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Single Cilia in Human Epidermis Are Susceptible to Challenge

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Single cilia were found in melanocytes and basal keratinocytes in normal epidermis and in epidermis subjected to various types of exposure. Quantitative electron microscopy showed that about 31% of the melanocytes and 71% of the keratinocytes from normal skin possessed a ciliary apparatus, but there was a wide individual variation. A statistically significant decrease in the number of ciliated keratinocytes followed exposure to nickel, sodium lauryl sulphate, UVA and UVB irradiation. There was no statistically significant difference between controls and skin subjected to various exposures regarding the number of ciliated melanocytes.

We have earlier reported that single cilia are frequently seen on epithelial cells capable of mitotic activity in human oral and vaginal epithelia. The present study showed that single cilia react to external exposures. The cilium might be a sensitive, easily damaged organelle, or the decrease in ciliated cells might reflect a change in normal mitotic activity as a result of exposure. ***Key words: UV irradiation; sodium lauryl sulphate (SLS); nickel; melanocytes; keratinocytes.***

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Warfvinge & Elofsson (1) have reported on the occurrence of single cilia (9+0 cilia, solitary cilia or non-motile cilia) in oral and vaginal epithelium. The distribution pattern of the cilia was consistent with a role of keratinocyte cilia in mitosis, but a light-related sensory function, as suggested by Elofsson et al. (2, 3), could not be ruled out for melanocyte cilia. Another study has confirmed the presence of solitary cilia in vaginal epithelium of rodents during development (4), although only the surface of the vaginal epithelium was investigated. However, these cilia disappeared between postnatal day 8 and 10. Nothing was reported about the presence of cilia in the deeper layers of the epithelium.

Single cilia are found in various cell types. The occurrence of cilia in the CNS has recently been reviewed by Wolfrum & Nitsch (5). Cilia have been found in retinal receptor cells of the kitten, the neurosecretory cells of the preopticus nucleus of the goldfish, in neurons of the human neocortex, in the mammalian nucleus caudate/putamen complex, and in astroglia of cat.

The present work concerned the effects of UV-light and experimentally induced contact dermatitis on the number of ciliated basal cells. Extensive observations of normal skin revealed the existence of pronounced inter-individual variations in the number of such cells.

MATERIAL AND METHODS

The volunteer group comprised 12 adults. Punch biopsies (3 mm) were taken from the upper back in all cases. Two individuals were exposed to repeated suberythema UVB over the whole body 3–4 times a week for 3 weeks, resulting in a total dose of UVB 3.2 and 4.3 J/cm^2, respectively. Three individuals were exposed to ordinary solarium treatment, i.e. repeated whole-body UVA was applied 3–4 times a week for 3 weeks, resulting in a total dose of UVA 167, 216 and 216 J/cm^2, respectively. Biopsies were taken 24 h after the last UV irradiation. Three subjects, who were positive to nickel on patch testing, were challenged (5% $NiSO_4$ for 48 h) and biopsies were taken 24 h after removal of the patch. Three individuals were patch-tested with 1% sodium lauryl sulphate (SLS); biopsies were taken after 4, 8 and 24 h of exposure. Biopsies of the naturally suntanned skin were obtained from the same 3 individuals and from an additional subject during the summer. Unexposed skin biopsies were taken as controls in all 12 cases during the winter. These specimens were also used for the study of individual variations in the number of ciliated cells.

The biopsies were processed for electron microscopy according to a method described by Andersson (6). Each biopsy was serial sectioned (200–300 serial sections). Each melanocyte and 5–15 basal keratinocytes, whose entire cell body was situated within the series, were examined for fully developed, developing or reduced cilia. The mapping was performed by starting the microscopical examination in a section in the middle of the series (for example section 150). Each melanocyte and 5–15 basal keratinocytes, with visible nuclei in this section, were selected for mapping. These cells were scrutinized for cilia in every section ahead of and behind section 150, until the cells had disappeared. This procedure secures the disclosure of a single cilium, since a single cilium may appear on only 2 to 3 serial sections.

Statistics

Values were assessed as the arcsine transform of

$$\frac{\text{number of cells missing cilia}}{\text{total number of cells}}$$

Differences between test specimens and controls were compared using a t test for paired replicates. The correlation between the presence of cilia and time after SLS treatment was analyzed with the Page test (7).

RESULTS

The results from the mapping of ciliated and non-ciliated cells are presented in Table I.

Melanocytes

In all, 341 melanocytes were examined for single cilia. Of these melanocytes, 134 were from control skin and 31% possessed a ciliary apparatus. Fig. 1 shows the considerable individual variation found in the ciliation of the melanocyte population.

