Clinical Study of 40 Cases of Incontinentia Pigmenti

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Objective: To analyze the distribution of manifestations in a pediatric cohort and define guidelines for follow-up of incontinentia pigmenti (IP).

Design: Retrospective study of 47 children referred to the Department of Pediatric Dermatology with a diagnosis of IP between 1986 and 1999.

Setting: The private or institutional practice of participating dermatologists and pediatricians.

Main Outcome Measures: Evaluation of IP clinical diagnosis using the Landy and Donnai criteria.

Results: Because hyperpigmentation following the Blaschko lines may be observed in several pigmented disorders, 7 patients were found misdiagnosed. During the neonatal period, erythema, vesicles, and hyperkeratotic lesions were rarely absent in the patients with IP. Ocular and neurological abnormalities were frequent (20% and 30%, respectively) but rarely severe (8% and 7.5%, respectively).

Conclusions: Clinical diagnosis is the first main step for a correct phenotype/genotype correlation, which remains indispensable to better understand the pathological mechanisms of IP and develop new therapies. In doubtful cases, molecular analysis is helpful but characteristic histological features must be added as major criteria for IP diagnosis. Multidisciplinary follow-up is needed, particularly during the first year of life, to detect possible ophthalmologic and neurological complications. Neuroimaging ought to be performed in the case of abnormal neurological examination results or when vascular retinopathy is detected.

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Incontinentia pigmenti (IP), or Bloch-Sulzberger syndrome, is a rare X-linked dominant genodermatosis that affects mostly female patients and is usually lethal for males in utero. It is a multisystem disorder, primarily of ectodermal origin, accompanied by dental, ocular, and central nervous system disorders such as seizures, spastic paralysis, microcephaly, and mental retardation. The typical phenotype results from a functional mosaicism, itself a consequence of lyonization (the random inactivation of one of the two X chromosomes in women).

For editorial comment see page 1206

The identification of nuclear factor-kappa B (NF-κB) essential modulator (NEMO) as the disease-causing gene, and the skewing of the X chromosome inactivation, are powerful new tools that have made the diagnosis of unusual forms of IP easier. Nevertheless, the diagnosis of IP is based on clinical examination. The skin lesions may occur in 4 classically successive diagnostic stages: erythema, then vesicles and pustules (stage 1); verrucous lesions (stage 2); linear hyperpigmentation (stage 3); and pallor and scarring (stage 4). Stages, however, may overlap or not occur at all in a same patient. A linear hyperpigmentation that follows the Blaschko lines leads to IP (a disease with a highly evocative name). However, Blaschko linear hyperpigmentation can be observed in a heterogeneous group of mosaic conditions, eg, hypomelanosis of Ito (HI). Thus, IP clearly appears to have been overdiagnosed in the past. For this reason, the frequency of the clinical features associated with the highly diagnostic cutaneous manifestations are discussed in the literature. Landy and Donnai classified IP criteria into 2 groups, negative family history and first-degree family history (Table 1). These criteria remain essential for distinguishing such disorders and their clinical and genetic implications.

The aim of our study was to evaluate with the Landy and Donnai criteria a series of 47 patients previously diagnosed as having IP. We also analyzed the distribution of clinical manifestations and compared our findings with the data in the literature, thereby demonstrating the importance of attentive clinical examination.
We reviewed the clinical records of pediatric patients diagnosed as having IP and referred to the Department of Pediatric Dermatology at Hôpital Necker–Enfants-Malades, Paris, France, between 1986 and 1999. The medical records of all affected patients, which included neonatal data as well as inpatient and outpatient records, were reviewed by 2 experienced dermatologists (D.F. and C.B.). They used a standardized form to collect clinical information (mostly regarding cutaneous, ocular, dental, and neurological manifestations as well as family history) and investigation results. When necessary, obstetric and pediatric medical records were consulted, as well as specialists from other disciplines who followed up the patients. The clinical data were analyzed according to the criteria set by Landy and Donnai (Table 1).

Skin biopsy samples obtained from 28 patients were examined by the same pediatric dermatopathologist (S.F.). Eosinophilic count in peripheral blood analysis was performed in 26 patients and skeletal radiographs in 20.

