Clinical Application of a High-resolution Electrophoresis System
A Review of Electrophoretic Patterns in Disease*

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ABSTRACT

A total of 702 sera, 81 cerebrospinal fluids and 131 urine specimens were studied for the evaluation of a high resolution electrophoresis system, as well as the usefulness of electrophoresis in general. Abnormal changes were found in 41.6 percent of the serum specimens. Meaningful changes of individual fractions were most frequently encountered in the gamma fraction. In six recognized electrophoretic patterns, more components can be identified by this system thus providing additional information for differential diagnosis. For instance, this system is able to demonstrate a prominent beta-lipoprotein band in case of nephrotic syndrome, and can, therefore, distinguish this syndrome from protein-losing enteropathy.

The high-resolution electrophoresis system produces good resolution for discrete gamma bands. The configuration of the monoclonal band revealed by this technique provides a preliminary identification of immunoglobulins, which is practically impossible with the conventional electrophoresis. The excellent capacity of demonstrating oligoclonal banding is one of the most distinguished features of this system. The oligoclonal bands detected in cerebral spinal fluid are very helpful for the diagnosis of demyelinating disease and may provide a clue of the presence of tumor if detected in serum. Urine electrophoresis is a good tool for screening of Bence Jones proteinuria; false-positive results were not found and multiple monoclonal banding is specific for myelomatous disorders especially for light chain myeloma.

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Introduction

The clinical application of a high-resolution electrophoresis system,* which is able to separate and identify 12 protein fractions instead of the five conventional fractions, will be discussed. This is accomplished by applying a high voltage during the electrophoretic process and the heat generated is absorbed by a specially designed cooling system to avoid damage of the agarose gel.

Our preliminary evaluation of this high-resolution electrophoresis system in a previous paper concluded that the protein fractions separated by this system are quantitatively proportional to and qualitatively related to the seven major proteins studied.22 The next question is then whether or not these additional bands are useful in evaluating a patient’s clinical status and whether or not they are helpful in providing a specific diagnosis. Although favorable reports on the studies of gamma globulin with this system have been presented briefly recently,9,16 this paper is a more comprehensive study of different electrophoretic patterns as well as individual fractions with the high-resolution electrophoretic system.

Materials and Methods

A total of 702 sera, 81 cerebrospinal fluids (CSF) and 131 urine specimens were studied. The serum samples were applied to the buffered agarose slides† in full strength, while the CSF and urine specimens were concentrated 10 to 100 times with the Minicone concentrator,‡ according to the original volume and the total protein concentration of the specimen. All specimens were run 50 minutes with the high-resolution electrophoresis system as previously reported.22 After electrophoresis, the serum samples were stained with Amido black, while the CSF and urine specimens were stained with 0.2 percent Coomassie brilliant blue R solution, which provided a darker staining for the protein fractions. Serum samples were usually evaluated in conjunction with SMA 12/60 results obtained from the same specimen. All the electrophoretograms were read by one of us (TS). When abnormal patterns were observed in CSF or urine specimens, a serum specimen was routinely requested to trace the source of such abnormality. In case of monoclonal gammopathy, immunoelectrophoresis or immunofixation technique was used for further identification. Immunoelectrophoresis was performed with appropriate equipment,† and IgG, IgA, IgM, IgD, IgE, kappa and lambda antisera were obtained.§ Immunofixation technique was performed according to Alper and Johnson2 with minor modification.23

Results

Serum

Electrophoretic patterns are shown in table I and figure I.3,12,13,24

Immediate response pattern. This is designated as the elevation of (positive) acute phase reactants (alpha-1-antitrypsin, haptoglobin and C3 complement) and the decrease of negative acute phase reactants (albumin and transferrin).26 This pattern was usually seen in patients with acute illness, especially acute inflammatory disease. Fifty-two patients showed this pattern. The high-resolution electrophoresis system reveals the changes of two additional components, C3 complement and transferrin, in comparison with the conventional electrophoresis system with only five fractions. The change in haptoglobin fraction can be distinguished from alpha-2 macroglobulin in the new system, although

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* Panagel® manufactured by Millipore Biomedica, Acton, MA 01720.
† Millipore Biomedica.
‡ Amicon Corporation.
§ Behring Diagnostics and Meloy Laboratories.
FIGURE 1. Normal and specific patterns in electrophoresis.

