Association of Red Cell Spherocytosis With Deletion of the Short Arm of Chromosome 8

By Robert R. Chilcote, Michelle M. Le Beau, Carlton Dampier, Eugene Pergament, Yury Verlinsky, Narla Mohandas, Henri Frischer, and Janet D. Rowley

Congenital spherocytic anemia is a common disorder, but in most cases the nature of the underlying membrane lesion is unknown and the genetic defect has not yet been unequivocally mapped to a chromosome. We studied two dysmorphic siblings with neurologic findings and hemolytic anemia. Clinical and laboratory findings in these two siblings were consistent with the diagnosis of congenital spherocytosis whereas both parents and two unaffected siblings were normal. The two affected children had an abnormal chromosomal complement as a result of a deletion of the short arm of chromosome 8 \([46,XX,del(8)(p11.1p21.1)]\). These results suggest that a gene whose deletion results in a congenital spherocytic anemia phenotype resides on this region on the short arm of chromosome 8.

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Table 1. Hematologic Values for the Two Patients

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<tbody>
<tr>
<td>Age (yr)</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Hemoglobin (g/dL)</td>
<td>9.2</td>
<td>15.2</td>
<td>10.2</td>
<td>25</td>
<td>15.2</td>
<td>8.8</td>
</tr>
<tr>
<td>Reticulocytes (%)</td>
<td>20</td>
<td>1.4</td>
<td>8.8</td>
<td>20</td>
<td>1.4</td>
<td>8.8</td>
</tr>
<tr>
<td>MCHC (g/dL)</td>
<td>35.0</td>
<td>35.9</td>
<td>34.6</td>
<td>35.0</td>
<td>35.9</td>
<td>34.6</td>
</tr>
<tr>
<td>Microspherocytes (0-4 +)</td>
<td>2 +</td>
<td>4 +</td>
<td>2+</td>
<td>2 +</td>
<td>4 +</td>
<td>2+</td>
</tr>
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</table>

*This patient had hyperbilirubinemia in the newborn period and, before splenectomy, four severe anemic episodes associated with splenomegaly and requiring transfusions. Hematologic values were obtained during stable periods with no recent transfusions. Two normal-appearing siblings have normal hematologic studies.

were assayed using ammonium ferrothiocyanate and silica gel (Fischer Silicon Gel G) thin-layer chromatography. Trypsin-Giemsa–banded chromosome studies were performed on phytohemagglutinin-stimulated peripheral blood lymphocytes on two occasions on each family member and on cultures established from skin biopsies of the parents. Multiple blood group and HLA markers were determined on both parents and the two older children.

RESULTS

Hematologic studies. The results of osmotic fragility studies of unincubated RBCs from one affected child (C.H.), are shown in Fig 1. Density centrifugation of fresh peripheral blood enriched the lower or denser, presumably older layers (as judged by the absence of reticulocytes), for spherocytes. Also shown in Fig 1 are the results of osmotic fragility studies obtained at the time of this child's splenectomy. RBCs taken from the splenic pulp and splenic vein had a higher proportion of osmotically fragile RBCs than did the peripheral blood, consistent with splenic "conditioning." Genetic studies. Metaphase cells from both affected children had an interstitial deletion of the short arm of chromosome 8 extending from band p11.1 to p21.1 (Fig 2): [46,XX,del(8)(p11.1p21.1)]. Peripheral blood lymphocytes from one unaffected sibling and both lymphocyte and skin fibroblast cultures from the parents had normal chromosomal complements.

RBC GSSG-R levels in the affected children were slightly lower than those of either parent, one unaffected sibling, or controls (C.H.: 8.6, 6.3; B.H.: 9.0, 11.2; unaffected sibling: 13.7; mother: 12.0, 15.2; father: 12.4; and nine controls: 13.2 ± 2.4 mmol/min/g Hb SD). Carbonic anhydrase I and II and plasma factor VII levels were not reduced. Blood group and lymphocyte HLA studies gave no evidence of nonpaternity.

Membrane studies. Ektacytometric studies of peripheral blood taken from both parents and the affected children were normal. These findings are consistent with the results noted in patients with classical hereditary spherocytosis in whom no specific skeletal protein defect can yet be identified.

SDS-polyacrylamide gels of RBC ghosts isolated from a normal control and the family members are illustrated in Fig 3. Spectrin (both α and β), actin, band 4.1, and other bands delineated by this technique were present; results were confirmed by two-dimensional gel analysis. Table 2 shows that the ratios of spectrin, band 4.1, and band 4.2 to band 3 for each of the affected children, both parents, and controls were similar. The membrane phospholipids, sphingomyelin, phosphatidylcholine, phosphatidylserine, and phosphatidylethanolamine were present in normal proportions.

![Fig 1. Osmotic fragility studies of C.H.'s peripheral RBCs (separated by density) and splenic RBCs. The results of studies of peripheral blood taken during a routine visit and separated by RBC density (centrifuged at 30 °C for 60 minutes at 27,000 g) (ref. 7) show that the least dense fraction with the highest proportion of reticulocytes from the top of the gradient was, as judged by osmotic fragility, the least severely damaged, whereas the denser layers (middle and bottom of the gradient, no reticulocytes) had a higher proportion of spherocyte cells (tail of osmotically fragile cells), suggesting that the patient's RBCs sphered with age. Studies of peripheral blood from a normal control (right-hand curves) showed no shift in osmotic fragility between top and bottom RBC layers. At the time of splenectomy, samples obtained from the splenic pulp and splenic vein contained the highest proportion of spherocytes, suggesting that the spleen was damaging RBCs in transit.](image-url)
resulted in the RBC membrane abnormality. The clinical strongly suggests that the loss of this chromosomal segment chromosome 8 and the absence of these findings in other family members with normal chromosomal complements two siblings with an interstitial deletion of the short arm of parents. and control.