Forty-seven patients believed to have IP (43 girls and 4 boys) were referred to us during this period with relevant medical records. However, we considered that only 40 of them (37 girls and 3 boys) had been rightly diagnosed. Age at diagnosis was unknown for 7 of the children who had IP; for the remainder, median age was 6 months 9 days (range, birth to 12 years). Among the 7 patients with a questionable IP diagnosis, 3 were finally diagnosed with HI, 1 with orofacial-digital syndrome, and diagnosis is still uncertain in the last 3 cases (Table 2).

### Table 1. Diagnostic Criteria for Incontinentia Pigmenti (IP) *

<table>
<thead>
<tr>
<th>No Incidence of IP in at Least 1 First-Degree Female Relative</th>
<th>Evidence of IP in at Least 1 First-Degree Female Relative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical neonatal rash</td>
<td>Suggestive history or evidence of typical rash</td>
</tr>
<tr>
<td>Erythema, vesicles, eosinophilia</td>
<td>Skin manifestation of IP</td>
</tr>
<tr>
<td>Typical hyperpigmentation</td>
<td>Hyperpigmentation</td>
</tr>
<tr>
<td>Mainly on trunk</td>
<td>Scarring</td>
</tr>
<tr>
<td>Following Blaschko lines</td>
<td>Hairless streaks</td>
</tr>
<tr>
<td>Fading in adolescence</td>
<td>Alopecia at vertex</td>
</tr>
<tr>
<td>Linear, atrophic, hairless lesions</td>
<td>Anomalous dentition</td>
</tr>
</tbody>
</table>

### Minor Criteria (Supportive Evidence)

- Dental involvement
- Alopecia
- Wooly hair, abnormal nails

At least 1 major criterion is necessary to make a firm diagnosis of sporadic IP. Minor criteria, if present, will support the diagnosis; because of their high incidence, complete absence should induce a degree of uncertainty.

The diagnosis of IP is likely in a first-degree female relative of an affected female patient if any of the mentioned minor criteria are present, alone or in combination.

*According to Landy and Donnai.

### Table 2. Clinical and Biological Characteristics of the 3 Patients With Uncertain Diagnosis

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Patient No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of suspected IP</td>
<td>2 y</td>
<td>1 d</td>
<td>1 d</td>
<td></td>
</tr>
<tr>
<td>Typical neonatal rash</td>
<td>NA</td>
<td>Erythema</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Linear hyperpigmentation</td>
<td>Occurred at 2 y</td>
<td>Occurred at 10 d</td>
<td>Occurred at 1 d</td>
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</tr>
<tr>
<td>Fading in adolescence</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Hypopigmentation</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Dental involvement</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Alopecia</td>
<td>Transient and occipital</td>
<td>Vertex</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Eosinophilia</td>
<td>768/µL</td>
<td>NA</td>
<td>NA</td>
<td></td>
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<tr>
<td>Family history</td>
<td>Psychomotor delay (brother)</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Associated disorders</td>
<td>NA</td>
<td>Bipolar aphthosis, myocardiopathy</td>
<td>Uretheroce</td>
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<tr>
<td>Chromosome X inactivation</td>
<td>Random</td>
<td>Not contributive</td>
<td>Random</td>
<td></td>
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<tr>
<td>NEMO rearrangement</td>
<td>NA</td>
<td>NA</td>
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</tr>
</tbody>
</table>

Abbreviations: IP, incontinentia pigmenti; NA, not applicable (absent); NEMO, nuclear factor–kappa B essential modulator.

**METHODS**

Information was available for all 40 patients. Dermatological manifestations were present as early as the first day after birth in 27 (68%) of them, during the neonatal period in 9 (22%), and after the age of 3 months in 4 **RESULTS**

**SKIN MANIFESTATIONS**
skin lesions were present before the second week of life in 36 (90%). Data are reported in Table 3 and manifestations shown in Figure 1.

