Imprinted H19 oncofetal RNA is a candidate tumour marker for hepatocellular carcinoma

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Abstract

Aims/Background—To study the expression of the H19 gene in hepatocellular carcinoma. H19 is an imprinted, maternally expressed gene, which is tightly linked, both physically and functionally, to the paternally expressed insulin-like growth factor 2 (IGF II). IGF II is known to be involved in liver carcinogenesis. H19 was first discovered in the fetal mouse liver to be under the same regulatory genes as a fetoprotein (αFP), a widely used tumour marker for hepatocellular carcinoma.

Methods—Using both radioactive and non-radioactive in situ hybridisation, the expression of the H19 gene was compared with the presence of αFP, as demonstrated by immunohistochemistry, in 18 cases of hepatocellular carcinoma.

Results—H19 expression was present in 13 of 18 cases, whereas staining for αFP was positive in only nine of 18 cases. Concordance was found in 12 of 18 tumours (66.7%). In general, the staining pattern for H19 was more diffuse than the immunohistochemical staining for αFP.

Conclusions—The addition of a non-radioactive in situ hybridisation assay for H19 RNA to the panel of tumour markers used for the histopathological and cytological diagnosis of hepatocellular carcinoma might be useful.

Keywords: hepatocellular carcinoma; H19; α fetoprotein

Imprinted genes—genes that are expressed from only one allele, depending on the parental origin—are implicated in playing an important role in the tumorigenesis of certain human neoplasms. To date, the H19 gene is one of the few genes proved to be imprinted in humans. Although it has been suggested by other investigators that H19 acts as a tumour suppressor gene, we have shown that it exhibits oncofetal characteristics, and is re-expressed in tumours arising from tissues that express the gene in fetal life. One of the organs that expresses H19 abundantly from the early stages of embryogenesis is the liver. Expression is confined to hepatocytes and mesenchymal tissues, and is undetectable in haemopoietic tissue, one of the main tissue components in the developing liver. H19 expression is downregulated in most adult tissues, including the liver, but may reappear in the liver during regeneration. We were the first to document H19 expression in hepatocellular carcinoma.
plasmid (Stratagene) behind the T7 and T3 RNA polymerase binding sites. In vitro RNA transcription with T7 RNA polymerase was used to produce antisense H19 cRNA from linearised plasmid DNA. Sense H19 RNA prepared with T3 polymerase was used for control.

**PREPARATION OF RIBOPROBE FOR RADIOACTIVE IN SITU HYBRIDISATION**

35S-labelled in vitro RNA transcripts (10^7 cpm/µg) were produced using the Amersham RPN 2006 Kit and RNA polymerases from Boehringer Mannheim (Mannheim, Germany). Linearised plasmids were prepared by digestion with HindIII (antisense) and EcoRI (sense). The fragments were separated from unincorporated nucleotidases by ethanolic precipitation.

**RADIOACTIVE IN SITU HYBRIDISATION**

The procedure was performed on paraffin wax sections as described in detail previously.10 The slides were examined and photographed using an Axioplan 2 (Carl Zeiss Jena GmbH, Göttingen, Germany) microscope under bright and dark field illumination.

The negative controls in this study included hybridisation with sense RNA probe and RNase prehybridisation treatment. Negligible signal was observed in all the controls. Positive controls consisted of sections of fetal renal and liver tissue.

**PREPARATION OF RIBOPROBE FOR NON-RADIOACTIVE IN SITU HYBRIDISATION**

Digoxigenin labelled in vitro RNA transcripts were produced by labelling with DIG-11-UTP by SP6, T3, or T7 RNA polymerase in an in vitro transcription reaction (Boehringer Mannheim).

