Detecting DNA repair capacity of peripheral lymphocytes from cancer patients with UVC challenge test and bleomycin challenge test

Zheng Wei¹, Jin Lifen¹, He Jiliang¹,², Lou Jianlin¹, Wang Baohong¹ and Deng Hongping¹

¹Institute of Occupational and Environmental Institute, Medical College, Zhejiang University, 353 Yan An road, Hangzhou 310006, Zhejiang, People’s Republic of China and ²Medical College of Jiaxing University, Jiaxing, 314001, Zhejiang, People’s Republic of China

The objective of this study was to evaluate DNA repair capacity of cancer patients with the bleomycin (BLM) challenge test and the UVC challenge test. The human peripheral lymphocytes were collected from 33 patients with different kinds of cancers and 33 controls in the same hospital. The lymphocytes of each subject were divided into two groups: (1) In the BLM challenge test, the lymphocytes were treated with BLM (20 μg/ml) for 30 min, and repaired for 15 min. The DNA damage before and after BLM exposure was detected with comet assay to assess DNA repair capacity. (2) In the UVC challenge test, the lymphocytes were exposed to UVC (254 nm) at the dose of 1.5 J/m². DNA damage of lymphocytes was measured before UVC exposure and at 90 and 240 min after UVC exposure using comet assay, then DNA repair percentage (DRP) was calculated. The results of this study indicate that the average DRPs of cancer patients were 75.63 ± 3.11 and 68.98 ± 4.19% calculated with tail length (TL) and tail moment (TM), respectively, in the BLM challenge test, which were significantly lower than those (91.11 ± 1.09 and 88.19 ± 1.71%) of controls (P < 0.01). Also, the mean DRPs of cancer patients were 49.19 ± 3.47 and 58.27 ± 3.64% calculated with TL and TM, respectively, in the UVC test, which were significantly lower than those (77.52 ± 2.06 and 83.12 ± 2.36%) of controls (P < 0.01). The correlation between the DRPs (%) drawn with TL and TM in the BLM test or between the DRPs (%) drawn with mean TL and mean TM in the UVC challenge test were significant (P < 0.05). The DNA repair capacity measured with the BLM and UVC challenge tests in 33 cancer patients was significantly lower than that in controls.

Introduction

The DNA repair machinery is essential in protecting the integrity of the genome. It is commonly accepted that the ability to repair DNA lesions is strongly associated with risk of cancer (1,2). Inter-individual variabilities in human response to carcinogens have been studied repeatedly. This notion was initially supported by rare autosomal recessive disorders such as ataxia-telangiectasia (A-T), Fanconi anemia, Bloom’s syndrome and xeroderma pigmentosum (XP) (3), which are associated with genetic instability, defective DNA repair and high cancer risk (1). Furthermore, individuals differ in their capacity to repair DNA damage induced by both exogenous agents and endogenous reactions, e.g. oxidation (3). Therefore, the epidemiology of DNA repair capacity and of its effect on cancer susceptibility in humans is an important area of investigation. A number of epidemiological studies have been conducted to compare the differences of DNA repair capacity between patients with cancer and healthy controls to assess the role of repair in the development of human cancer (3,4). Dybdahl et al. reported that the high capacity to repair the DNA damage protected psoriasis patients against chemically induced basal cell carcinoma (5). Zheng et al. found that low DNA repair capacity played a significant role in lung cancer risk (1), and Ramos et al. determined that deficiency in DNA repair capacity was a susceptibility factor for breast carcinoma (6).