A. Normal pattern, abbreviations: A. albumin; b. alpha-1 antitrypsin; c. alpha-2 macroglobulin; e. transferrin; f. beta-lipoprotein; g. C3 complement; and h. gamma globulin.

B. Hyperbilirubinemia, showing bilirubin-conjugated albumin.

C. Alpha-1 antitrypsin deficiency, showing absence of alpha-1 antitrypsin band.

D. Nephrotic syndrome, showing hypoalbuminemia, hypogammaglobulinemia, elevation of alpha-2 macroglobulin and beta-lipoprotein.

E. Protein-losing enteropathy, showing similar changes as in nephrotic syndrome except for the absence of hyperbeta-lipoproteinemia.

F. Hemolytic anemia, showing marked decrease in haptoglobin.

G. Hyperbeta-lipoproteinemia, showing prominent beta-lipoprotein band.

H. Hypocomplementemia, showing markedly decreased C3 complement.

I. Hypogammaglobulinemia.

J. Hepatic cirrhosis, showing hypoalbuminemia and hypergamma-globulinemia with beta-gamma bridging.

K. IgG multiple myeloma, showing a monoclonal band in gamma zone with smooth edges and bulging ends.

L. IgA multiple myeloma, showing a broad band in beta-gamma zone with blurred edges and markedly bulging ends.

M. IgM macroglobulinemia, showing a monoclonal band in gamma zone with wavy edges and flattened ends. The background is markedly hypoproteinemic.

N. Bence Jones proteinuria, showing two monoclonal bands in gamma zone.

O. Multiple sclerosis, showing two to three oligoclonal bands in gamma zone of a cerebral spinal fluid specimen.

Pattern of nephrotic syndrome (figure 1-D). This pattern is characterized by the present authors as hypoalbuminemia, hypogammaglobulinemia, elevation of alpha-2 macroglobulin and beta-lipoprotein. The prominent beta-lipoprotein fraction demonstrated by the high-resolution electrophoresis system is a reflection of hypercholesterolemia, which is very helpful in distinguishing this pattern from the pattern of protein losing enteropathy. This pattern was seen in 12 cases.

both fractions are components of alpha-2 globulin.

Delayed response pattern. This pattern is composed of changes in all the components mentioned in the immediate response pattern with the addition of hypergamma-globulinemia. This comprises a group of patients with chronic infection or distress and the pattern was seen in 11 cases in our series. The high-resolution electrophoresis system offers the same advantages as noted in the previous pattern description.
TABLE I
Frequencies of Electrophoretic Patterns and Changes of Individual Fractions in 702 Sera

<table>
<thead>
<tr>
<th>Findings</th>
<th>Total No.</th>
<th>Abnormal Cases*</th>
<th>% Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patterns</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediate response</td>
<td>52</td>
<td>17.8</td>
<td>7.4</td>
</tr>
<tr>
<td>Delayed response</td>
<td>11</td>
<td>3.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Nephrotic syndrome</td>
<td>12</td>
<td>4.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Protein losing enteropathy</td>
<td>2</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Hepatic cirrhosis</td>
<td>22</td>
<td>7.5</td>
<td>3.1</td>
</tr>
<tr>
<td>Monoclonal gammopathy</td>
<td>53</td>
<td>18.2†</td>
<td>7.5</td>
</tr>
<tr>
<td><strong>Changes in Fractions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypoalbuminemia</td>
<td>20</td>
<td>6.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Increased AAT</td>
<td>31</td>
<td>10.6</td>
<td>4.4</td>
</tr>
<tr>
<td>AAT deficiency (PI Z type)</td>
<td>2</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Increased AMG</td>
<td>4</td>
<td>1.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Increased Hp</td>
<td>20</td>
<td>6.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Decreased HP</td>
<td>4</td>
<td>1.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Increased Trf</td>
<td>2</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Decreased Trf</td>
<td>17</td>
<td>5.8</td>
<td>2.4</td>
</tr>
<tr>
<td>Increased ELP</td>
<td>6</td>
<td>2.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Increased C3</td>
<td>3</td>
<td>1.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Decreased C3</td>
<td>4</td>
<td>1.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Hypogammaglobulinemia</td>
<td>66</td>
<td>22.6</td>
<td>9.4</td>
</tr>
<tr>
<td>Polyclonal gammopathy</td>
<td>41</td>
<td>14.0</td>
<td>5.8</td>
</tr>
<tr>
<td>Oligoclonal gammopathy</td>
<td>17</td>
<td>5.8</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>Abnormal cases</strong></td>
<td>292</td>
<td>100.0</td>
<td>41.6</td>
</tr>
<tr>
<td><strong>Normal cases</strong></td>
<td>410</td>
<td>0</td>
<td>56.4</td>
</tr>
</tbody>
</table>

