Immune response to ultraviolet radiation-modified skin antigens has been suggested as a pathomechanism of skin lesions in discoid lupus erythematosus and polymorphous light eruption. In order to elucidate the role of T-lymphocyte subsets in this response, we studied the distribution of CD45RO⁺, CD45RA⁺, and CD31⁺ cells and the endothelial expression of adhesion molecules E-selectin/P-selectin, intercellular adhesion molecule-1 and CD31 antigen in photoprovoked and spontaneous skin lesions. Typically, CD45RA⁺ cells were the prevailing inflammatory cell population of discoid lupus erythematosus, whereas CD45RO⁺ cells prevailed in both diseases and in healthy controls. Epidermotropism of any T-cell subset was more typical of discoid lupus erythematosus, whereas no major differences in endothelial adhesion molecule expression was found between the 2 diseases. Strong keratinocyte ICAM-1 expression was associated with adjacent CD45RO⁺ cell infiltrates, not with CD45RA⁺ or CD31⁺ cell infiltrates. We conclude that the cellular immune response to UV radiation is dissimilar in discoid lupus erythematosus and polymorphous light eruption. Key words: CD45RO⁺ cells; CD45RA⁺ cells; CD31⁺ cells; helper inducer; suppressor inducer.

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PATIENTS AND METHODS

Patients

The study group comprised 2 male and 8 female DLE patients (mean age 40 years, range 14 – 78 years), and 9 female PLE patients (mean age 38 years, range 12 – 52 years), who had been followed-up at the Department of Dermatology in Tampere University Hospital, Tampere, Finland (Table I). The diagnoses of DLE and PLE were based on generally accepted clinical, (immuno)histological and serological findings (16). Four DLE patients had also experienced PLE-like symptoms. As controls, 13 healthy medical students or members of hospital staff, without any history of photosensitivity, volunteered (7 men, 6 women, mean age 30 years, range 16 – 42 years).

Photoprovocation

Eight DLE patients, 6 PLE patients and 5 control persons (Table I) were UVA- and UVB- provoked with UVASUN 3000 (emission spectrum 340 – 400 nm) and UVB-provoked with Philips TL 20W/12 (emission spectrum mainly 280 – 370 nm), as described previously (17). The provocations were performed on intact upper back, upper arm or forearm skin, of 5 × 8 cm skin area, during 3 consecutive days after the minimal erythema dose (MED) for both UVA and UVB were determined. Individual UVR doses used in patients and control persons were 10 – 100 J/cm² (maximally 2 MEDs) of UVA and 1.3 – 2 MEDs of UVB. The mean total doses of UVA and UVB varied from 293 to 300 J/cm² and from 4.8 to 5.3 MEDs, respectively. The
procedure was approved by the ethics committee of the hospital and was performed, after informed consent, during 3 consecutive days. The test areas were evaluated about 24 h after each irradiation and thereafter every 4–7 days for up to 3–6 weeks. Any erythematous papular-vesicular or plaque photoprovocation reaction was considered pathological. Erythema, and eventual slight oedema, disappearing within 3 days, as well as pigmentation were considered normal (17).

Immunohistochemical and histological studies of skin biopsies

A biopsy was obtained for immunohistochemical studies from DLE- and PLE-like lesions as soon as a clinically pathological UVA- or UVB-provoked reaction was seen. Serial biopsies were further obtained 2 or 3 times at approximately 7-day intervals as long as the lesion persisted. The mean interval between the last provocation and the biopsy was 11 days (range 1–31 days) in DLE patients, 3 days (range 1–8 days) in PLE patients and 7 days (range 6–7 days) in control persons. The short mean interval in PLE patients was due to the short duration of the skin rash. In addition, spontaneous DLE and PLE lesions from sun-exposed skin, non-lesional UVA- and UVB-provoked skin from both patients and control persons and non-UVR-exposed intact skin of healthy control persons were examined immunohistologically (Table I).