DNA repair processes are classified into several pathways: base excision repair (BER), nucleotide excision repair (NER), homologous recombination repair (HRR), non-homologous end-joining (NHEJ) and mismatch repair (MR) (4,7). So far, five kinds of techniques have been used to estimate DNA repair capacity: (1) Tests based on DNA damage induced with chemicals or physical agents, such as the mutagen sensitivity test, the G2-radiation assay, induced micronuclei and the comet assay; (2) indirect tests of DNA repair, such as un-programmed DNA synthesis (UDS); (3) tests based on more direct measures of repair kinetics, such as the host cell reactivation assay (HCR); (4) measures of genetic variation associated with DNA repair; and (5) combinations of more than one category of assay (3). Among them, the comet assay is considered as a simple, sensitive assay to detect all types of DNA damage, including frank single strand break, double strand break and alkali-labile lesions (8,9). In addition, this sensitive technique allows one to obtain information on inter-individual differences in DNA repair kinetics through the measurement of residual DNA damage at multiple time points. The comet assay, in combination with the mutagen challenge test, can be utilized to evaluate indirectly individual DNA repair capacity, and to assume that variation in the response to treatment is determined by individual DNA repair capacity (10–12).

Therefore, we designed a study to compare the differences of DNA repair capacity between patients with different kinds of cancers and controls and to test the hypothesis that a low DNA repair capacity is a susceptibility factor for cancer development. However, the mechanisms repairing DNA damage induced by different mutagens are varied. For example, DNA damage induced by UVC is repaired through NER pathway, but DNA double strand breaks and single strand breaks produced by bleomycin (radiometric agent) (BLM) is repaired through HRR, NHEJ and BER pathways. For these reasons, the UVC and BLM challenge tests combined with comet assay were utilized to assess DNA repair capacity of cancer patients in this study. In addition, ‘DNA repair percentage’ (DRP) was

¹To whom correspondence should be addressed. Tel: +86 571 87217188; Fax: +86 571 86996525; Email: he_jiliang@hotmail.com

© The Author 2005. Published by Oxford University Press on behalf of the UK Environmental Mutagen Society. All rights reserved. For permissions, please email: journals.permissions@oupjournals.org
used to represent the capacity to remove the DNA lesions in this investigation (13).

Materials and methods

Subjects

A total of 33 cancer patients (14 males and 19 females; 6 smokers; average age: 55.8 years) with different kinds of cancers (e.g. 9 mastocarcinoma patients, 3 lung cancer patients, 2 esophagus cancer patients, 3 nasopharyngeal carcinoma and so on), who had never received primary radio-therapy or chemotherapy, were recruited in the tumor department of a hospital. From the same hospital 33 controls were selected and matched to the cases for gender, age, and smoking history. The general situation of cancer patients and controls was listed in Table I, which showed no significant difference between cancer patient group and control group for gender, age, and smoking habits.

Separation of peripheral blood lymphocytes

Venous blood from each subject was drawn into heparinized tubes, and carefully layered over the same volume of histopaque gradients (Histopaque 1077, Sigma) at room temperature and centrifuged at 1600 r.p.m. for 30 min. The buffy coats were removed and washed with phosphate-buffered saline (PBS). Before incubation, the cells were suspended in RPMI 1640 medium (GIBCO, containing 20% heat-inactivated fetal calf serum, antibiotics and PHA 10 μg/ml). Then, the cells were incubated at 37°C for 20 h, and aliquots were subsequently treated with BLM (Sigma) or UVC.

Cells viability test

The trypan blue test was performed on 10 μl of lymphocyte suspension to determine the percentage of viable cells for every individual. The mean percentage viability calculated for each group was >90%.

UVC challenge and repair

Each lymphocyte sample for UVC challenge test was divided into three aliquots. The first aliquot was served as the untreated group. The second and third aliquots were left in the Petri dish (Φ 90 mm) and covered with 10 ml RPMI 1640 medium. The dishes were placed on ice and exposed to UVC. The UVC (254 nm, 1.5 Jm−2) exposure was radiated with a UV germicidal lamp (Waldmann ST 204 with Philips bulb) (14). The energy flux was measured with a short-wave ultraviolet intensity meter (UVP, USA). The first aliquot was used to quantitate basal DNA damage (untreated group). The second and the third aliquots were incubated in the dark at 37°C for 90 and 240 min, respectively, then lymphocyte DNA damage of the three aliquots was detected with comet assay (15). The maximum DNA damage usually appeared at 90 min after UVC exposure. According to our previous experiment, the DNA damage at 240 min after UVC exposure was adjacent to the DNA damage level before UVC exposure (16).

