Demonstration of carcinoembryonic antigen in bone marrow from patients with carcinoma

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SUMMARY Primary and secondary tumour and bone marrow trephine biopsies from 20 patients with carcinomas were stained for carcinoembryonic antigen by the three stage immunoperoxidase method. Six marrow biopsies contained tumour deposits, five of which were positive for carcinoembryonic antigen. A further five marrow biopsies contained single carcinoembryonic antigen positive cells of uncertain origin. Carcinoembryonic antigen staining may be a useful adjunct to conventional histology in the diagnosis of marrow metastases.

Few patients with carcinomas have demonstrable metastases in the bone marrow. In an examination of bone marrow specimens taken from 2191 such patients only 8-5% showed metastatic tumour using conventional stains. Multiple biopsies, multiple sections, and the simultaneous use of aspirates, clot sections, and trephine biopsies have all been used in attempts to increase the detection rate. More recently, immunochemical stains have been introduced for specific tumour antigens. Metastatic adenocarcinoma expressing carcinoembryonic antigen (CEA) has been shown in regional lymph nodes from patients with colonic and breast carcinoma, and Cal antibody has been used to distinguish malignant from non-malignant cells in serous fluids. Immunohistochemical detection of epithelial membrane antigen in sections of bone marrow aspirate has yielded an increased number of positive samples and shown a greater extent of tumour infiltration. In the present study, tumour tissue and bone marrow samples from patients with carcinomas of varying origin were stained for CEA using an immunoperoxidase method.

Patients and methods

Patients

Twenty patients with carcinomas were studied. A Te-99m radioisotope bone scan and chest x ray examination were performed and painful bony areas were also examined radiographically. Scans and x ray films were considered positive only if there was unequivocal evidence of metastatic disease.

Plasma carcinoembryonic antigen

Concentrations were measured using the double antibody radioimmunoassay method. CEA values were estimated preoperatively in patients undergoing surgical removal of tumour. One patient (Table 1) had a primary tumour excised in 1953 and had a plasma CEA estimated at the time of first recurrence.

Primary and secondary tumours

Biopsy samples were fixed in 10% buffered formol-saline and embedded in paraffin wax; 5μm sections were stained with haematoxylin and eosin and for CEA.

Bone marrow

Bone marrow was obtained from the sternum or iliac crest using a Salah needle. Smears were fixed in 95% methanol and stained with May-Grünwald-Giemsa; similarly fixed smears were stained for CEA.

Bone marrow aspirate, collected directly into fixative of equal parts of 15% formalin and absolute isopropanol, was embedded in celloidin and paraffin wax using a modified Raman method. Sections (5μm) were dewaxed with xylene, and the celloidin was removed with acetone to prevent loss of sections during staining with haematoxylin and eosin and for CEA.

Trephine biopsies were obtained from the iliac crest using a Jamshidi needle, fixed in 10% buffered formol-saline, and decalcified in 10% edetic acid solution (pH 7-0) for a minimum of five days at 50°C before embedding in paraffin wax. Sections (5μm) were stained with haematoxylin and eosin and for CEA.

Carcinoembryonic antigen antisemur

CEA antiserum was a commercially available
**Demonstration of carcinoembryonic antigen in bone marrow from patients with carcinoma**

Table 1  Patients with marrow trephine biopsies containing tumour metastases (haematoxylin and eosin)

<table>
<thead>
<tr>
<th>Primary tumour</th>
<th>Metastases</th>
<th>Marrow trephine biopsy</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Site</td>
<td>CEA stain</td>
</tr>
<tr>
<td>Prostate</td>
<td>+</td>
<td>None</td>
</tr>
<tr>
<td>Prostate</td>
<td>+</td>
<td>None</td>
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<tr>
<td>Prostate</td>
<td>–</td>
<td>None</td>
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<tr>
<td>Breast</td>
<td>++</td>
<td>Skin</td>
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<tr>
<td>Breast*</td>
<td>+ +</td>
<td>Skin</td>
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<tr>
<td>Prostate</td>
<td>–</td>
<td>None</td>
</tr>
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CEA = carcinoembryonic antigen.
ND = not done.
*Primary tumour excised in 1953.
+ = few, ++ = moderate, +++ = many positive cells.

immunoglobulin fraction prepared in rabbits by immunisation with highly purified human CEA obtained from hepatic metastases of colonic adenocarcinoma (Dakopatt anti-CEA; Code A115). Rabbit CEA antiserum contained antibody to non-specific cross reacting antigen (NCA), which was absorbed with a human spleen extract treated with perchloric acid before application. The method described by Krupey et al and modified by Smith was used.

**IMMUNOPEROXIDASE METHOD**
Paraffin sections were dewaxed with xylene, taken to water, and stained for CEA by the indirect, or three stage, immunoperoxidase method. 9 10

**CONTROLS**
Removal of anti-NCA activity from the CEA antiserum was assessed by applying the unabsorbed and absorbed antisera to blood smears prepared from a patient with chronic granulocytic leukaemia and to sections of normal spleen. 11 Sections of normal colon, stomach, breast, and prostate were negative controls, while sections of carcinomas of these tissues were positive controls for absorbed antiserum. Normal trephine biopsies from patients with non-malignant conditions were also included. Slides of all control specimens were included in each staining batch.

