Short Communication

Enhanced transplantability of human ovarian cancer lines in cyclophosphamide-pretreated nude mice

M.M. Nauta¹, E. Boven¹, H.M.M. Schlüper¹, C.A.M. Erkelens² & H.M. Pinedo¹

¹Department of Oncology; ²Central Laboratory for Experimental Medicine, Free University, Amsterdam, The Netherlands.

The transplantability of human malignancies in athymic nu/nu mice varies greatly and for some tumour types the establishment of serially transplantable tumour lines has proven to be difficult (Giovanella et al., 1978; Fogh et al., 1980). The take rate and tumour growth do not only depend on properties of the tumour type, but other factors have also been implicated, such as the selected mouse strain (Maruo et al., 1982), the site of implantation (Kyriazis & Kyriazis, 1980) and the hormonal status of the mouse (Leung & Shiu, 1981).

In the nude mouse with T cell immune deficiency, the residual immune system may be a major mechanism in the inhibition of tumour transplantability. The higher phagocytic activity of macrophages that can be observed in these animals as a possible mechanism to overcome the immunological defect, was shown to play a role in the rejection of heterologous tumour tissue (Kopper et al., 1980, 1981; Vetvicka et al., 1984; Sharp & Colston, 1984). In addition, nude mice are known to possess a higher natural killer (NK) cell activity as compared to normal mice (Herberman et al., 1975). NK cell activity appears to be an important mechanism to prevent tumour cell proliferation. For instance, the number of NK cells in mice correlates inversely with the number of experimental pulmonary metastases (Hanna et al., 1982; Talmadge et al., 1980).

In our laboratory the transplantation of ovarian cancer tissue from patients into nude mice resulted in a take rate of 32% with 11% established tumour lines (Boven, 1986). These figures correspond with data obtained in ovarian cancer by other investigators (Kullander et al., 1978; Teufel et al., 1981; Friedlander et al., 1985). Furthermore, the take rate in subsequent passages does not always reach 100% and may vary greatly. In order to improve the take rate and growth of human ovarian cancer xenografts, we pretreated our mice with cyclophosphamide (CY) in an attempt to reduce the NK cell activity. The effect of CY on the spontaneous NK cell activity in our mice was also measured.

Female 6-week-old B10 LP/Cpb nude (nu/nu) mice, were purchased from TNO, Zeist, NL. The animals were maintained in cages with paper filter covers. Cages, covers, bedding, food, and water were sterilized and changed weekly. Animal handling was done in a laminar down-flow hood. Seven tumour lines of ovarian cancer origin and differing in histological subtype and growth rate were studied (Table I). Tumour lines FKo, FCo, and FMa were kindly provided by Dr W. Kleine.

Table I Human ovarian cancer lines

<table>
<thead>
<tr>
<th>Tumour line</th>
<th>Histology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ov.Ri(C)</td>
<td>moderately differentiated serous adenocarcinoma</td>
</tr>
<tr>
<td>Ov.He</td>
<td>moderately differentiated mucinous adenocarcinoma</td>
</tr>
<tr>
<td>FKo</td>
<td>moderately differentiated serous adenocarcinoma</td>
</tr>
<tr>
<td>FCo</td>
<td>poorly differentiated clear cell carcinoma</td>
</tr>
<tr>
<td>Ov.Gi</td>
<td>poorly differentiated serous adenocarcinoma</td>
</tr>
<tr>
<td>Ov.SI</td>
<td>moderately differentiated serous adenocarcinoma</td>
</tr>
<tr>
<td>FMa</td>
<td>poorly differentiated endometrioid adenocarcinoma</td>
</tr>
</tbody>
</table>

Correspondence: E. Boven.
Received 2 January 1986; and in revised form, 18 April 1986.

Albert-Ludwigs University, Freiburg, FRG, while
the other lines were established in our laboratory.
Tumour fragments of $3 \times 2 \times 2$ mm were implanted
s.c. in both flanks in the thoracic region in a series
of 8-week-old animals. Tumours were measured once
a week with vernier calipers by the same observer.
The tumour volume was expressed by the equation
length $\times$ width $\times$ height $\times 0.5$ in mm$^3$. A tumour
size was scored, if the nodule reached at least a
volume of 50 mm$^3$. Volume doubling time was
calculated as the number of days for the tumour
to grow from 50 mm$^3$ to 100 mm$^3$ ($T_{D50-100}$). The
latency period ($T_{L50-100}$) was the number of days
from implantation until a volume of 50 mm$^3$ was
reached.