BLM challenge and repair

After testing viability, the cells were divided into two aliquots. One aliquot served as control. The other aliquot was incubated with BLM (Sigma) at ultimate concentration of 20 μg/ml for 30 min. The cells were washed twice with PBS to remove the BLM, then incubated in RPMI 1640 medium at 37°C for 15 min. The lymphocyte DNA damage in the two aliquots was measured with comet assay (11,17).

Table I. The general information of cancer patients and controls

<table>
<thead>
<tr>
<th>Patients</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject Gender Age Smoking Malignancy UICC</td>
<td>Subject Gender Age Smoking Disease</td>
</tr>
<tr>
<td>1 F 48 NS Meningeoma I 1 F 49 NS Hepatitis B</td>
<td></td>
</tr>
<tr>
<td>2 F 73 NS Leiomyosarcoma IIIa 2 F 76 NS Hepatitis B</td>
<td></td>
</tr>
<tr>
<td>3 F 61 NS Glioblastoma IIIa 3 F 54 NS Pulmonary tuberculosis</td>
<td></td>
</tr>
<tr>
<td>4 M 73 NS Nasopharyngeal carcinoma II 4 M 78 NS Pulmonary tuberculosis</td>
<td></td>
</tr>
<tr>
<td>5 M 73 NS Esophagus cancer IIIB 5 M 85 NS Pulmonary tuberculosis</td>
<td></td>
</tr>
<tr>
<td>6 M 35 10 years Spermatocytoma 6 M 41 NS Pulmonary tuberculosis</td>
<td></td>
</tr>
<tr>
<td>7 F 69 NS Mastocarcinoma II 7 F 59 NS Acute enterogastritis</td>
<td></td>
</tr>
<tr>
<td>8 M 38 20 years Nasopharyngeal carcinoma IIIA 8 M 67 NS Bronchitis</td>
<td></td>
</tr>
<tr>
<td>9 F 57 NS Glioblastoma IIIB 9 F 59 NS Cholestatic hepatitis</td>
<td></td>
</tr>
<tr>
<td>10 F 53 NS Mammary cancer IV 10 F 39 NS Anaphylactoid purpura</td>
<td></td>
</tr>
<tr>
<td>11 M 65 NS Rectum cancer IIIIB 11 M 57 NS Pneumonia</td>
<td></td>
</tr>
<tr>
<td>12 M 57 30 years Lung cancer IIIIB 12 M 66 NS Pneumonia</td>
<td></td>
</tr>
<tr>
<td>13 M 46 NS Spermatocytoma IIB 13 M 52 NS Gastritis</td>
<td></td>
</tr>
<tr>
<td>14 F 52 NS Endometrium adenocarcinoma IIB 14 F 49 NS Thrombocytopenia</td>
<td></td>
</tr>
<tr>
<td>15 M 65 30 years Rectum cancer IIIIB 15 M 80 50 years Pneumonia</td>
<td></td>
</tr>
<tr>
<td>16 F 44 NS Mammary cancer IIIB 16 F 40 NS Myocarditis</td>
<td></td>
</tr>
<tr>
<td>17 F 43 NS Mastocarcinoma IIIB 17 F 27 NS Chronic enterogastritis</td>
<td></td>
</tr>
<tr>
<td>18 F 55 NS Mastocarcinoma IIIB 18 F 61 NS Chronic enterogastritis</td>
<td></td>
</tr>
<tr>
<td>19 F 39 NS Mastocarcinoma IIIB 19 F 32 NS Hemolytic anemia</td>
<td></td>
</tr>
<tr>
<td>20 F 55 NS Mastocarcinoma IIB 20 F 39 NS Gastritis</td>
<td></td>
</tr>
<tr>
<td>21 F 59 NS Mastocarcinoma IIIIB 21 F 54 NS Myocarditis</td>
<td></td>
</tr>
<tr>
<td>22 M 73 NS Rectum cancer IIIIB 22 M 64 NS Pulmonary tuberculosis</td>
<td></td>
</tr>
<tr>
<td>23 F 50 NS Mastocarcinoma IIIB 23 F 54 NS Myocarditis</td>
<td></td>
</tr>
<tr>
<td>24 M 74 35 years Laryngocarcinoma IIIA 24 M 70 30 years Bronchitis</td>
<td></td>
</tr>
<tr>
<td>25 F 51 NS Mastocarcinoma IIIB 25 F 72 NS Pneumonia</td>
<td></td>
</tr>
<tr>
<td>26 M 58 NS Rectum cancer IIIIB 26 M 39 10 years Bacillary dysentery</td>
<td></td>
</tr>
<tr>
<td>27 M 79 NS Esophagus cancer IIIA 27 M 57 NS Pneumonia</td>
<td></td>
</tr>
<tr>
<td>28 M 78 NS Lung cancer IIIB 28 M 48 NS Gastritis</td>
<td></td>
</tr>
<tr>
<td>29 F 36 NS Mammary cancer IIIIB 29 F 53 NS Coronary disease</td>
<td></td>
</tr>
<tr>
<td>30 M 74 30 years Lung cancer IV 30 M 56 32 years Gastritis</td>
<td></td>
</tr>
<tr>
<td>31 F 56 NS Endometrium adenocarcinoma IV 31 F 53 NS Gastritis</td>
<td></td>
</tr>
<tr>
<td>32 F 41 NS Mastocarcinoma IIIIB 32 F 42 NS Bronchitis</td>
<td></td>
</tr>
<tr>
<td>33 F 36 NS Nasopharyngeal carcinoma IIIIB 33 F 47 NS Myocarditis</td>
<td></td>
</tr>
</tbody>
</table>