**INTERPRETATION**
Immunoperoxidase staining was graded according to the number of positive cells seen: + = few; ++ = moderate; +++ = many. Intensity of staining was not quantified.

**Results**
Interpretation of bone marrow findings has been based on trephine biopsies alone since loss of tissue during the process of immunoperoxidase staining often precluded the valid use of bone marrow smears and clot sections.

Complete absorption of anti-NCA activity from the CEA antiserum by human spleen extract was shown by the failure of the antiserum to stain sections of normal spleen and smears of chronic granulocytic leukaemia. Sections of normal colon, stomach, breast, prostate, and bone marrow trephine biopsies also gave a negative reaction for CEA. Positive staining cells in sections of primary and secondary carcinoma and bone marrow trephine biopsies were a distinct yellow-brown viewed against the light blue background of the surrounding tissue. (Figure (a, b)). Free stain deposit was noted occasionally but was easily identified by careful focusing.

Fifteen of 19 primary tumours had positive reactions for CEA; the least number of positive reac-

Table 2  Patients with marrow trephine biopsies negative for tumour metastases (haematoxylin and eosin) but positive for carcinoembryonic antigen (CEA) stain

<table>
<thead>
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<tr>
<td>Breast</td>
<td>–</td>
<td>Node</td>
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<tr>
<td>Breast</td>
<td>+</td>
<td>Node</td>
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<tr>
<td>Breast</td>
<td>+</td>
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<tr>
<td>Stomach</td>
<td>+++</td>
<td>None</td>
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<td>Colon</td>
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ND = not done.
+ = few, ++ = moderate, +++ = many positive cells.
Carcinoembryonic antigen (CEA) positive bone marrow trephine biopsies. (a) Metastatic deposit of breast carcinoma. ×400. (b) Infiltrating metastatic carcinoma of prostate. ×100. (c)(d) CEA positive single cells in unaffected marrows (haematoxylin and eosin) of two patients with breast carcinoma. ×630.
tions was found in sections of prostatic carcinoma (Tables 1–3). Sections of one primary tumour were not available for study. Metastatic tumour was biopsied in nine cases, of which six had positive and two had negative primary tumours. Six of these metastatic tumours were CEA positive, of which four had positive primary tumours. Only one patient had a CEA positive primary tumour with negative metastases.

Patient data have been tabulated in three groups on the basis of bone marrow staining. Tumour deposits were identified by haematoxylin and e...
1 Similar cells were not seen in either control marrows or the marrows from nine other patients with carcinoma (Table 3). Indeed the vast proportion of haemopoietic tissue in the marrows in which these cells were seen was CEA negative. As stated above, erythroblasts do not stain for either NCA or CEA in both normal and leukaemic subjects and cross reactivity of the CEA antiserum with blood group antigens is eliminated during its purification by absorption with erythrocytes until agglutination is abolished.

2 Passive absorption of circulating or locally secreted CEA by bone marrow cell membranes cannot be excluded. It certainly occurs with normal colonic mucosal cells which lie adjacent to benign or malignant tumours.

3 Likewise, macrophages concerned with processing antigen could account for these cells. It may be that small numbers of unidentified tumour cells in the marrow elaborate CEA in concentrations below the threshold sensitivity of the staining method and that cells of macrophage monocyte origin might then bring about sufficient concentration of the antigen on the cell surface or in the cytoplasm to allow its detection. If such a process is occurring in some patients but not in others this may reflect important differences in host response to the tumour. Whatever the origin of these cells, they serve to identify a subpopulation of patients with carcinoma which we feel deserves further investigation with regard to the pattern of metastases, response to treatment, and prognosis.

With regard to plasma CEA, bone scan, and x-ray film findings, statistical evaluation was precluded by the small number of patients. It was noted, however, that the highest median plasma CEA concentration (70 µg/l) and the highest incidence of positive bone scans and x-ray films occurred in the group of patients with histologically confirmed marrow metastases (Table 1). These investigations failed to distinguish between patients in Tables 2 and 3.

In conclusion, we have shown that the peroxidase-antiperoxidase method may be applied to bone marrow trephine sections which have been fixed, decalcified, and embedded in paraffin wax, although in our hands it was not suitable for use with bone marrow smears or clot secretions. The staining method is suitable for use in the histology laboratory of any general hospital and uses commercially available reagents. Since we have convincingly demonstrated the expression of CEA by carcinoma cells after they have metastasised to the marrow, the stain may prove useful in the interpretation of infiltrated marrows where the cell origin is difficult to identify—for example, in poorly differentiated lymphomas. In addition, we have identified a group of patients with small numbers of CEA positive cells, which may be indirectly or directly related to the presence of tumour in the marrow. The use of monoclonal antibodies may help to dispel any doubt over the specificity of the CEA antiserum, and follow up of patients should show any correlation between the presence of single, CEA positive cells within the marrow and prognosis, in particular, the subsequent development of overt marrow involvement.

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