CY (ASTA Werke, Bielefeld, FRG) was dis-
solved in distilled water at a concentration of
20 mg ml$^{-1}$ prior before use. Twelve animals were
randomly divided into a treatment group and a
control group each of 5 to 7 mice. Treatment consisted of
a single dose of CY 100 mg kg$^{-1}$ i.p. 24 h before
tumour implantation.

The cytotoxic capacity of nude mouse NK cells
was assayed using the method described by Romijn (1985). Briefly,
效应细胞 were prepared as single cells from
mouse spleens at three different concentrations.
YAC-1 target cells were labelled with $200 \mu$Ci
$\text{Na}_2\text{CrO}_4$ solution per $1 \times 10^9$ cells for 1 h at 37°C
($\frac{51}{2}$Cr at a specific activity of 50-400 mCi mg$^{-1}$ was
obtained from Amersham, Buckinghamshire, UK).
Viable target cells at a number of $1 \times 10^4$ in 0.1 ml
culture medium were incubated with the effector
cells in 0.1 ml culture medium at three different
ratios 1:25, 1:50 and 1:100 in 96-well round-
bottom microtiter plates for 4 h at 37°C. After
incubation the plates were centrifuged for 10 min at
150 g and the release of $^{51}$Cr in the supernatants
determined by counting radioactivity in a gamma
counter. The degree of cytotoxicity was calculated
according to the following formula:

$$\text{specific release} = \frac{\text{experimental release} - \text{spontaneous release}}{\text{maximum release} - \text{spontaneous release}} \times 100\%$$

All tests were done in quadruplicate with four
control and four CY-treated mice, 8 weeks of age.

In order to analyze the differences between the
tumour take rate in treated and control mice the $\chi^2$
test was applied to each of the tumour lines. The
statistical differences in the NK cell cytotoxicity
assay were evaluated using Student’s $t$ test.

In serial transplantation the take rate in the seven
human ovarian cancer lines was always below
100% (Table II). In four of them, Ov.He, FCo, Ov.Sl, and FMA, the take rate was frequently below
50%. After CY administration at a dose of
100 mg kg$^{-1}$ i.p. 24 h before tumour implantation,
the transplantability increased in Ov.He, FKo,
FCo, and Ov.Sl. These results could be repeated
and were significantly different from the take rate
in control animals (Figure 1). The slight improve-
Table II  Effect of cyclophosphamide pretreatment on the take rate, latency period and tumour doubling time in seven human ovarian cancer lines in nude mice

<table>
<thead>
<tr>
<th>Tumour line</th>
<th>Passage</th>
<th>Take rate*</th>
<th>T_{V50}</th>
<th>T_{D50-100}</th>
<th>Take rate*</th>
<th>T_{V50}</th>
<th>T_{D50-100}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ov.Ri(C)</td>
<td>6</td>
<td>90 ± 5</td>
<td>11 ± 3</td>
<td></td>
<td>100 ± 5</td>
<td>8 ± 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>100 ± 7</td>
<td>10 ± 4</td>
<td></td>
<td>75 ± 4</td>
<td>8 ± 4</td>
<td></td>
</tr>
<tr>
<td>Ov.He</td>
<td>10</td>
<td>100 ± 17</td>
<td>8 ± 6</td>
<td></td>
<td>83 ± 18</td>
<td>13 ± 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>92 ± 5</td>
<td>8 ± 7</td>
<td></td>
<td>25 ± 3</td>
<td>1 ± 12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>100 ± 5</td>
<td>4 ± 2</td>
<td></td>
<td>20 ± 5</td>
<td>5 ± 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>75 ± 6</td>
<td>9 ± 5</td>
<td></td>
<td>50 ± 15</td>
<td>10 ± 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>58 ± 7</td>
<td>7 ± 4</td>
<td></td>
<td>25 ± 2</td>
<td>6 ± 1</td>
<td></td>
</tr>
<tr>
<td>FKo</td>
<td>3</td>
<td>100 ± 3</td>
<td>14 ± 5</td>
<td></td>
<td>40 ± 5</td>
<td>14 ± 11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>93 ± 5</td>
<td>8 ± 7</td>
<td></td>
<td>50 ± 2</td>
<td>8 ± 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>100 ± 7</td>
<td>7 ± 4</td>
<td></td>
<td>50 ± 2</td>
<td>10 ± 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>100 ± 9</td>
<td>9 ± 4</td>
<td></td>
<td>67 ± 2</td>
<td>14 ± 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>100 ± 5</td>
<td>8 ± 2</td>
<td></td>
<td>60 ± 4</td>
<td>9 ± 3</td>
<td></td>
</tr>
<tr>
<td>FCo</td>
<td>3</td>
<td>67 ± 6</td>
<td>14 ± 6</td>
<td></td>
<td>80 ± 7</td>
<td>13 ± 12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>50 ± 4</td>
<td>7 ± 3</td>
<td></td>
<td>80 ± 2</td>
<td>17 ± 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>70 ± 4</td>
<td>18 ± 10</td>
<td></td>
<td>25 ± 6</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>83 ± 9</td>
<td>15 ± 14</td>
<td></td>
<td>38 ± 3</td>
<td>8 ± 5</td>
<td></td>
</tr>
<tr>
<td>Ov.Gl</td>
<td>10</td>
<td>67 ± 10</td>
<td>12 ± 5</td>
<td></td>
<td>75 ± 13</td>
<td>21 ± 11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>100 ± 6</td>
<td>18 ± 1</td>
<td></td>
<td>33 ± 9</td>
<td>19 ± 8</td>
<td></td>
</tr>
<tr>
<td>Ov.Si</td>
<td>3</td>
<td>40 ± 9</td>
<td>9 ± 5</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>92 ± 14</td>
<td>21 ± 12</td>
<td></td>
<td>38 ± 12</td>
<td>19 ± 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>83 ± 15</td>
<td>18 ± 7</td>
<td></td>
<td>67 ± 25</td>
<td>13 ± 4</td>
<td></td>
</tr>
<tr>
<td>FMa</td>
<td>5</td>
<td>21 ± 5</td>
<td>17 ± 4</td>
<td></td>
<td>20 ± 7</td>
<td>14 ± 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>42 ± 17</td>
<td>6 ± 2</td>
<td></td>
<td>20 ± 5</td>
<td>5 ± 3</td>
<td></td>
</tr>
</tbody>
</table>