**NON-RADIOACTIVE IN SITU HYBRIDISATION**

Sections were prepared as for radioactive ISH, and were rehydrated through a series of alcohols, followed by a wash in 0.9% NaCl and then a wash in phosphate buffered saline (PBS). Basic proteins were removed by incubation in 0.1 N HCl at room temperature for 15 minutes. After a further wash in distilled water, sections were treated with 10 µg/ml proteinase K (Sigma, Poole, Dorset, UK) in 50 mM Tris, 5 mM EDTA for 30 minutes at 37°C, rinsed in PBS, and then rinsed for five minutes in 4% paraformaldehyde/PBS. Thereafter, the sections were rinsed in PBS and acetylated for 10 minutes in fresh acetic anhydride diluted 1/400 in 0.1 M triethanolamine (Sigma) at pH 8.0. The slides were then rinsed in PBS for five minutes.

**Table 1** Clinical data of 18 patients with hepatocellular carcinoma and the results of the in situ hybridisation for H19 RNA and immunohistochemistry for α fetoprotein.

<table>
<thead>
<tr>
<th>Case</th>
<th>Sex</th>
<th>Age</th>
<th>Tumour size</th>
<th>HBsAg</th>
<th>αFP</th>
<th>αFP</th>
<th>H19</th>
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<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>47</td>
<td>Multicentric</td>
<td>+</td>
<td>+</td>
<td>f</td>
<td>+ d</td>
</tr>
<tr>
<td>2</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>+ f</td>
<td>+ d</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>49</td>
<td>Biopsy</td>
<td>+</td>
<td>+</td>
<td>d</td>
<td>+ d</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>63</td>
<td>Multicentric</td>
<td>+</td>
<td>+</td>
<td>f</td>
<td>+ d</td>
</tr>
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<td>F</td>
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<td>−</td>
<td>−</td>
<td>+ f</td>
</tr>
<tr>
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<td>+</td>
<td>−</td>
<td>−</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>+ f</td>
<td>+ d</td>
<td></td>
</tr>
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<td>8</td>
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<td>−</td>
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<td>9</td>
<td>M</td>
<td>59</td>
<td>10 x 10 x 10 cm</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>48</td>
<td>Multicentric</td>
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<td>−</td>
<td>+</td>
<td>+ f</td>
</tr>
<tr>
<td>11</td>
<td>F</td>
<td>49</td>
<td>10 x 10 x 10 cm</td>
<td>+</td>
<td>+</td>
<td>d</td>
<td>−</td>
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<tr>
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<td>−</td>
<td>−</td>
<td>+ f</td>
</tr>
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<td>d</td>
<td>+ d</td>
</tr>
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<td>+</td>
<td>−</td>
<td>+ f</td>
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<td>+</td>
<td>d</td>
<td>+ d</td>
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<td>M</td>
<td>63</td>
<td>7 x 7 x 7 cm</td>
<td>+</td>
<td>+</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>52</td>
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<td>−</td>
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<td>49</td>
<td>7 x 7 x 7 cm</td>
<td>+</td>
<td>+</td>
<td>−</td>
<td>−</td>
</tr>
</tbody>
</table>

HBsAg, hepatitis B surface antigen; αFP, serum α fetoprotein; f, focal; d, diffuse; NA, data not available.

**Figure 1** (A) Immunohistochemical staining for α fetoprotein in hepatocellular carcinoma. Positive staining is present in single tumour cells (arrows). (B) H19 expression in the same tumour, as demonstrated by digoxigenin labelled in situ hybridisation. Expression is evident in most tumour cells.
minutes and in 0.9% NaCl for another five minutes, dehydrated, and air dried.

The hybridisation buffer contained 50% deionised formamide, 0.3 M NaCl, 20 mM Tris-HCl (pH 7.4), 5 mM EDTA, 10 mM NaH₂PO₄ (pH 8.0), 10% dextran sulphate, 1× Denhardt’s solution, and 0.5 µg/ml yeast tRNA. Each section was covered with 30 µl of the hybridisation solution containing 30–100 ng of DIG labelled RNA probe. The sections were covered with siliconised coverslips. Hybridisation was performed at 48–52°C for at least 16 hours in a humid chamber. After hybridisation, coverslips were gently floated off in 5× saline sodium citrate (SSC) at 50°C for 30 minutes. Subsequently, tissues were subjected to a stringent wash at 60°C in 5% deionised formamide, 2× SSC for 20 minutes.