The biopsy specimens were snap-frozen in liquid nitrogen and stored at −70°C until analysis. The avidin-biotin peroxidase technique, using a Vectastain Elite ABC kit (Vector Laboratories, Burlingame, CA, USA), was used for immunohistochemistry. Briefly, 5-µm thick cryostat sections were fixed in cold acetone followed by chloroform, and blocked with normal horse serum. The sections were then incubated with primary mouse monoclonal antibodies, diluted in 0.01 mol/l phosphate-buffered saline containing 0.1% bovine serum albumin, followed by biotinylated secondary antibody. The following monoclonal antibodies were used: CD4 (OKT-4A, Ortho Diagnostic Systems Inc, Raritan, NJ, USA) dilution 1:10, CD8 (Leu 2a, Beckton-Dickinson, San Jose, CA, USA) dilution 1:200, CD22 (isotype IgG1 kappa, a marker for B-cells, Dako, Glostrup, Denmark.) dilution 1:100, CD45RO (Central Laboratory of the Netherlands Red Cross Blood Transfusion Service (CLB), Amsterdam, the Netherlands) dilution 1:30, CD45RA (CLB) dilution 1:15, CD31 (platelet/endothelial cell adhesion molecule-1, CLB) dilution 1:200, CD54 (ICAM-1, R&D Systems, Abingdon, UK) dilution 1:2000, CD62E/CD62P (E-selectin/P-selectin, R&D Systems) dilution 1:2000. After quenching the endogenous peroxidase with 0.3% H₂O₂ in methanol, the sections were incubated with an avidin-biotin peroxidase complex. The reaction was visualized with diaminobenzidine and the slides were counterstained with haematoxylin.

The immunostained sections were examined independently by 2 of the authors (TH and AR), blinded to identity and time-point of the biopsy. The overall infiltration of inflammatory cells was graded as scanty, moderate, strong or very strong. As counting of the exact number of inflammatory cells was considered insufficiently accurate in most frozen specimens, the proportional quantity of the cells was estimated and marked as + if <25%, ++ if 26–50%, +++ if 51–75% and ++++ if 76–100% of the infiltrating mononuclear cells stained positively. For statistical analysis, the values were scored from 1 to 4, respectively. Intraepidermal infiltration of inflammatory cells was graded as scattered, focal or wide. Endothelial cell staining was graded as weak (=1), moderate (=2), strong (=3) and very strong (=4). In order to grade the epidermal (keratinocyte) ICAM-1 staining, the scores of 4 variables were added: (i) intensity of the reaction; (ii) quantity of positive cells on the horizontal; and (iii) vertical axes of the section (each scored from 0 to 3) and (iv) type of the staining, which was either intracellular (scored as 1) or membranous (scored as 2). Summing up the scores, 4 or 5 were graded as weak, 6 or 7 as moderate, 8 or 9 as strong and 10 or 11 as very strong staining.

Biopsy specimens for routine histological evaluation were obtained from 6 UVA- or UVB-provoked or spontaneous DLE lesions and from 10 UVA- or UVB-provoked or spontaneous PLE lesions simultaneously with the biopsies for immunohistochemistry.

Statistical analysis

For comparing the proportional quantity of T-cell subsets in different patient and control groups and the associations of strong epidermal expression of CD54 (ICAM-1) to different T-cell subsets, Fisher’s exact test (2-tailed) was used and performed with Statistics® for Windows (Version 5.1, StatSoft Inc, Tulsa, Okla, USA). Values of p<0.05 were considered statistically significant.

RESULTS

Inflammatory cell subtypes in photoprovoked and spontaneous lesions of DLE and PLE

Six of 8 DLE lesions and 10 of 13 PLE lesions (photo-provoked or spontaneous) were examined histologically. All 6
DLE lesions fulfilled the criteria of LE histology. In the PLE lesions, a PLE-like histology was seen in 4 biopsies, whereas 6 biopsy specimens showed unspecific perivascular dermatitis, often seen as the only histopathological finding in PLE (16).

In photoprovoked or spontaneous DLE and PLE lesions, CD4+ T-cells were the prevailing cell population of the inflammatory cell infiltrations (>50% of the cells positive for CD4 antigen) and outnumbered CD8+ cells in all DLE and PLE lesions examined for these markers. Sparse CD22+ cells (representing B-lymphocytes) were found only occasionally among mononuclear cell infiltrates in 7 biopsy specimens examined (5 DLE and 2 PLE lesions, either photoprovoked or spontaneous).