Erythema and vesicles (stage 1) were the first manifestations in 37 (92%) of the 40 patients, but stage 1 was absent in 3 (8%), and 2 had late recurrences of stage 1 lesions: 7 episodes of blisters occurred during the first year in one of them, and several episodes until the age of 3 years in the other.

Typical stage 2 hyperkeratotic lesions were noted in 32 (80%) patients but were absent in 6 (15%), and information was not available for 2 (5%). For 1 patient, stage 1 skin manifestations were absent and skin disease began with hyperkeratotic lesions. Frequently diffuse, stage 2 lesions were limited to the scalp (1 case) or the extremities (2 cases).

Linear hyperpigmented stage 3 lesions were present in 36 (90%) patients, but absent in 4 (10%) who were referred before the age of 2 months. Hyperpigmented lesions initiated skin manifestations in 2 patients and were present at birth in 1.

Finally, stage 4 manifestations were recorded in 12 (30%) patients but absent in 20 (50%), and information was not available for 8 (20%) patients. Linear, reticulate, or macular atrophic lesions were described in 9 (75%) of the 12 patients; lesions were present before the second week of life in 4, and after 1 year in 2. Linear hypopigmentation was noted in 4 (10%) of the 40 patients with IP. Information on the evolution of pigmentation anomalies was not available because there was no long-term follow-up.

Alopecia of the vertex was observed in 11 (28%) of the 40 patients, was absent in 24 (60%), and informa-
tion was not available for 5 (12%). Alopecia was present in 7 patients younger than 6 months and in 4 older than 6 years.

Nail dystrophy was present in only 3 (10%) of the 30 patients for whom this information was noted. Nails were striated and thick in a 4-month-old girl, while onycholysis and hyperkeratosis of the 10 fingernails were present in another severely affected 10-year-old girl. Trachyonychia was noted at birth in 1 girl and supernumerary nipples were noted in 2.

NEUROLOGICAL INVOLVEMENT AND NEUROIMAGING

Clinical neurological manifestations were observed in 13 (32%) of the 40 patients (Table 4, patients 1-13). Neurological manifestations occurred within the first weeks, even within the first day of life, in the 5 (38%) children in this group cared for since birth in our department. Seizures were the prominent feature in 10 (77%) of the 13 patients with neurological involvement. Grand mal seizures occurred in 2 patients (patients 8 and 9) and led to death due to vascular cerebral damage: thalamic hemorrhage in one and ischemia and necrosis of both hemispheres in the other. These 2 individuals presented with early and extensive skin manifestations. Delayed psychomotor development was noted in 7 (54%) of the 13 patients, while mental retardation was reported in 3 (23%), and a spastic hemiplegia sequela was reported in 2 (15%).

Neuroimaging performed in 12 of the 13 patients revealed neurological manifestations in 10, and 2 had normal results (Table 4, patients 14 and 15). Transfontanellar ultrasonography was performed in 3 (25%) of these 12 patients; a computed tomographic scan in 5 (42%), all of whom had neurological symptoms; and magnetic resonance imaging (MRI) in 6 (50%). Cerebral atrophy and local or extensive hemorrhagic necrosis were the prominent features in the 5 patients who had a computed tomographic scan. Porencephalia was reported in 3 (25%) of the 12 patients, enlargement of lateral ventricles also in 3 (25%), and hypoplasia of the corpus callosum in 2 (17%). Leukodystrophy was detected in patient 15, who presented with severe retinal detachment.

Table 4. Neurological Manifestations and Neuroimaging Findings in 15 of 40 Patients With Incontinentia Pigmenti

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<tr>
<th>Patient No.</th>
<th>1</th>
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<th>4</th>
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<th>7</th>
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<th>10</th>
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<th>12</th>
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<tr>
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<tr>
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<tr>
<td>Lateral ventricle enlargement</td>
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<td>Leukodystrophy</td>
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<tr>
<td>Corpus callosum hypoplasia</td>
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</tbody>
</table>

Abbreviations: A, abnormal; D, death; N, normal; +, present; −, absent.