There was no statistically significant difference between controls and challenged skin regarding the number of ciliated melanocytes.

Keratinocytes

Of the 356 keratinocytes examined for single cilia, 129 keratinocytes were mapped in the control specimens and 71% of these possessed a ciliary apparatus.

The number of ciliated cells in normal skin varied between individuals (Fig. 2). The variation in this case was less pro-

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Table I. *Number of ciliated cells ("Cilium"), un-ciliated cells ("Missing") and cells with a reduced or developing ciliary apparatus ("Remnant") in the entire material*

Object	Treatment	[Melanocytes]			[Keratinocytes]		
		Cilium	Remnant	Missing	Cilium	Remnant	Missing
A	Normal	0	0	5	8	1	6
A	Nickel	0	1	6	0	2	7
B	Normal	0	1	6	1	4	4
B	Nickel	1	1	9	2	1	5
C	Normal	2	1	9	5	2	3
C	Nickel	1	2	9	3	4	6
D	Normal	2	3	3	4	8	2
D	UVB	1	2	3	2	0	12
E	Normal	2	0	8	3	3	7
E	UVB	0	1	5	3	2	6
F	Normal	0	8	3	6	4	1
F	UVA	0	0	6	1	2	4
G	Normal	0	2	12	5	4	2
G	UVA	0	0	11	1	3	10
H	Normal	1	5	8	6	8	0
H	UVA	3	4	7	3	1	9
I	Tanned	1	3	4	6	2	2
I	Normal	3	2	2	3	3	4
J	Tanned	1	0	5	5	1	5
J	Normal	0	2	13	4	4	2
J	SLS 4 h	0	2	11	7	1	4
J	SLS 8 h	0	0	9	7	2	3
J	SLS 24 h	0	0	15	1	4	8
K	Tanned	1	4	4	2	2	2
K	Normal	3	1	3	1	2	2
K	SLS 4 h	2	5	4	8	0	5
K	SLS 8 h	1	4	5	1	0	10
K	SLS 24 h	0	4	4	1	2	5
L	Tanned	3	1	3	8	0	1
L	Normal	1	3	20	1	2	4
L	SLS 4 h	0	4	11	0	6	6
L	SLS 8 h	0	3	12	3	3	6
L	SLS 24 h	1	1	6	0	2	7

nounced than in the melanocyte population. There was also an individual variation in the reaction to the different kinds of exposure. A significant reduction in the number of ciliated cells was observed after UVA/UVB irradiation (Fig. 3) ($p < 0.02$) and during inflammation (Ni/SLS 24 h; $p < 0.002$) (Fig. 4). Further, there was a correlation between the loss of cilia and time after SLS challenge ($p < 0.05$).

DISCUSSION

There is much evidence that cilia of the type found in epidermis may have a sensory function (for refs, see 1). Elofsson et al. (2, 3) presented the hypothesis that single cilia in human epidermis may have a sensory function in the regulation of pigmentation. A study of oral and vaginal epithelium by Warfvinge & Elofsson

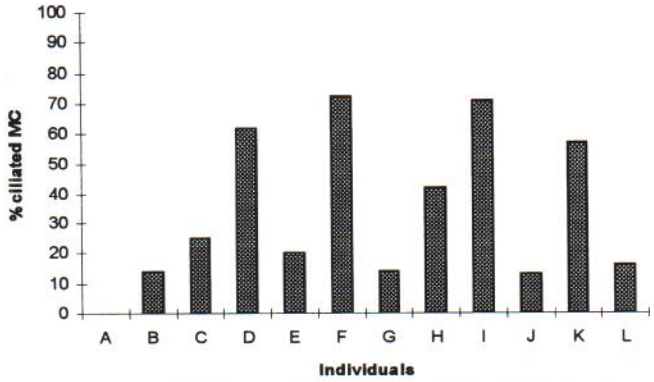

Fig. 1. Demonstration of the considerable individual variation found in the ciliation of the melanocyte (*MC*) population.

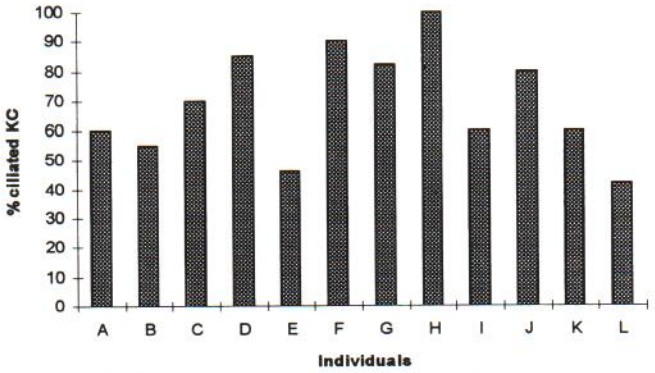

Fig. 2. Demonstration of the individual variation found in the ciliation of the keratinocyte (*KC*) population.