*Some abnormal cases showed more than one change.
†Unusually high percentage owing to many referral cases.
§Those included in the patterns were not included in change in fractions.

Pattern of protein-losing enteropathy (figure 1-E). This is distinct from the nephrotic pattern by the absence of hyperbetalipoproteinemia and less obvious changes in albumin and gammaglobulin. There were only two cases seen in our series.

Pattern of hepatic cirrhosis (figure 1-J). The pattern includes hypoalbuminemia and hypergammaglobulinemia with beta-gamma bridging.

TABLE II
Comparison of Heat Test, Electrophoresis and Immunoelectrophoresis for Bence Jones Proteinuria

<table>
<thead>
<tr>
<th>Heat Test</th>
<th>Electrophoresis</th>
<th>Immunoelectrophoresis</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Free Kappa</td>
<td>Free Lambda</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>5</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
<td>7</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>

which is due to an elevation of gammaglobulin, usually IgA, in the beta-gamma region. Twenty-two cases were seen with this pattern. Not infrequently, liver enzymes were within normal limits in cases of hepatic cirrhosis proved by liver biopsy. Serum electrophoresis then provided an important clue.

Pattern of monoclonal gammopathy (figures 1-K, 1-L, 1-M and table II). This is usually defined as a homogenous, narrow band present in the gamma zone. However, in certain gammopathies, such as IgA or light chain myeloma, the abnormal bands can be seen in another zone. By immunoelectrophoresis, 20 cases of IgG, six of IgA, one of IgD, two kappa and three lambda myeloma cases were detected. Another myeloma case, proved by bone marrow biopsy, showed Bence Jones proteinuria and an apparently normal serum electrophoresis was also classified as light chain myeloma. IgM macroglobulinemia was encountered in five cases. The second group comprised 10 cases in which either no clinical evidence of myeloma or macroglobulinemia was present or no further analysis was done, although an abnormal immunoelectrophoretic pattern was demonstrated. One case was an IgG producing lymphoma. The others might have been early cases of myeloma or macroglobulinemia. The last group was composed of five cases which showed no abnormality in immunoelectrophoresis and no clinical evidence of myelomatous disorder. The clinical diagnosis in these five cases were syphilis, idiopathic epilepsy, chronic lymphocytic leukemia, multiple carcinomas (hepataoma, prostatic and rectal carcinomas) and one healthy laboratory worker. A monoclonal band was first detected in the CSF in the first two cases, and serum electrophoresis showed a similar monoclonal band in both cases; however, no further analysis was done to prove or disprove myeloma on a clinical basis.
C-reactive protein and fibrinogen were occasionally seen in the gamma zone resembling monoclonal bands.\textsuperscript{12,13} C-reactive protein is usually located at the cathodal end of the gamma zone and can be identified by immunofixation technique. Fibrinogen is present anodal to the application site and can be eliminated by adding thrombin to the patient's serum. Lysozyme\textsuperscript{10} and post-gamma fraction\textsuperscript{14} can also be confused with the monoclonal gamma band but these two components were not encountered in the present series.