M: male; F: female; NS: non-smoker.
electrophoresis unit. The slides were allowed to sit in this buffer for 20 min for DNA unwinding. Then, the DNA was electrophoresed at 20 V and 300 mA for 20 min. Both unwinding and electrophoresis were performed at 4°C. The slides were washed gently to remove alkali and detergent in a neutralization buffer (0.4 M Tris–HCl, pH = 7.5) and fixed in methanol for 3 min, then stained with 50 μl ethidium bromide (20 μg/ml). All steps described above were conducted under yellow light or in the dark to prevent additional DNA damage. The pictures of 50 cells per treatment sample (25 cells/slide) were taken individually under a fluorescence microscope (Olympus, BX51) with digital camera (Olympus, DP50) at 400× magnification. Nuclear width and the extent of migration of DNA fragments (tail length, tail moment) were analyzed using Image-Pro Plus program (Media Cybernetics, USA).

**Statistical analysis**

For UVC challenge test, mean tail length (MTL) and mean tail moment (MTM) of 50 cells were calculated as the indexes of DNA migration. DNA repair capacity was represented by DRP. The numerator indicates repaired DNA and the denominator indicates damaged DNA at 90 min after UVC exposure. The formula is:

$$DRP\% = \frac{\text{Detected cell number}}{\text{Undamaged cell number before BLM treatment}} \times 100\%$$

For the BLM challenge test, the 95% confidence limit of tail length (TL) and tail moment (TM) distribution of detected cells among controls served as the criteria of the damaged cells. DNA repair capacity was represented with DRP. The formula (17) is:

$$DRP\% = \frac{\text{MTL}_{240} - \text{MTL}_{0}}{\text{MTL}_{90} - \text{MTL}_{0}} \times 100\%$$

For the BLM challenge test, the 95% confidence limit of tail length (TL) and tail moment (TM) distribution of detected cells among controls served as the criteria of the damaged cells. DNA repair capacity was represented with DRP. The formula (17) is:

$$DRP\% = \frac{\text{MTM}_{240} - \text{MTM}_{0}}{\text{MTM}_{90} - \text{MTM}_{0}} \times 100\%$$

For the BLM challenge test, the 95% confidence limit of tail length (TL) and tail moment (TM) distribution of detected cells among controls served as the criteria of the damaged cells. DNA repair capacity was represented with DRP. The formula (17) is:

$$DRP\% = \frac{\text{Detected cell number}}{\text{Undamaged cell number}} \times 100\%$$

The DRP difference between cancer patients and controls was analyzed by non-parametric Wilcoxon rank-sum test. Meanwhile, Kendall’s rank test was performed to assess the correlation between the DRPs calculated from TL(MTL) and TM(MTM) or between the BLM test and the UV test. Statistical analyses were fulfilled using the SPSS 11.0.

