 BRAF V600), confirming the negative result. All the BDTs showed loss of nuclear BAP1 immunostaining.

One of the melanomas involved a sentinel lymph node, but the complete lymph node dissection was negative. Computed tomographic scans and blood test results suggested no evidence of further metastatic disease. The patient was given interferon alfa but tolerated the therapy for only 1½ months because of dysgeusia and palmoplantar paresthesias. He has had ophthalmologic examinations every 6 months for the last 2 years, which have revealed no evidence of uveal melanoma.

The proband’s family history was significant in that the patient’s mother died of lung adenocarcinoma. He denied any personal or family history of pancreatic cancer or additional cutaneous or uveal melanomas. The patient has a 16-year-old son who also had a BDT.

After obtaining approval from the Northwestern University Cancer Center and the Northwestern University Institutional Review Board and following receipt of written informed consent from the patient and his son and daughter, DNA was extracted from the paraffin-embedded blocks of one of the proband’s BDTs and from one SSM, as well as from his saliva and the saliva of his 16-year-old son and 13-year-old daughter. Sanger sequencing was performed to analyze the germline DNA for BAP1, CDKN2A, and CDK4 mutations. The proband and his son had identical germline nonsense mutations in BAPI (c.592G>T, p.Glu198X) (Figure 4C and D). One
of the patient’s BDTs also showed loss of heterozygosity at $BAP1$ (Figure 4A), with loss of the wild-type allele. Analysis of a melanoma from the same patient demonstrated the presence of the germline mutation, while the other allele was wild type (Figure 4B). There were no germline $CDKN2A$ or $CDK4$ mutations.

**Figure 2. Histologic Findings in a Superficial Spreading Melanoma**

A, Shown is a junctional proliferation of atypical melanocytes (hematoxylin-eosin, original magnification ×40). B, An irregular junctional proliferation of atypical melanocytes with suprabasal movement is shown (hematoxylin-eosin, original magnification ×100). C and D, Shown at intermediate-power magnification (red chromogen, ×100), the tumor cells do not immunostain with anti-BRAF V600E (C) or anti-BAP1 (D).

The tissues were mounted on positively charged slides and allowed to dry in an oven. The slides were dewaxed on the autostainer. BAPI immunohistochemistry was performed on the autostainer with a high-pH retrieval for 20 minutes. For detection of the antibody, an alkaline phosphatase-based chromagen was used with the kit (Polymer Refine Red Detection). Tumors were scored as positive or negative depending on whether or not their nuclei immunostained with BAPI. The BRAF V600E immunostain was also performed on the autostainer using a low-pH retrieval for 20 minutes, followed by detection using the kit (Polymer Refine Red Detection). The $BRAF$ mutation was detected using DNA extracted from formalin-fixed paraffin-embedded tissue with the mutation test (cobas 4800 BRAF V600), performed according to the manufacturer’s protocol.

**Discussion**

Multiple cutaneous melanomas have been associated with mutations in different genes (eg, $CDKN2A$ or $CDK4$). Germ-line variants in $BAP1$ have an increased susceptibility for different malignancies, with cancers appearing earlier than sporadic cases. These malignancies include uveal melanoma.
and (less frequently) cutaneous melanoma, as well as other cancers. To our knowledge, this is the first report of a patient with dysplastic nevus syndrome and an inactivating germline \textit{BAP1} mutation.

While all the SSMs from our patient demonstrated loss of \textit{BAP1} expression, none of them were found to have a \textit{BRAF} mutation by polymerase chain reaction or by immunostaining. Conversely, 3 of the 6 BDTs that were evaluated for a \textit{BRAFV600E} mutation were positive. Hence, there may be distinct tumorigenic pathways in patients with constitutive \textit{BAP1} inactivation. If the cooperating driver mutation is \textit{BRAFV600E}, the melanocytic proliferation may more likely evolve into a characteristic BDT. This is supported by another recent study in which a high concordance between nuclear \textit{BAP1} loss and \textit{BRAFV600E} expression was reported. On the other hand, if a cooperating driver mutation is an oncogenic hit other than \textit{BRAFV600E}, there may be a higher likelihood of melanoma considering that none of our patient’s SSMs had a \textit{BRAF} mutation, although this model is speculative. Nevertheless, 3 of our 6 BDTs tested did not have a \textit{BRAF} mutation. Therefore, BDTs can develop in the context of other potential oncogenic stimuli.

To our knowledge, the p.Glu198X is a novel germline \textit{BAP1} mutation, although this mutation has been observed in an unrelated tumor specimen. The \textit{BAP1} protein is a tumor suppressor that acts as a ubiquitin carboxyl-terminal hydrolase functioning as a deubiquitinizing enzyme. It is a binding partner to \textit{BRCA1} (OMIM 113705), as well as to other transcription factors such as HCF1, and is implicated in DNA damage repair and regulation of apoptosis, senescence, and cell cycle regulation. \textit{BAP1} also interacts with ataxia telangiectasia mutated and ataxia telangiectasia and Rad3-related proteins,
Figure 4. Electropherogram Showing a Nonsense Mutation in Exon 8 in the BAP1 Gene

A-C. In the proband, the mutation was found in the DNA from a BAP1-deficient tumor (A), a melanoma (B), and the saliva (C), thereby demonstrating germline origination. D. The same mutation was identified in the saliva of the patient’s 16-year-old son.

which regulate the DNA damage induced by UV radiation. Therefore, mutations in BAP1 could increase the susceptibility to UV radiation and the risk for melanomas. BRAF mutations have been identified in melanomas resulting from intense intermittent bouts of UV exposure. This case also illustrates the importance of histopathology in guiding patient management. Patients with BDTs should undergo a thorough review of their family history as it pertains to all cancers. Lesional skin biopsy specimens may be screened for BAP1 loss by immunohistochemistry. It is thought that loss of nuclear expression correlates with absence of BAP1 function.

Conclusions

Identification of this germline BAP1 mutation in a patient with a constellation of multiple cancers and multiple atypical melanocytic tumors expands the cutaneous phenotype of the BAP1 tumor predisposition syndrome. To date, most reports suggest a favorable prognosis for BDTs and BAP1-deficient Spitz tumors, including the patient described herein. We speculate that the presence of a BAP1 germline mutation in a patient who phenotypically has dysplastic nevus syndrome may result in a considerable increased risk for cutaneous melanomas. However, further research is needed to determine if the BAP1 germline mutation increases the risk of cutaneous melanoma beyond the dysplastic nevus phenotype alone. Although no formal guidelines exist for patients with germline BAP1 alterations, strict sun protection and regular dermatologic and ophthalmologic evaluations are advisable.

REFERENCES