Of the CD45 subsets, CD45RA+ cells were the prevailing cell population almost only in DLE lesions, whereas CD45RO+ cells prevailed in most skin samples in both patients and control persons (Table II). CD31+ cells did not clearly dominate in the inflammatory infiltrates of any patient or control group, although they tended to be somewhat more numerous in DLE lesions than in other samples studied (Table II).

In DLE lesions, CD45RO+, CD45RA+ and CD31+ cells were seen as subepidermal band-like or intraepidermal infiltrates in 60–100% of the biopsy specimens. These patterns were statistically less frequent in PLE lesions, found in 9–46% of the biopsy specimens (p-values ranged from 0.0005 for intraepidermal CD45RO+ cells to 0.0384 for subepidermal CD31+ cells). Furthermore, in PLE lesions with subepidermal band-like cell infiltration, typically dermal papillae (besides perivascular spaces) were invaded, while a more dispersed and continuous infiltration was seen in DLE lesions. Subepidermal band-like or intraepidermal cell infiltrates were found in only 1 and 3 specimens, respectively. Intraepidermal or band-like subepidermal infiltration of CD45RO+ cells persisted in all biopsy specimens taken later than 9 days after the provocation. During such a later time-point, also CD45RA+ (9 of 10 biopsy specimens examined) and CD31+ cells (all 10 biopsy specimens examined) were found as intraepidermal or band-like subepidermal infiltrations.

In neither DLE nor PLE lesions, clear-cut differences in relation to UVA or UVB exposure in the dermal or epidermal invasion of the cell types examined were found. Neither were there any major differences in cellular immune response between spontaneous and UVR-induced skin lesions in either diseases. The low number of spontaneous lesions did not permit any statistical comparisons, however (data not shown).

### Table II. Percentage of CD45RA+, CD45RO+ and CD31+ cells among all inflammatory cells in skin samples of DLE, PLE and controls. The numbers denote samples

<table>
<thead>
<tr>
<th></th>
<th>UV-provoked or spontaneous DLE lesions (n=15)</th>
<th>Non-lesional UV-provoked skin in DLE patients (n=9)</th>
<th>UV-provoked or spontaneous PLE lesions (n=11)</th>
<th>Non-lesional UV-provoked skin in PLE patients (n=3)</th>
<th>UV-provoked healthy skin (n=10)</th>
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<td><strong>CD45RA+ cells</strong></td>
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<td><strong>CD31+ cells</strong></td>
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<td>0–25%</td>
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*For statistical analysis (Fisher’s exact, 2-tailed) the values of 0–25% and 26–50% were pooled and those of 76–100% and 51–75%, respectively. All the different groups were compared statistically with each other, except for the group ‘non-lesional UV-provoked skin in PLE patients’, which was excluded due to the small number of samples. Only the statistically significant p values between different groups are shown. DLE = discoid lupus erythematosus; PLE = polymorphous light eruption.

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*Endothelial E-selectin/P-selectin, ICAM-1 and CD31 antigen expression and association of epidermal ICAM-1 expression to inflammatory cell subtypes*

The endothelial expression of E-selectin/P-selectin and ICAM-1 was upregulated in photoprovoked skin sites in both patients and control persons (data not shown). The median values between different groups are shown.
grade of endothelial E-selectin/P-selectin staining was strong (grade 3) and that of ICAM-1 and CD31 antigen moderate (grade 2) in both DLE and PLE lesions. Thus, no clear differences in endothelial adhesion molecules examined were observed between DLE and PLE.

When evaluating the relationship of keratinocyte ICAM-1 expression to different T-lymphocyte subsets it was observed that strong or very strong (scores 8–11) keratinocyte ICAM-1 expression, either in DLE or in PLE lesions, associated statistically significantly more often with adjacent intra- or subepidermal CD45RO\(^+\) cell infiltrates than with CD45RA\(^+\) or CD31\(^+\) cell infiltrates \((p=0.003\) and 0.0004, respectively, Fig. 1).

DISCUSSION

We examined the dermal and epidermal infiltration pattern of naive and memory T-cells in UVA- and UVB-induced and spontaneous DLE and PLE lesions to find eventual differences between the 2 diseases. We also compared the findings with those obtained from the UVR-provoked healthy skin of control persons. As our main intention was to evaluate the ongoing...
immunological process necessary to maintain the skin lesion and not the initial UVR-induced events, the serial biopsies were taken several days or weeks after UVR provocation.