Fig 2. Interstitial deletion of chromosome 8. A: Schematic diagram of the banding pattern of the normal (left) and deleted (right) chromosome 8. The deleted segment is identified by arrows on the normal homologue. B through E: Partial karyotypes of family members illustrating chromosome 8 homologues from trypsin-Giemsa–banded metaphase cells derived from phytohemagglutinin-stimulated peripheral blood lymphocytes. B: father; C: mother; D: patient C.H.; E: patient B.H. D and E: The deleted chromosome is shown on the right of each pair of homologues (arrows).

DISCUSSION

The association of congenital spherocytic anemia in these two siblings with an interstitial deletion of the short arm of chromosome 8 and the absence of these findings in other family members with normal chromosomal complements strongly suggests that the loss of this chromosomal segment resulted in the RBC membrane abnormality. The clinical course, hematologic findings, osmotic fragility studies, the role of the spleen in damaging RBCs, membrane loss with cell age, and ektacytometric measures of RBC structural stability in these two patients are compatible with previous descriptions of patients with congenital spherocytic anemias such as HS.6,12,14

Kimberling and associates described a family with spherocytosis and a balanced translocation between chromosomes 8 and 12 [t(8;12)(p11;p13)].1,2 whereas Bass and associates1 described another family with spherocytosis and a translocation between chromosomes 3 and 8 [t(3;8) (p21;p11)]. These data, along with our observations of an interstitial deletion involving bands p11.1 and p21.1, suggest that a functional alteration in a gene on the short arm of chromosome 8, at band p11, is associated with spherocytosis.

GSSG-R levels were slightly reduced in the two affected children relative to their parents and the unaffected sibling but did not approach half-normal values expected from GSSG-R gene dosage studies in patients trisomic for this region of chromosome 8.13 These results are ambiguous and do not confirm or deny the cytogenetic findings, which indicate that the deletion extends to 8p21, the region to which the GSSG-R gene has been assigned.16 It is unlikely that the moderate reduction in GSSG-R activity would cause hemolysis and, in a previous study of a kindred with both HS and GSSG-R deficiency, the two genes segregated independently and family members who had GSSG-R deficiency alone were asymptomatic.17 Levels of carbonic anhydrase II and factor VII, genes with structural or control loci assigned to chromosome 8,18 were not reduced, but the deletion observed in our patients probably involved a number of other genes, resulting in dysmorphology and the neurologic findings.

The pattern of inheritance in this family is unusual in that two siblings were affected whereas the parents and a third sibling were chromosomally normal. Cytogenetic analysis on a fourth sibling has not yet been performed, but the child has a normal physical exam and hemoglobin values. Studies of blood groups and HLA antigens in this family were consistent with the presumed paternity. Although other possible mechanisms may explain our observations, the most likely explanation is that one parent is mosaic for this abnormality.

It is likely that congenital spherocytic anemias are a heterogeneous group of disorders but, other than a deficiency of α and β spectrin described in a small number of patients,19

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**Table 2. Comparison of Ratios of Spectrin, Band 4.1, and Band 4.2 to Band 3**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Spectrin:Band 3</th>
<th>Band 4.1:Band 3</th>
<th>Band 4.2:Band 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Father</td>
<td>1.06 ± 0.08</td>
<td>0.24 ± 0.01</td>
<td>0.14 ± 0.02</td>
</tr>
<tr>
<td>Mother</td>
<td>1.05 ± 0.04</td>
<td>0.23 ± 0.04</td>
<td>0.14 ± 0.02</td>
</tr>
<tr>
<td>B.H.</td>
<td>1.06 ± 0.05</td>
<td>0.23 ± 0.03</td>
<td>0.14 ± 0.02</td>
</tr>
<tr>
<td>C.H.</td>
<td>1.06 ± 0.06</td>
<td>0.25 ± 0.02</td>
<td>0.14 ± 0.02</td>
</tr>
<tr>
<td>Control</td>
<td>1.08 ± 0.06</td>
<td>0.25 ± 0.02</td>
<td>0.15 ± 0.02</td>
</tr>
</tbody>
</table>

All results are means ± SD (n = 7). Results were determined by dye elution of Coomassie blue stain of 3.5% to 7.5% gradient sodium dodecyl sulfate polyacrylamide gels.

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![Image of SDS gel with bands labeled MO, FA, BH, CH, NL, spectrin, band 3, band 4.1, and band 4.2.](https://example.com/sds-gel.png)
the results of SDS-PAGE of RBC ghosts derived from peripheral blood of HS patients, as in our two cases, show no qualitative abnormalities. Functional studies have detected abnormalities of spectrin-band 4.1 binding and cytoskeletal structure in small groups of patients.

Hemizygosity for a gene on 8p might alter the quantity or function of a membrane protein in a manner not detectable by the semiquantitative gel systems used in this study. For example, an enzymatic deficiency resulting in a failure to modify appropriately a structural protein after translation could affect that protein's binding capacity. Additional studies will be needed to delineate the defect, but these findings may narrow the chromosomal region in which to search for a gene responsible for spherocytosis; the availability of a cell line should help in these investigations.

ACKNOWLEDGMENT

We would like to thank Drs Louis Miceli and Edward Klimek for referring the patient and Dr Ted Steck for helpful discussions. Barbara Jones provided technical assistance, and the carbonic anhydrase studies were performed by Dr Richard Tashian.

A lymphoblastoid cell line from patient B.H. has been placed with the NIGMS Human Genetic Cell Repository, Camden, NJ.

REFERENCES

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