In most cases, different immunoglobulins assume certain characteristic features, thus providing preliminary identification. The IgG band usually shows smooth edges with slightly bulging ends (figure 1-K). The IgM band is usually narrower than the IgG band and has wavy edges and flattened ends (figure 1-M). The electrophoretogram frequently reveals a generalized hypoproteinemia background which is, in addition to the reduction of uninvolved immunoglobulins, probably the result of plasmapheresis, a standard therapeutic procedure for macroglobulinemia. The IgA band is typically located in the beta or beta-gamma zone, which is usually a much broader band than IgG and IgM, and has blurred edges and markedly bulging ends (figure 1-L). This band is usually tapered toward the anodal end forming a trapezoidal configuration. The broadness of this band is probably due to the presence of polymerized forms. The lambda and kappa light chains theoretically can be seen in any electrophoretic zone, however, in our series, the light chains were mostly located on either side near the application point. There is no special configuration for light chains although they are usually narrower than any of the complete immunoglobulin molecules.

Changes in individual fractions are shown in table I and figure 1.\textsuperscript{1,3,8,11,12,13,24} Albumin. Hypoalbuminemia was seen in practically all six electrophoretic patterns. However, hypoalbuminemia as a single manifestation was seen in only 20 cases. In jaundiced cases, bilirubin is conjugated with albumin, which shows a broad band with a tapered head (figure 1-B). The anodal part is composed of the fast albumin conjugated with bilirubin. Absolute elevation of albumin is practically non-existent.

Alpha-1 antitrypsin (AAT). Besides being found in immediate and delayed response patterns, increased AAT alone was seen in 11 cases. Another 20 cases of increased AAT were seen together with elevation of other acute phase reactants. Homozygous AAT deficiency was detected in two cases (figure 1-C). Both were proved to be of Pi Z type. Heterozygous AAT deficiency may show a double alpha-1 antitrypsin peak which was, however, not shown in the authors' four proven cases.

Alpha-2 globulin. This is mainly composed of alpha-2 macroglobulin (AMG) and haptoglobin (Hp). The AMG is usually elevated in nephrotic syndrome and Hp in immediate and delayed response patterns. Increase of AMG alone was seen in four cases. Decrease in Hp was found in four cases, all of which showed clinical evidence of hemolysis (figure 1-F). Hp elevation together with other acute phase reactants was seen in 20 cases.

Transferrin (Trf). As a negative acute phase reactant, this fraction was frequently decreased in immediate and delayed response patterns. Decrease in Trf alone was seen in 17 cases and an increase in two cases. These changes were roughly proportional to the total iron binding capacity.

Beta-lipoprotein (BLP). Elevation of BLP was always seen in nephrotic syndrome. An increase of this fraction alone was found in six cases (figure 1-G), all of which showed a high serum cholesterol
level. BLP is easily disintegrated or overlaps with adjacent fractions and its decrease is, therefore, of no clinical significance.

**C₃ complement.** The increase in C₃ is usually seen in the early stage of immediate response pattern and returns to normal rapidly. Thus, its elevation was not frequently noted in the immediate response patterns recorded in the present series. Elevation of C₃ alone was seen in three cases and a decrease in four cases (figure 1-H).

**Gamma globulin.** Besides being seen in nephrotic syndrome and protein-losing enteropathy, hypogammaglobulinemia was the most frequently encountered single change in the electrophoretogram (figure 1-I) with 66 cases being recorded in this series. Hypergammaglobulinemia was also frequently encountered. In addition to the 53 cases of monoclonal gammopathy, there were 17 cases of oligoclonal gammopathy (presence of faint, narrow, discrete gamma bands, usually multiple), and 41 cases of polyclonal gammopathy, not including the 11 cases seen in the delayed response pattern and 22 cases in the cirrhotic pattern. Oligoclonal gammopathy can be the early stage of polyclonal gammopathy, although nine of the oligoclonal cases coincided with polyclonal gammopathy, indicating that these two gammopathies do not always represent consecutive stages. Malignant or lymphoproliferative disorders were found in 10 oligoclonal cases which included five carcinomas (one liver, one pancreas, one rectum and two lung), one each in Hodgkin's disease, immunoblastic lymphadenopathy, lymphoproliferative disorder and polycythemia vera as well as one hepatic cirrhosis with plasmacytosis in the bone marrow.