*D Neurological manifestations occurred before 3 weeks of life in patients 2, 3, 4, 8, and 9. Age of onset is unknown for the others. Patients 14 and 15 had normal neurological examination results. Patients 3 and 13 are males. Patients 7 and 15 had retinal detachment and patient 11 had occlusion of the central retinal artery.

DENTAL ABNORMALITIES

At evaluation, 23 (58%) of the 40 patients with a verified IP diagnosis were younger than 1 year and teeth examination was impractical, but information was available for 17 (42%) patients. Among these 17 patients, 10 (59%) presented with tooth abnormalities: 7 (70%) with partial anodontia of deciduous or permanent teeth, and 5 (50%) with conical teeth; this was an isolated condition in only 2 (20%). Microdontia and delayed eruption of permanent teeth were reported in only 1 patient. Two sisters and their mother had isolated cleft palate.

EYE ABNORMALITIES

Information concerning a detailed ophthalmologic examination was available for 34 (85%) of the 40 patients studied and anomalies were noted in 7 (20%) of them. The association of ocular and neurological manifestations is reported in Table 4. Strabismus was noted in 4 patients (12%); the condition was isolated in 3 (9%) and was associated with ophthalmoplegia of the sixth cranial nerve as a complication of cerebral hemorrhage in the fourth. Unilateral microphthalmia was reported in 2 patients (6%); it was associated with retinal detachment in one and with retinal detachment, aneurysm, hemorrhage, cataract, early seizures, and monocular blindness as a sequela in the other. Each of the following features was reported in only 1 patient: unilateral retinal pigmentation, coloboma, and occlusion of the central retinal artery.
IP IN BOYS

Our series included 3 boys (8%) with a sporadic form of IP. One presented with stage 4 skin manifestations only. His karyotype was normal (46,XY). The second presented with skin manifestations, and with such neurological abnormalities as hemiparesis of the left arm and porencephalia of the left globus pallidus on computed tomographic scan. The third presented with skin manifestations, strabismus, and seizures, and MRI showed ischemic lesions of the frontal lobes (Table 4). His karyotype was normal (46,XY).

ASSOCIATED DISORDERS

One patient had associated Down syndrome. It was diagnosed by chromosomal analysis (47,XX+21) and probably related to maternal age. Each of the following was reported in this patient only: exudative enteropathy, megalourethra, port-wine stains on the superior lip and scalp, laryngomalacia, tumor of the vertebral lumbar canal, and recurrent pulmonary infections.

FAMILY HISTORY

On examination, 11 (28%) of the 40 patients studied had a family history of IP involving at least the mother. Clinically, IP was considered sporadic in 25 patients (62%). All affected boys were diagnosed as having a sporadic form. Information was not available for 4 (10%) of the patients.

HISTOLOGICAL FEATURES

A skin biopsy sample was obtained for 26 of the 40 patients, and skin lesion stage was known for 21 of the samples. There were 11 with histological analysis of stage 1 lesions, 8 of stage 2 lesions, and 2 of stage 3 lesions. The results are reported in Table 5 and shown in Figure 2.

Table 5. Histological Features From 21 Biopsies of Patients With Incontinentia Pigmenti*

<table>
<thead>
<tr>
<th>Lesion Stage</th>
<th>1</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Biopsies, No.</td>
<td>11</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Histological features</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eosinophilic spongiosis</td>
<td>11</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Dyskeratosis</td>
<td>10</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Free melanin in dermis</td>
<td>3</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Dermal infiltration by lymphocytes and eosinophils</td>
<td>5</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

*Stage of skin eruption was known for 21 biopsies. Histological features reflect progressive keratinocyte apoptosis and may be added as major criteria for incontinentia pigmenti diagnosis.

15400/µL. Skeletal radiographs showed normal bones in the 20 patients tested.

MOLECULAR INVESTIGATIONS

Karyotype screening performed in 7 (18%) of the 40 patients (3 with familial forms, 3 with sporadic forms, and 1 with an undetermined form of IP) showed an abnormal result only in the girl with Down syndrome. Samples of DNA were available for only 12 patients (1 with familial and 11 with sporadic forms of IP). Inactivation of an X chromosome and NEMO deletion were tested in all of them. The skewing of chromosome X inactivation was constant; it concerned the maternal X chro-
mosome in 4 patients (in 3 with sporadic forms and in the patient with the familial form of IP) and the paternal X chromosome in the 8 remaining patients. The NEMO rearrangement (deletion of exons 4 through 10) was present in 9 of the 12 patients (4 with sporadic and 5 with familial forms).