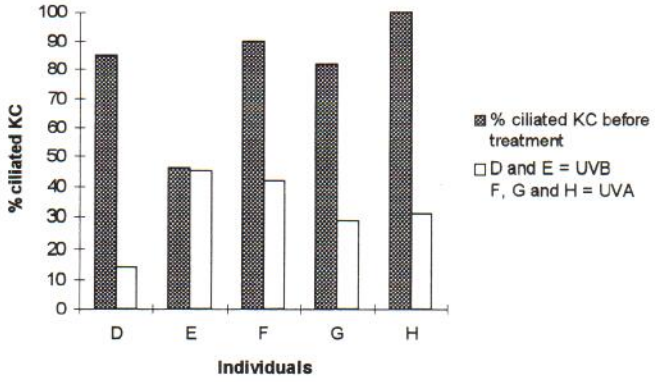

Fig. 3. The figure demonstrates the effect of UVA or UVB treatment on the number of ciliated keratinocytes (*KC*).

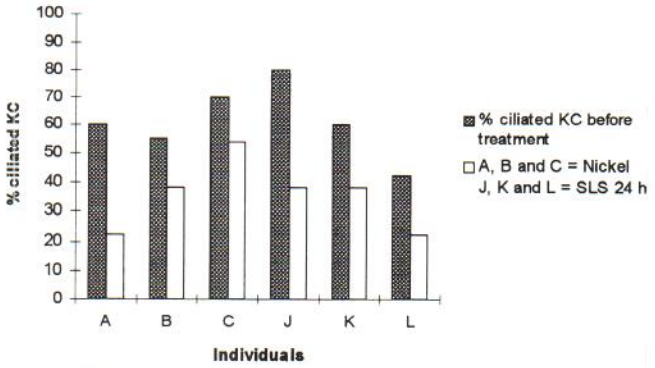

Fig. 4. The number of ciliated keratinocytes (*KC*) before and after treatment with nickel or SLS for 24 h.

(1) showed that different functions for melanocyte and keratinocyte cilia could not be excluded, because most of the melanocytes in these epithelia were non-ciliated, while basal keratinocytes were often ciliated. The fact that ciliated keratinocytes occurred in these tissues excluded a sensory function concerning light.

The present electron microscopic study comprised a large number of sections. For example, 341 melanocytes were studied; on average 120 sections are needed to scrutinize one whole cell body. A single cilium may appear on only 2 to 3 serial sections. This study provides new information regarding cilia, although from the statistical point of view, a larger sampling population can always be considered favourable.

Ciliated melanocytes were few in skin from the back and, moreover, showed no statistically significant decrease or increase in response to UV treatment or normal suntanning. Thus, it seems less likely that the melanocyte cilia have a sensory function in relation to light. However, it seems reasonable to assume that, in the view of the results obtained with the keratinocyte cilia, UV has a damaging effect on the ciliary apparatus.

Wilson & McWhorter (8) found occasional cilia in basal epidermis, whereas Elofsson et al. (3) found a much more regular occurrence of these organelles in basal keratinocytes. Both reports considered that the cilia might have a function related to mitotic activity. This view was supported by the finding that keratinocytes in oral and vaginal epithelium were found to have cilia only at sites of cell renewal (1). A sensory function for cilia is not excluded in this case, since the cilium may provide a specific site of action for messengers triggering mitosis.

A novel finding in this study was that UV irradiation and inflammatory situations (allergic and irritant contact dermatitis) caused a decrease in ciliation.

Warfvinge & Elofsson (1) emphasized that a presumed function of epidermal cilia is not readily studied experimentally. They recommended that the strategy of choice presently was to map the prevalence of cilia in various stratified epithelia to reveal the function of this enigmatic organelle. However, a significant negative conclusion from this study is that the extremely time-consuming electron microscopic mapping of epithelial cilia may be of little use in future searches for a function of epidermal solitary cilia.

These data do indicate, however, that the hypothesis regarding a UV sensor function has been invalidated. The function of the melanocyte cilia remains unknown, but the possibility is not eliminated that these cilia are also involved in mitotic regulation.

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