**Results**

**DNA repair capacity of cancer patients measured with BLM test**

Table II showed DRP values which were measured with the BLM challenge test. When TL served as an indicator, the range of DRPs in cancer patients was 19.35–95%. Among them, DRPs of 14 cancer patients were <80%. In the control group, the range of DRP values was 73.68–97.87%, and the DRP values of most controls were >80% (Figure 1). Moreover, the DRPs of cancer patients averaged out to 75.63%, which was significantly below the average (91.11%) of controls ($P < 0.01$). When TM acted as the indicator, the ranges of DRPs for 33 cancer patients and 32 controls were 85–98 and 60–100%, respectively, DRPs of 19 patients were <80%, while DRPs of 27 controls were >80% (Figure 2). The average DRPs of cancer patients and controls were 68.98 and 88.19%, respectively. The difference between cancer patients and controls was significant ($P < 0.01$).

**DNA repair capacity of cancer patients measured with UVC test**

Table III denoted DRP values measured with UVC challenge test. For the indicator of MTL, the range of DRP values for cancer patients was 11.20–89.69%, and the average value of DRP was 49.19%. However, for control samples, the range of DRP values was 51.97–99.34%, with an average value of 77.52%. For the indicator of MTM, the range of DRP values for cancer patients was 11.20–89.69%, and the average value of DRPs of 27 controls were 60–100%, respectively, DRPs of 19 patients were <80%, but the DRP values of most controls were >80% (Figures 3 and 4). Both the DRPs calculated with MTL and MTM had significant statistical difference between the cancer patients and controls ($P < 0.01$).

**Correlation analysis**

The correlation between DRPs (%) measured with two kinds of different indicators (TL/TM or MTL/MTM) was assessed by Kendall’s rank test (Table IV). A highly significant correlation was observed between the DRPs (%) drawn with TL and TM or between the DRPs (%) drawn with MTL and MTM in both cancer patients and controls ($P < 0.05$).

**Discussion**

The failure to maintain genome integrity is central to the problem of carcinogenesis. Increased genetic instability, either spontaneous or mutagen-induced, has been considered as a predisposing factor for neoplastic transformation (1). So the DNA repair capacity is essential for cell survival and the maintenance of cell cycle control. Inter-individual variation in DNA repair capacity has been observed in several in vitro
### Table II. DNA repair capacity of cancer patients measured with BLM challenge test in comet assay (TL and TM)