**Other fractions.** Alpha lipoprotein and hemopexin fraction were difficult to estimate by electrophoresis and failed to correlate with clinical situations.

**Urine**

This is shown in table II and figure 1-N. Although a few clinicians had requested urine electrophoresis for estimation of other fractions such as transferrin, its most important function is still the screening for Bence Jones protein. To evaluate the sensitivity and specificity of the electrophoretic method in detecting Bence Jones protein, comparison was made in 131 urine specimens with the classical heat test and with immunoelectrophoresis (table II). The results indicated that the electrophoretic method was more reliable than the heat test, which missed about 66 percent of the cases with Bence Jones proteinuria. While there was no false-positive result given by electrophoresis, a false-negative result was seen in five cases. It is interesting to note, however, that all five were non-myelomatous cases. They included acute myeloblastic leukemia with sepsis, malignant pleural tumor probably mesothelioma, acute glomerulonephritis, urinary tract infection with sepsis and urinary tract infection with anemia. Our criterion for Bence Jones protein is the presence of one or more discrete gammaglobulin bands, the so-called monoclonal banding. The presence of oligoclonal or polyclonal banding in the gamma zone is considered negative. In the five false-negative cases, three showed oligoclonal banding and two polyclonal banding.

The position (electrophoretic mobility) of the monoclonal bands varies. One was found at the application point, three on the anodal side of the application point and seven on the cathodal side. In six specimens which showed more than one band, the monoclonal bands were located at both anodal and cathodal sides. In another two cases, the bands were seen in the beta zone. More than one band was seen in 11 specimens. It was interesting to note that all light chain myeloma cases showed two to three bands in the electro-
phoretogram, and none of the non-myelomatous cases showed more than one band.

CEREBROSPINAL FLUID

This is shown in table III and figure 1-O. The electrophoresis of CSF again is mainly for the evaluation of the gamma fraction. Among 81 CSF specimens, there were two cases of monoclonal gammopathy, two cases of polyclonal gammopathy and 16 cases of oligoclonal gammopathy (table III). The two monoclonal cases also showed monoclonal bands in serum electrophoresis. As mentioned in the serum electrophoresis section, the diagnoses in these two cases were syphilis and idiopathic epilepsy. In the oligoclonal cases, 12 cases were definite or probable multiple sclerosis. The other four cases were diagnosed as chronic spinal disease, cerebral atrophy, right cerebral dysfunction and transient global amnesia. The total protein (average 68 mg per dl) and percentage of gammaglobulin (average 23.5 percent) of the demyelinating group were higher than the "non-demyelinating" group (average total protein 41 mg per dl, gammaglobulin 9.3 percent), although demyelinating disease could not be ruled out entirely from the latter group.

In the 61 cases with a normal electrophoretogram, four were probable multiple sclerosis, 47 were definitely not cases of demyelinating disease and the remaining 10 were cases with an unknown diagnosis.

Discussion

Seven of the nine fractions identified by the high-resolution electrophoresis system were found to be useful under certain clinical situations. However, electrophoresis can only provide a rough estimation. Some fractions, such as beta-lipoprotein and C3 complement, disintegrate so quickly that helpful information could only be assured when the serum specimen was drawn in an ideal situation and delivered promptly to the laboratory. This reason explains why only a small percentage of cases revealed definite changes of individual fractions, such as hyperbetaalipoproteinemia and hypocomplementemia. Since the changes in electrophoresis are in terms of percentage, this semi-quantitative technique will become meaningful only when a good normal control and an accurate quantitation of total protein and albumin are available.

The electrophoretic patterns are often non-specific and supplementary, although occasionally a nephrotic or cirrhotic pattern may lead to an early diagnosis of the corresponding disorder. As far as the electrophoretic pattern is concerned, the capacity of separating beta-lipoprotein from other fractions in the high-resolution electrophoresis system provides a great help for the differential diagnosis between nephrotic syndrome and protein losing enteropathy.