COMMENT

Between 1986 and 1999, 47 children diagnosed as having IP in the Department of Pediatric Dermatology were reevaluated using the Landy and Donnai criteria, and 7 were found misdiagnosed. Hypomelanosis of Ito had been mistaken for IP in 3 patients, 2 girls and 1 boy. Since birth, these 3 children had had linear hyperpigmentation following the Blaschko lines, with indistinct edges to the hyperpigmented or hypopigmented areas, and no recorded episodes of vesicular or verrucous lesions. They had no family history of HI and no psychomotor development delay, which is more frequent in the exceptional cases of familial HI. Genetic counseling is different in the case of HI as, unlike IP, it is frequently related to chromosomal anomalies. Orofacial-digital syndrome was diagnosed in a girl who presented with linear hyperpigmentation and hypopigmentation, microcephaly, cleft palate, ear abnormalities, coloboma of the optic nerve, and interventricular communication. Diagnosis is still uncertain for the 3 remaining girls who had no family history of HI and no psychomotor development delay. Follow-up lasts up to 5 years. The absence of histological IP features, the random nature of X chromosome inactivation, and the absence of NEMO gene rearrangement permitted to exclude IP for all the misdiagnosed children. The association of inflammatory colitis, bipolar aphthosis, and linear hyperpigmentation previously reported as Behçet disease with IP did not satisfy the Landy criteria. Nevertheless, such an association may provide a key for understanding the molecular basis of IP and should to be further explored.

According to the Landy and Donnai criteria, 40 patients had been rightly diagnosed as having IP (Table 1). All 4 classic stages of IP skin lesions were found (Table 3 and Figure 1). Several stages may overlap, making diagnosis difficult. However, the first 2 stages are rarely absent during the neonatal period, and the features of the last 2 stages are helpful for diagnosing IP in adulthood. Stage 1 lesions frequently occur, and were noted in 92% of our cases. They are characteristic of IP and no differential diagnosis may be evoked regarding vesicles following the Blaschko lines and preceded by erythema scattered over the face (Figure 1A). As previously reported, stage 1 lesions appear before the second week of life in 90% of cases and clear within the first 4 months. In our series, recurrence of stage 1 lesions was noted in 2 patients and reported elsewhere. The frequency of such late recurrences, sometimes several years after the neonatal period, remains unknown. Thus, a diagnosis of IP could be considered in the case of a child presenting with recurrent inflammatory lesions of unknown origin along the Blaschko lines. The frequency of stage 2 verrucous and keratotic lesions in our series was consistent with published data (80% vs 70%, Figure 1B), as well as the lesions’ time of appearance (within the first 2 months of life) and duration (they cleared within 6 months). Verrucous lesions may be localized (Table 3), and are highly evocative on the scalp. Late onset of focal verrucous lesions has been reported. In our series, stage 3 linear hyperpigmentation began at 2 weeks of life, earlier than previously reported (Table 3 and Figure 1C). On the trunk, the spontaneous occurrence and nonscarring resolution of Blaschko linear hyperpigmentation are major characteristics of IP. Such isolated hyperpigmented lesions during adulthood may be confused with other pigmented disorders. Interestingly, 1 of 2 biopsy results of stage 3 lesions showed free dermal melanin associated with focal dyskeratosis. Pale, stage 4 macular and reticular atrophic lesions were observed in only 9 (22%) of the 40 patients in our series. These lesions occurred before 1 year of age in 78% of cases (Table 3 and Figure 1D). Classically, stage 4 begins later than the other stages; and because it persists in adulthood, it is helpful in the tardive diagnosis of IP in women.