<table>
<thead>
<tr>
<th>Subject Patients</th>
<th>Pre-BLM treatment</th>
<th>BLM treatment</th>
<th>DRP (%)</th>
<th>Subject Controls</th>
<th>Pre-BLM treatment</th>
<th>BLM treatment</th>
<th>DRP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total cell number</td>
<td>Undamaged cell number</td>
<td>Total cell number</td>
<td>Undamaged cell number</td>
<td></td>
<td>Total cell number</td>
<td>Undamaged cell number</td>
</tr>
<tr>
<td>TL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>50</td>
<td>31</td>
<td>50</td>
<td>6</td>
<td>19.35</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>40</td>
<td>50</td>
<td>38</td>
<td>95.00</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>45</td>
<td>50</td>
<td>41</td>
<td>91.11</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>25</td>
<td>50</td>
<td>12</td>
<td>48.00</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>3</td>
<td>50</td>
<td>2</td>
<td>66.67</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>21</td>
<td>50</td>
<td>7</td>
<td>33.33</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>37</td>
<td>50</td>
<td>27</td>
<td>72.97</td>
<td>7</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>30</td>
<td>50</td>
<td>21</td>
<td>70.00</td>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>9</td>
<td>50</td>
<td>46</td>
<td>50</td>
<td>38</td>
<td>82.61</td>
<td>9</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>28</td>
<td>56.00</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>11</td>
<td>50</td>
<td>48</td>
<td>50</td>
<td>42</td>
<td>87.5</td>
<td>11</td>
<td>50</td>
</tr>
<tr>
<td>12</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>45</td>
<td>90.00</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>13</td>
<td>50</td>
<td>47</td>
<td>50</td>
<td>42</td>
<td>89.36</td>
<td>13</td>
<td>50</td>
</tr>
<tr>
<td>14</td>
<td>50</td>
<td>46</td>
<td>50</td>
<td>37</td>
<td>80.43</td>
<td>14</td>
<td>50</td>
</tr>
<tr>
<td>15</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>40</td>
<td>80.00</td>
<td>15</td>
<td>50</td>
</tr>
<tr>
<td>16</td>
<td>50</td>
<td>49</td>
<td>50</td>
<td>40</td>
<td>81.63</td>
<td>16</td>
<td>50</td>
</tr>
<tr>
<td>17</td>
<td>50</td>
<td>47</td>
<td>50</td>
<td>36</td>
<td>66.67</td>
<td>17</td>
<td>–</td>
</tr>
<tr>
<td>18</td>
<td>50</td>
<td>49</td>
<td>50</td>
<td>41</td>
<td>83.67</td>
<td>18</td>
<td>50</td>
</tr>
<tr>
<td>19</td>
<td>50</td>
<td>49</td>
<td>50</td>
<td>46</td>
<td>93.88</td>
<td>19</td>
<td>50</td>
</tr>
<tr>
<td>20</td>
<td>50</td>
<td>48</td>
<td>50</td>
<td>37</td>
<td>77.08</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>21</td>
<td>50</td>
<td>47</td>
<td>50</td>
<td>36</td>
<td>76.60</td>
<td>21</td>
<td>50</td>
</tr>
<tr>
<td>22</td>
<td>50</td>
<td>45</td>
<td>50</td>
<td>42</td>
<td>52.00</td>
<td>22</td>
<td>50</td>
</tr>
<tr>
<td>23</td>
<td>50</td>
<td>49</td>
<td>50</td>
<td>46</td>
<td>93.88</td>
<td>23</td>
<td>50</td>
</tr>
<tr>
<td>24</td>
<td>50</td>
<td>27</td>
<td>40</td>
<td>24</td>
<td>88.89</td>
<td>24</td>
<td>50</td>
</tr>
<tr>
<td>25</td>
<td>50</td>
<td>41</td>
<td>50</td>
<td>26</td>
<td>63.41</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>26</td>
<td>50</td>
<td>48</td>
<td>50</td>
<td>36</td>
<td>75.00</td>
<td>26</td>
<td>50</td>
</tr>
<tr>
<td>27</td>
<td>50</td>
<td>48</td>
<td>50</td>
<td>43</td>
<td>89.58</td>
<td>27</td>
<td>50</td>
</tr>
<tr>
<td>28</td>
<td>50</td>
<td>49</td>
<td>50</td>
<td>45</td>
<td>91.84</td>
<td>28</td>
<td>50</td>
</tr>
<tr>
<td>29</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>49</td>
<td>88.00</td>
<td>29</td>
<td>50</td>
</tr>
<tr>
<td>30</td>
<td>50</td>
<td>47</td>
<td>50</td>
<td>38</td>
<td>80.85</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>31</td>
<td>50</td>
<td>39</td>
<td>50</td>
<td>24</td>
<td>61.54</td>
<td>31</td>
<td>50</td>
</tr>
<tr>
<td>32</td>
<td>50</td>
<td>45</td>
<td>50</td>
<td>40</td>
<td>88.89</td>
<td>32</td>
<td>50</td>
</tr>
<tr>
<td>33</td>
<td>50</td>
<td>40</td>
<td>50</td>
<td>32</td>
<td>80.00</td>
<td>33</td>
<td>50</td>
</tr>
</tbody>
</table>

\[ X \pm SE \]

- Data deletion.
- Cancer patients versus controls: \( P < 0.01 \).
### Table III. DNA repair capacity of cancer patients measured with UVC challenge test in comet assay (MTL and MTL)