After a double rinse for 10 minutes in washing buffer (0.4 M NaCl, 10 mM Tris-HCl, and 5 mM EDTA), treatment with RNase A (20 µg/ml) was performed for 30 minutes at 37°C. The sections were rinsed again for five minutes in a washing buffer, then washed in 2× SSC, 0.5× SSC, and 0.1× SSC at 37°C. The sections were then incubated in whole sheep’s serum diluted 1/50 for 30 minutes (to avoid non-specific crossreactions of the primary antibody). Incubation with the antidigoxigenin antibody (Boehringer) diluted 1/1000 in buffer 1 was performed for two hours at room temperature. After two washes in buffer 1, the sections were equilibrated in buffer 2 (100 mM Tris-HCl, 100 mM NaCl, and 50 mM MgCl₂, pH 9.5) for two minutes and incubated with a freshly prepared colour substrate solution containing nitroblue tetrazolium salt (340 µg/ml), 5-bromo-4-chloro-3-indolyl, phosphate toluidine salt (170 µg/ml), and levamizole (1 mM) in buffer 2. The slides were placed in a humid chamber and allowed to develop in the dark for 12–14 hours at room temperature. The reaction was stopped in buffer 3 (10 mM Tris-HCl and 1 mM EDTA, pH 7.4) for a few minutes. Finally, the sections were counterstained with 3% Giemsa stain, quickly dehydrated, and mounted in Entellan.

Controls for the specificity of the ISH included as follows: RNase A pretreatment of the sections; hybridisation with a sense RNA probe; and hybridisation with hybridisation buffer without the probe. A section of fetal kidney, which expresses H19 in the metanephric blastema, was used as a positive control.

IMMUNOHISTOCHEMISTRY

A polyclonal rabbit primary antibody was used for histochemical detection of αFP on paraffin wax sections (DPC ImmunoStain, Los Angeles, California, USA). Visualisation of αFP in the sections was made by the streptavidin–biotin immunoperoxidase technique using Histostain SP Kit (Zymed Lab Inc, San Francisco, California, USA) according to the manufacturer’s directions.

Results

The clinical and laboratory data are presented in table 1.

Expression of H19 was detected by ISH in 13 of 18 samples with hepatocellular carcinoma. Expression was found to be prominent and diffuse in eight of 13 positive samples (fig eight), and weak or prominent and focal (in less than one third of the tumour) in the remaining five samples (table 1). In six cases, we noted a gradual increase in the amount of expression in the malignant hepatocytes at the boundary of the tumour nodule (fig 2). The results of the radioactive and the newly developed non-radioactive studies were found to be essentially identical.

Immunohistochemical staining for αFP was found to be positive in nine of 18 samples. Of those, it was present only focally in single cells throughout the tumour in four cases (fig 1), and in a relatively large number of cells in the remaining five positive tumours (table 1). Non-neoplastic liver tissue was present in 14 of 18 sections and in all but one section this non-neoplastic tissue was negative for H19 expression. In the one positive sample, prominent expression of H19 was noted in the nodules of cirrhotic liver, whereas no expression was detected in the tumour itself. It is of interest to note that this sample was from an HBsAg positive patient. The remaining eight samples from HBsAg positive patients that included non-neoplastic liver tissue in the histological section were negative for H19 in the cirrhotic liver tissue.

![Figure 2](http://mp.bmj.com/)

Figure 2 H19 expression in hepatocellular carcinoma. (A) Bright and (B) dark field. The expression is most prominent at the boundary of the tumour nodule. (In situ hybridisation of 35S-labelled antisense of H19 with haematoxylin and eosin as a counterstain.)
When the expression of H19 (by ISH) was compared with immunohistochemical staining for αFP, concordance was found in 12 of 18 cases: in eight samples, both were found to be positive and in four samples, both were negative. In the remaining six cases, the results were discordant: in five samples, the H19 gene was expressed and αFP was not present, and in one sample, H19 expression was not detected but αFP was found to be positive (table 2).