Hair, nail, dental, and nipple involvements are minor but useful criteria for IP diagnosis in adults. The frequency of alopecia of the vertex was less (28%) in our retrospective study than previously reported in the literature (38%). Wooly hair has been reported but hair shaft is usually found normal on microscopic examination. Nail involvement ranges from mild pitting to onychogryphosis. The low frequency of nail anomalies in our study (8% vs 40% elsewhere) may be related to our recording only severe forms. In 1 case, subungual hyperkeratosis of all fingernails was painful and neither topical treatment with salicylic acid nor retinoic acid given orally was efficient. Unfortunately, follow-up was not possible. Supernumerary nipples were noted in 2 girls. As it is 10 times more frequent in patients with IP than in the general population, breast involvement may be added as a minor criterion for IP diagnosis. The early age of our patients may explain the low frequency (25%) of dental involvement, which is usually common in IP. The deciduous and/or permanent dentitions may be affected. Partial anodontia (lateral incisors and premo-lars) and conical teeth (incisors and canines) are common in IP and were noted in 70% of our patients; however, these tooth abnormalities are frequent in the pediatric population (6% and 0.33% for partial anodontia and conical teeth, respectively). Microdontia, enamel dysplasia, delayed eruption, or caries have also been reported in IP. During the neonatal period, panoramic radiography is not necessary. Cleft palate has been described in 1.1% of patients with IP, vs 0.28% in the general population.

The severity of IP is related to ocular and neurological impairment. In our series, ocular involvement was less frequent (20%) than that reported (approximately 40%) because we chose not to record myopia and astigmatism, which are common in the general population. Ophthalmologic manifestations are divided into retinal (retinal detachment, visual loss) and nonretinal (strabismus, catacar, pigmentation of the conjunctiva). The incidence of strabismus is significantly higher in IP than the 3.7% found in the general population. Mi-
crophthalmia, which occurred in 6% of our patients, has also been reported in IP.\textsuperscript{29} The frequency of only severe ocular impairment, ie, retinal detachment or visual loss, was similar to that reported in previous studies and close to 8%.\textsuperscript{14} Retinal detachment is a consequence of neovascularization following retinal ischemia caused by abnormal peripheral retinal vessels.\textsuperscript{29} The entire process may occur slowly over several years or quickly within the first month of life. Thus, careful and regular ophthalmologic follow-up is required during the first year\textsuperscript{7,26} so that specific therapy for retinal detachment, such as laser treatment, may be implemented.\textsuperscript{31} Since vascular abnormalities may explain severe ocular and neurological involvement, neuroradiological explorations must be performed if any vascular retinopathy is identified.\textsuperscript{31,33} Leukodystrophy was detected by MRI in a 9-year-old girl who presented with severe retinal detachment and normal neuroradiological examination, and MRI or computed tomography scan may detect microphthalmia and retinal detachment.\textsuperscript{31,34} In IP, vascular retinopathy constitutes a predictive risk factor for cerebral involvement.

In 1976, Carney\textsuperscript{14} stressed the frequency of neurological manifestations, which he reported occurring in 30.5% of his 653 patients. Landy and Donnai, however, consider that Carney overestimated this frequency because of misdiagnosed cases and found neurological manifestations in 18% of their own 111 patients.\textsuperscript{5} In our series, even when considering the Landy and Donnai criteria, neurological impairment was found to be frequent (32%) and severe—causing death in 2 cases (Table 4). Mental retardation, found in about 8% of patients with IP, could be a consequence of early and frequent convulsive episodes, mostly within the first year of life.\textsuperscript{3,14,35-38} Thus, the child should be watched carefully during this period. Limited data concerning central nervous system imaging have been published.\textsuperscript{37-46} In our series, MRI and computed tomographic scan results confirmed the findings of clinical examination. Cerebral atrophy, porencephalia, hemorrhage, and hypoplasia of the corpus callosum (2 cases in this study) have also been reported elsewhere.\textsuperscript{34,41,42} The IP-induced pathogenesis of the central nervous system is still unknown, but developmental inflammatory mechanisms, occlusive phenomena in small vessels, or both, have been suggested.\textsuperscript{34,36,37,43} Developmental malformations such as spina bifida seem to be fortuitous in IP. We observed 1 case, with isolated megalu-urethre; this led to excluding the diagnoses of mammo-renal or acromammo-renal syndromes, in which urinary malformations are associated with abnormal nipples.\textsuperscript{44}