<table>
<thead>
<tr>
<th>Subject Patients</th>
<th>MTL</th>
<th>Pre-irradiation</th>
<th>90 min</th>
<th>240 min</th>
<th>DRP (%)</th>
<th>MTL</th>
<th>Pre-irradiation</th>
<th>90 min</th>
<th>240 min</th>
<th>DRP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Controls

Controls

capacity of lung cancer patients was significantly lower than that of breast cancer; Wu et al. (21) reported that the DNA repair capacity of lung cancer patients was significantly lower than that of controls; Udumudi et al. (22) found that low DNA repair capacity may be an important risk factor for various cancers. 

Up to the present, five categories of assays of DNA repair capacity have been developed, but there are some limitations in most assays currently used. For example, the measurement of cell survival (usually by cloning efficiency) is too long and too expensive to apply in large-scale studies; the variability of UDS is ~20%, depending on the growing potential of the cultured cells and the variability of the HCR assay differs a lot from one laboratory to another (3,4). Recently, the comet assay has been used to measure the DNA repair capacity of human lymphocytes from different individuals, as a rapid screening assay. The used tests in this experiment were based on DNA damage induced with a chemical (e.g. BLM) or with physical (e.g. UVC) agents. However, the mechanism by which UVC induces DNA damage is different from that by which BLM induces DNA damage. UVC induces 6–4 photoproducts and cyclobutane pyrimidine dimers (CPD) which are also repaired by NER (2,13,14,24–26). BLM is a radiomimetic agent causing mainly single-strand breaks and double-strand breaks by forming a complex with ferrous ions and molecular oxygen, resulting in the release of oxygen radicals at the site of DNA intercalation. Only a very small proportion of single-strand breaks can be rejoined directly by DNA ligase; the rest are repaired mainly by BER, HR and NHEJ (17,27). In this experiment, the results of the DNA repair capacity level measured with both the results of the UVC test and BLM test in cancer patients and controls were very similar and this showed that the average DRP of the cancer patient group was significantly lower than that of the control group. But there was a small difference between the UVC and the BLM test for individuals, i.e. the DNA repair capacity level for a few of individuals in the UVC test was different from that in the BLM test. For example, lymphocytes from No. 2 patient and No.12 patient showed great efficiency in repairing the DNA lesions induced in the BLM challenge test, but the same two patients expressed lower DNA repair capacity level in the UVC test. This difference indicates the possibility that individuals have different susceptibilities to BLM and UVC or that there are different DNA repair pathways in the UVC and the BLM tests so that the same individual reflects different DNA repair capacity levels in two different tests. We suggest that two or more different mutagen challenge tests should be used to detect human DNA repair capacity in a molecular epidemiological study. The results obtained from various tests will be more objective than those from a single test.

Meanwhile, in this experiment it was interesting to find that the MTL at baseline was slightly higher in controls than that in patients (see Tables II and III). There was no significant difference between the two groups, which was analyzed by rank-sum test. However, this result was not consistent with the relevant literature (22,23), which reported the DNA damage at baseline of cancer patients was higher than that of controls. This discrepancy might be related to the samples, e.g. life-style and sample-size.

In this study, it was found that the MTL at 90 and 240 min after UV radiation was higher in controls than in patients, but

lymphocyte assays. The differences in DNA repair capacity among individuals reflect genetic differences. The DNA repair capacity in different subpopulations of lymphocytes from the same individual has similar repair capacity, and the intra-individual variation in the repair capacity is significantly smaller than the variation among individuals (4,17). Therefore, detecting DRPs (%) of human peripheral lymphocytes can express individual DNA repair capacity.

Several case–control studies have indicated that low DNA repair capacity is an independent risk factor for several kinds of cancers (1,2,12,13,19–23). Popanda et al. (20) reported that deficiency in DNA repair is a risk factor for the development of breast cancer; Wu et al. (21) reported that the DNA repair capacity of lung cancer patients was significantly lower than that of controls; Udumudi et al. (22) found that low DNA repair capacity may be an important risk factor for various cancers.