Discussion
Despite extensive research for more than a decade, the biological role of the H19 gene is still not understood. A clue might lie in its tight linkage with the gene for IGF II. The latter is a member of a family of growth factors and their receptors that play an important role in cell proliferation and differentiation.22 The H19 and IGF II genes are reciprocally imprinted and their expression is linked in fetal and adult tissues.12 23–25 The relation between their allelic status and abundance of expression has been investigated in certain types of human cancer.1 2 15 26–30 The two genes reside close to each other on chromosome 11p15.5, and it has been shown in mice that they share a common enhancer.31

IGF II is one of the growth factors known to be involved in liver carcinogenesis in humans and animal models.4 15 22 32–38 It regulates tissue specific gene expression in rat and human hepatomas, and this effect seems to be dependent on the degree of tumour differentiation.22 In the experimental model of woodchuck liver carcinogenesis, IGF II blocks apoptosis induced by N-myc.32 37 Loss of heterozygosity in SV40 Tag induced murine hepatocellular carcinoma was demonstrated in one third of the tumours with partial or complete loss of maternal chromosome 7 (the mouse syntenic gene of the human chromosome 11), which resulted in overexpression of IGF II and suppression of H19 expression.39 Although the allelic status of H19 was not the subject of our study, it appears from our findings of H19 expression in 13 of 18 tumours, that this is not the case in human hepatocellular carcinoma. In fact, a deletion at 11p13–14, not at the region investigated in certain types of human cancer,1 3 15 26–30 was found to be involved in liver carcinogenesis, IGF II blocks apoptosis induced by N-myc.

The differential diagnosis includes primary cholangiocarcinoma and metastatic carcinoma. Further difficulty may arise in differentiating atypical regenerating hepatocytes in liver cirrhosis from hepatocellular carcinoma in cores of needle biopsies.

When immunohistochemical staining for αFP is performed, a weak staining is often seen, although this was not our experience in the present study. Difficulty in the interpretation of this weak staining is probably the reason for the wide range of positive staining for αFP documented in the literature.62 Moreover, αFP may also be detected in non-neoplastic hepatocytes by the immunohistochemical method.63 When comparing the immunohistochemical staining of αFP in our series to the expression of the H19 gene as demonstrated by ISH, the latter method gave a more diffuse staining pattern (fig 1) and was positive in more cases (table 2), although the difference was not statistically significant (p>0.28, using Fisher’s exact test). The use of the ISH technique for diagnosis in routine laboratories of pathology has become possible as a result of the development of commercial kits for non-radioactive ISH. The procedure is only slightly more complicated than immunohistochemistry. We intend to study more cases of hepatocellular carcinoma in order to assess the possible value of H19 as a tumour marker.

Recently, the diagnosis of hepatocellular carcinoma in fine needle aspirates has been introduced.61 64 The cytological findings are assisted by various immunohistochemical stains, including αFP. Staining for αFP was found to be positive in only 44% of the cases and was present focally in single cells in the fine needle aspirates.64 We have recently developed a method for detection of H19 expressing cells in cytological specimens, such as urine (unpublished data). It is possible that ISH for H19 expression, taking into account the more diffuse and uniform pattern in tissue sections, may prove to be useful for the diagnosis of hepatocellular carcinoma in fine needle aspirates.

We suggest that further work should be carried out to investigate the use of H19 as a candidate tumour marker to be applied to

### Table 2 Comparison of staining for H19 RNA by ISH and for αFP by immunohistochemistry

<table>
<thead>
<tr>
<th>H19+</th>
<th>H19−</th>
</tr>
</thead>
<tbody>
<tr>
<td>αFP+</td>
<td>8</td>
</tr>
<tr>
<td>αFP−</td>
<td>5</td>
</tr>
</tbody>
</table>

αFP was found to be positive (table 2).
histological and cytological preparations, along with other special stains and immunohistochemistry, for the diagnosis of hepatocellular carcinoma.

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