The main merit of electrophoresis is still in the field of gamma globulin study. The high-resolution electrophoresis system

<table>
<thead>
<tr>
<th>Normal Pattern</th>
<th>Oligoclonal Gammopathy</th>
<th>Monoclonal Gammopathy</th>
<th>Polyclonal Gammopathy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demyelinating</td>
<td>Other Diseases</td>
<td>Unknown</td>
<td>Demyelinating</td>
<td>Other Diseases</td>
</tr>
<tr>
<td>4</td>
<td>47</td>
<td>10</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>4.9%</td>
<td>58.0%</td>
<td>12.3%</td>
<td>14.8%</td>
<td>4.9%</td>
</tr>
</tbody>
</table>
undoubtedly produces a good resolution of the discrete gamma bands. In addition, the configuration of monoclonal bands revealed by this technique provides a preliminary classification as to what kind of immunoglobulin is involved. The incidence of monoclonal gammopathy is relatively high in this study; the bias is due to the fact that most of the specimens were from the hematology division and many myeloma cases were referred to the authors' hospital for treatment. The excellent capacity of demonstrating oligoclonal banding is one of the most distinguished features of this system. These faint, small bands are supposed to be produced by small clones of plasma cells in the early immune response, which finally leads to polyclonal gammopathy. Over one-half of the cases in this article, however, showed a coexistence of oligoclonal and polyclonal features. The oligoclonal gammopathy then may well be a special immune response rather than an early response in such cases. As a matter of fact, Laurel found this pattern mainly in cases of malignant tumor or viral infection. In this series, malignant or lymphoproliferative disorders were detected in 10 of the 17 oligoclonal cases. None of them showed abnormal immunoelectrophoretic pattern. This information may prove to be very helpful in cases of occult malignancy. Viral infection is difficult to verify as many viral infections are transient phenomena or complication of the main disease and are easily neglected.

The usefulness of oligoclonal banding detection is also illustrated by the finding in CSF in which 12 of the 16 oligoclonal cases were compatible with demyelinating disease. Oligoclonal banding can also be found in subacute sclerosing panencephalitis and probably other viral infections. Thus, it is possible that the other four might not be false-positive cases. On the other hand, of the 61 cases with normal patterns, only four were possibly false-negative. Although the relationship between oligoclonal banding in CSF and multiple sclerosis has been studied by several authors, the advantage of using a high-resolution electrophoresis system was only recently reported. Nevertheless, other parameters should be explored to substantiate the diagnosis. The CSF IgG/albumin ratio is currently being used by the present authors and is being compared with the serum IgG/albumin ratio. Normally, the serum ratio should be higher than the CSF ratio. Change of this relation indicated production of IgG in the brain, thus pointing to the possibility of demyelinating disease.

As to the detection of Bence Jones protein in urine, electrophoresis is better than the heat test but not as sensitive as immunoelectrophoresis. However, urine electrophoresis in the present series correlates better with serum electrophoresis than immunoelectrophoresis. All cases except one with positive urine electrophoresis showed monoclonal gammopathy in their sera. On the other hand, the five immunoelectrophoresis positive but electrophoresis negative cases revealed no serum gammopathy. In other words, electrophoresis serves as a good tool for urine screening of Bence Jones protein related to myelomatous disorders. Although Bence Jones proteinuria can be seen in malignant disease other than myeloma or even in so-called benign monoclonal gammopathy, the presence of overt Bence Jones proteinuria without serum gammopathy is usually discussed under light chain disease or, rarely, light chain nephropathy. In this series, all three of the non-malignant cases had renal involvement, but the relation with Bence Jones proteinuria requires further study.

It should be emphasized that the number of monoclonal bands present in urine electrophoresis is very important in terms of differential diagnosis. More than
one monoclonal band in cases of non-myelomatous disorders has never been seen by the present authors. On the other hand, all light chain myeloma cases that have been encountered showed more than one monoclonal band. Multiple banding is not only seen in light chain myeloma. For instance, two cases of IgG myeloma in this series also showed the same features.

In short, the high-resolution electrophoresis system is a very useful tool for the study of gammopathy. Its usefulness is especially obvious in the study of CSF and urine specimens.

References