CY was injected i.p. at a dose of 100 mg kg⁻¹ 24 h before tumour implantation. The take rate refers to the number of nodules growing beyond 50 mm³ as a percentage of the tumours that could be expected. The latency period (T_{V50}) is the number of days (± s.d.) from transplantation to 50 mm³ and the tumour doubling time is the number of days (± s.d.) from 50 mm³ to 100 mm³.

The significant increase of the take rate in four of seven ovarian cancer lines in CY-pretreated mice in combination with the observed reduced NK cell activity in these animals strongly suggests that some human ovarian cancer xenografts are susceptible to
NK cell-mediated cytotoxicity. Because we are employing our tumour lines for chemotherapy studies (Boven et al., 1985a, b), it is of the utmost importance to optimise the number of tumour-bearing animals to achieve reliable results.

CY is known as an alkylating agent with anti-tumour and immunosuppressive properties. The drug is a potent inhibitor of spontaneous NK cell activity in both normal and nude mice (Djeu et al., 1979; Riccardi et al., 1981). In two separate studies it was shown that in normal mice with a low NK cell activity upon CY treatment, the formation of experimental pulmonary metastases was markedly enhanced (Hanna & Fidler, 1980; Vollmer & Conley, 1984). The NK cell activity in nude mice does not only vary with age and health of the animals (Hanna et al., 1982), but also with the nude mouse strain (Herberman et al., 1975).

Recently, Fodstad et al. (1984) reported on the lack of correlation between NK cell activity and tumour growth control in nude mice of varying immune-deficient backgrounds. These data are suggestive of a complex mechanism in the regulation of the immune response in nude mice. In addition, Romijn (1985) demonstrates that tumour lines with a relative insensitivity to NK cells may also have a better growth pattern in young nude mice. Besides reduction of NK cell activity CY is known to effectively suppress other cell-mediated immuno-
logic reactions in man and animals (Hunninghake & Fauet, 1976). Whether these immunological mechanisms play a role in the rejection of human tumour tissue in the nude mouse has yet to be clarified.

Because of the short plasma half-life of 5 to 6 h (Bagely et al., 1973), CY cannot be expected to exert its cytotoxic action on tumour tissue fragments implanted one day after administration. Moreover, CY pretreatment did not affect the latency period and the doubling time of our tumour lines. These observations are of importance, if tumour lines are being used for chemotherapy studies.

From our studies it can be concluded that CY pretreatment can increase the take rate of several human ovarian cancer lines. CY suppressed NK cell activity in our nude mice, which may be an explanation for the enhanced transplantability. Further investigations are warranted, to determine the effect of CY on the success rate of primary transplants of ovarian cancer.

This work was supported by the Netherlands Cancer Foundation (KWF) through grant IKR 83-2, Dr A.D.M. Kester and Dr J.C. Romijn are gratefully acknowledged for their respective contributions on the statistical analysis of the data and the NK cell cytotoxicity assay.

References