Up to the present, five categories of assays of DNA repair capacity have been developed, but there are some limitations in most assays currently used. For example, the measurement of cell survival (usually by cloning efficiency) is too long and too expensive to apply in large-scale studies; the variability of UDS is ~20%, depending on the growing potential of the cultured cells and the variability of the HCR assay differs a lot from one laboratory to another (3,4). Recently, the comet assay has been used to measure the DNA repair capacity of human lymphocytes from different individuals, as a rapid screening assay. The used tests in this experiment were based on DNA damage induced with a chemical (e.g. BLM) or with physical (e.g. UVC) agents. However, the mechanism by which UVC induces DNA damage is different from that by which BLM induces DNA damage. UVC induces 6–4 photoproducts and cyclobutane pyrimidine dimers (CPD) which are also repaired by NER (2,13,14,24–26). BLM is a radiomimetic agent causing mainly single-strand breaks and double-strand breaks by forming a complex with ferrous ions and molecular oxygen, resulting in the release of oxygen radicals at the site of DNA intercalation. Only a very small proportion of single-strand breaks can be rejoined directly by DNA ligase; the rest are repaired mainly by BER, HR and NHEJ (17,27). In this experiment, the results of the DNA repair capacity level measured with both the results of the UVC test and BLM test in cancer patients and controls were very similar and this showed that the average DRP of the cancer patient group was significantly lower than that of the control group. But there was a small difference between the UVC and the BLM test for individuals, i.e. the DNA repair capacity level for a few of individuals in the UVC test was different from that in the BLM test. For example, lymphocytes from No. 2 patient and No.12 patient showed great efficiency in repairing the DNA lesions induced in the BLM challenge test, but the same two patients expressed lower DNA repair capacity level in the UVC test. This difference indicates the possibility that individuals have different susceptibilities to BLM and UVC or that there are different DNA repair pathways in the UVC and the BLM tests so that the same individual reflects different DNA repair capacity levels in two different tests. We suggest that two or more different mutagen challenge tests should be used to detect human DNA repair capacity in a molecular epidemiological study. The results obtained from various tests will be more objective than those from a single test.

Meanwhile, in this experiment it was interesting to find that the MTL at baseline was slightly higher in controls than that in patients (see Tables II and III). There was no significant difference between the two groups, which was analyzed by rank-sum test. However, this result was not consistent with the relevant literature (22,23), which reported the DNA damage at baseline of cancer patients was higher than that of controls. This discrepancy might be related to the samples, e.g. life-style and sample-size.

In this study, it was found that the MTL at 90 and 240 min after UV radiation was higher in controls than in patients, but

lymphocyte assays. The differences in DNA repair capacity among individuals reflect genetic differences. The DNA repair capacity in different subpopulations of lymphocytes from the same individual has similar repair capacity, and the intra-individual variation in the repair capacity is significantly smaller than the variation among individuals (4,17). Therefore, detecting DRPs (%) of human peripheral lymphocytes can express individual DNA repair capacity.

Several case–control studies have indicated that low DNA repair capacity is an independent risk factor for several kinds of cancers (1,2,12,13,19–23). Popanda et al. (20) reported that deficiency in DNA repair is a risk factor for the development of breast cancer; Wu et al. (21) reported that the DNA repair capacity of lung cancer patients was significantly lower than
still DRP in patients was lower than that in controls. Because at 90 min after UV radiation, DNA incision is dominant, low MTL can express DNA incision decrease and low DNA capacity. At 240 min after UV radiation, most of DNA breaks are repaired, so the MTL reflects repair level. However, the lower MTL at 240 min after UV radiation appeared in cancer patients, which might not be due to the high DNA repair capacity but due to the significant decrease of DNA incision at 90 min after UV radiation. According to the DRP formula, DNA repair capacity value was related not only to DNA breaks at 90 min after UV radiation but also to DNA breaks at 240 min after UV radiation.

Acknowledgement
This research work was supported by International Cooperative Foundation of Science-Technique Bureau of Zhejiang Province (No. 012104), 2001–2002.

References

Received on January 25, 2005; revised on March 28, 2005; accepted on April 14, 2005