Few paraclinical explorations are required for IP diagnosis. According to Landy and Donnai, eosinophilia is a major criterion during the neonatal period. Eosinophilia then decreases slowly to normal values and is usually not complicated by visceral disorders.\textsuperscript{45} Histological analysis may be helpful for diagnosis.\textsuperscript{46} Stage 1 lesions are characterized by eosinophilic spongiosis of the epidermis (in 100% of patients in our series), which disappears at the beginning of stage 2 lesions. Focal dyskeratosis occurs very early, persists until the onset of stage 4 lesions (Table 3 and Figure 2), and was clearly determined to be related to keratinocyte apoptosis.\textsuperscript{47} During the neonatal period, association of both apoptosis and eosinophilic spongiosis characterize IP. With stage 3 lesions or, later, with residual linear hyperpigmentation in adults, the association of both apoptosis and free melamin is highly suggestive of IP. Although their absence cannot exclude a positive diagnosis, the detection of such histologic features should be considered a major criterion for IP diagnosis. Intensity of skin manifestations and eosinophil count are not related to more severe visceral involvement and have no prognostic value.\textsuperscript{3}

Careful and systematic examination of first-degree relatives allowed the detection of minor manifestations in the relatives of 11 of our 40 patients. In 2000, IP was shown to be caused by mutations of the NEMO 10 exons gene. In 9 (80%) of our 12 patients for whom DNA samples were available, the disease-causing mutation was a large-scale deletion of exons 4 to 10, which produces an unstable protein.\textsuperscript{4} The NF-κB pathway is involved in local inflammatory response and in the control of keratinocyte apoptosis, which explains the clinical and histological features of apoptosis in IP.\textsuperscript{15} The severity of the clinical manifestations of the disease are not related to the type of mutation. Skewed X inactivation is detected in over 98% of female patients with IP and in our series, it was detected in all 12 tested girls. Testing X inactivation is helpful for diagnosing mild forms of IP or identifying the paternal origin of the mutated X chromosome in sporadic cases.\textsuperscript{47} Germline mutations in the father’s gonads explains over 80% of sporadic IP cases.\textsuperscript{48} As indicated earlier, the mutated X chromosome was of paternal origin in 8 of the 11 sporadic cases in our series, revealing the occurrence of paternal-germline mosaicism. Usually, affected male fetuses die in utero at the end of the first trimester.\textsuperscript{49,50} As the diagnosis is not systematically established, the frequency of IP in boys is probably underestimated; in this study, 3 boys with normal karyotype fulfill the criteria. In boys, the disease may occur with a broad spectrum of phenotypic manifestations, from isolated skin involvement to severe neurological impairment.\textsuperscript{51} Genetically, such cases may be explained by the presence of the Klinefelter syndrome (47,XXY) or early somatic mutation of the NEMO gene.\textsuperscript{51,52} Interestingly, NEMO mutations have also been reported in anhidrotic ectodermal dysplasia with immune deficiency.\textsuperscript{53} This emphasizes the strong relations between these 2 diseases affecting ectoderm-derived structures.\textsuperscript{56}

The diagnosis of IP is initially based on clinical criteria. Dermatologists and pediatricians are those first concerned. As, at birth, both eosinophilic spongiosis and apoptosis are characteristic of IP, histological features may be added as major criteria for diagnosis. The follow-up of patients with IP is based on multidisciplinary collaboration, and its primary goal is the detection of rare ophthalmologic and neurological involvement as early as possible in the first year of life. Neuroimaging is performed when abnormal findings on neurological examination, vascular retinopathy, or both, are detected. Genetic counseling must involve both patient and relatives. In doubtful cases, DNA studies are helpful to ascertain or rule out the diagnosis. Clinical diagnosis is the first main step toward a correct phenotype/genotype correlation, which remains indispensable for a better understanding of the
pathological mechanisms of IP and for developing new therapies.

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