It was typical only for DLE lesions that CD45RA\(^+\) cells were the prevailing cell population among inflammatory cell infiltrations. The phenomenon that in some DLE lesions the proportion of both CD45RA\(^+\) and CD45RO\(^+\) cells was over 50\%, refers to the dual positivity of these 2 antigens. This obviously means an interchanging phase between CD45RA\(^+\) and CD45RO\(^+\) cells, which has been shown to occur (11). The observation of CD45RA\(^+\) cell dominance in DLE lesions together with our finding that intra- or subepidermal CD45RA\(^+\) cell infiltrates were more common in DLE than in PLE lesions suggests a role for CD45RA\(^+\) cells (regarded as suppressor inducer cells) in the pathogenesis of keratinocyte damage in DLE. Interestingly, the activity of SLE has been reported to associate positively with the number of circulating CD45RA\(^+\) cells, but not with CD45RO\(^+\) cells (regarded as helper inducer cells) (18), which also refers to pathogenetic role of CD45RA\(^+\) cells in the process of LE. A contradictory finding with the present study was reported previously (19). According to this study only minor amounts of naive T-cells were found in DLE skin lesions. Compared with the present study, however, monoclonal antibodies of different source were used. Furthermore, the number of DLE lesions examined in the previous study was only 4 and the age of the lesions was not stated. As PLE patients were not biopsied later than 8 days after the provocation, we cannot totally exclude the possibility that biopsies taken at a later time-point from PLE lesions would have revealed more CD45RA\(^+\) infiltrations. It is not probable, however, that the clinically entirely resolved reaction sites would have contained considerable amounts of pathogenetically important inflammatory cells.

Our finding of CD45RO\(^+\) cell dominance among the inflammatory cell infiltrates elicited by UVR provocation in healthy control skin agrees with the recent report of selective influx of memory CD4\(^+\) T-cells into the human healthy skin upon UVR irradiation (20). As CD45RO\(^+\) dominance was found in both DLE and PLE skin lesions (spontaneous and photoprovoked) and, also, in UVR-provoked non-lesional skin of both disorders, influx of CD45RO\(^+\) cells does not discriminate between DLE and PLE, and is in keeping with earlier reports of preferentially CD45RO\(^+\) cells in several inflammatory dermatoses (19, 21).

CD31 antigen has been shown to be expressed on such T-cells that mostly display the CD45RA\(^+\) phenotype (22) and on those CD45RO\(^+\) cells that are at an intermediate state of maturation (12). The infiltration kinetics of CD31\(^+\) cells followed rather than that of CD45RA\(^+\) than CD45RO\(^+\) cells in the present study.

Concurrent with the previous studies, the endothelial expression of E-selectin/P-selectin and ICAM-1 were upregulated with UV-provocation in healthy control persons, whereas the expression of CD31\(^+\) did not change due to UV irradiation (23, 24). Between the 2 diseases examined, there were no major differences in the endothelial expression of any of the adhesion molecule studied. This suggests that the mechanism of adhesion and transmigration of the T-lymphocytes through the dermal endothelial cells does not differ in the skin lesions of PLE and DLE.

In several skin disorders, colocalization of ICAM-1-positive keratinocytes and leukocytic dermal infiltration has been observed (8), whereas in early UVR-induced LE lesions, such an association has not always been found (25). We now show that a strong epidermal ICAM-1 expression associates statistically significantly more often with CD45RO\(^+\) than with CD45RA\(^+\) or CD31\(^+\) cell infiltrations. This finding supports the suggestion of recent in vitro studies that naive resting CD4\(^+\) T-cells may utilize other than ICAM-1-mediated adhesion mechanisms (15, 26). However, our finding of a different pattern of intra- or subepidermal infiltration of CD45RO\(^+\) cells despite an equally strong expression of epidermal ICAM-1 in DLE compared with PLE lesions remains to be explained.

In conclusion, a dissimilar pattern of naive and memory T-cell invasion in the skin in DLE compared with PLE suggests a different immunopathomechanism in these 2 photoaggravated diseases. Furthermore, our findings suggest that besides CD45RO\(^+\) cells also CD45RA\(^+\) cells and CD31\(^+\) cells, attracted to the target site by other than ICAM-1 adhesion, play a role in the development of DLE skin lesions.

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