

## Evaluation of Scratch Movements by a New Scratch-Monitor to Analyze Nocturnal Itching in Atopic Dermatitis

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Itching is very important in atopic dermatitis, but the details of itching or scratch movements, especially during sleep at night, have not yet been fully comprehended. We designed a new, simple device, the Scratch-Monitor (SM), to evaluate scratch movements at night and assessed the usefulness of this device by a comparison involving 26 patients and 17 healthy controls. The SM, a box weighing only 25 g with a pressure sensor on the bottom, is attached to the back of each hand under a cotton glove and records the number as scratch movements per minute in the case of more than three successive changes of pressure. The SM indicated that patients with atopic dermatitis scratched more frequently and suffered more severe sleep disturbance than healthy controls. Although the SM had several problems related to specificity and sensitivity, we conclude that the SM is a useful tool for evaluating nocturnal itching. **Key words:** sleep disturbance; computer analysis; pressure sensor.

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There is no question that itching is of great importance in atopic dermatitis. However, since itching is a subjective sensation, it is difficult to evaluate its level objectively and accurately. If it were possible to measure itching or scratch movements clinically, we could select the best method of therapy for itching in atopic dermatitis. However, the details of itching or scratch movements, especially those during sleep at night, have not yet been fully clarified.

In recent years many devices for measuring the degree of itching have been used. For instance, as part of a patient's self-evaluation, VAS (visual analogue scale) has been used in Europe (1). VAS is very useful for evaluating the degree of itching when the subject is awake. Sometimes VAS can be used to make a global evaluation, such as for itching during the previous week. However, this method depends on the eagerness and intelligence of the subject. Besides its lack of objectivity, VAS cannot be utilized at night when itching is most severe.

To measure scratch movements at night several methods have been reported: muscle potential (2), proximity vibration transducer (3), self-winding watch (3), electromagnetic movement detector (4), paper strain gauge (5) and scratch radar (6). Bergasa & Jones (7) have described a computerized scratch-monitoring system based on piezoelectric devices attached to the fingernails.

In this report, we describe a newly designed, simple and easy-to-use device, the Scratch-Monitor (SM), to evaluate scratch movements at night in atopic dermatitis and assess its usefulness.

### MATERIAL AND METHODS

#### *The Scratch-Monitor and its problems*

The SM is a small plastic box, 4.5 cm long, 4.0 cm wide and 1.5 cm high, weighing only 25 g (Fig. 1). The switch button is on the upper side, and a button for the marker is on the left side. A pressure sensor is attached under the SM, by which the number of scratch movements is recorded if there are more than three consecutive changes in pressure at a rate of about once or more/second. Three levels of sensitivity are available for sensing the change of pressure. We used the medium sensitivity in this study. The SM can record data about 5 days continuously with a dry battery. It is installed under a cotton glove on the back of the hand and is taped on the front and rear so that it will not move. We used two cotton glove sizes to fit the hands of different patients.

The data are recorded as the numbers of scratch movements per minute (frequency) at each minute and are analyzed by software installed in a personal computer. However, the SM has the following problems related to specificity and sensitivity: the data do not always reflect the scratch movements exactly. When subjects grip or curve their hands, the SM sometimes registers a small pressure change. As a result, the SM may record a high frequency of movements that are not caused by scratching. When subjects are awake, they may use their fingers for various purposes, thereby causing confusing changes in pressure. The SM records all of these movements as scratch movements. Thus, the SM should be used only when subjects are asleep. In addition, the SM does not always count the number of scratch movements exactly.

#### *Sensitivity test*

We investigated the SM sensitivity in the following ways: in 10 healthy controls, we registered how many times the SM recorded scratching



Fig. 1. The Scratch-Monitor (SM). The two SMs (the right one is No.1 and the left one is No.2) have the same structure. The switch button is on the upper side, and a button for the marker is on the left side. A pressure sensor is under the SM, by which the number of scratch movements is recorded if there are more than three consecutive changes in pressure at a rate of about once or more/second.

on the thigh thirty times. This was repeated 10 times at intervals of 3 min.

### Subjects

Subjects consisted of 26 inpatients with atopic dermatitis, 14 males and 12 females, mean age 23.5 years (range 14 to 42 years), all fulfilling the diagnostic criteria of Hanifin & Rajka (8), who were in our hospital from October 1993 to April 1994, and 17 healthy controls, 8 males and 9 females, mean age 25.3 years (range 14 to 42 years). There were no significant differences in the age or sex distribution between the two groups of subjects. All patients had been hospitalized more than 2 weeks before our experiment. Prior to installing the SM, 15 patients had taken some antihistamines and 11 had not. At the hospital, 17 patients had been treated with some topical corticosteroids, while 9 had been treated without these.

The clinical severity of AD was determined as follows: 1. A patient with more than 50% of the body surface, according to the rule of nine, affected by atopic eczema was severe; 2. A patient with 10% to 50% was intermediate; 3. A patient with less than 10% or localized eczema was mild. The subjects included 13 severe, 8 intermediate, and 5 mild cases. All the patients were assessed by the same investigator, namely Kaoru Endo, just before the SM was installed.

As healthy controls, we chose normal volunteers with no histories of allergic or dermatological diseases. They all had the SM installed by their family members in their own home, instead of at hospital.

The study protocol was approved by the ethics committee of Habikino Hospital in September 1993. After the study had been fully explained, informed consent was obtained from all patients and healthy controls.

### Method

In this study we used two SMs, which had the same structure. Just before the patient went to bed at 21:30, the SM (No.1) and the SM (No.2) were always installed on the back of the left hand and the right hand, respectively, by a nurse when she used to turn off the lights in our hospital. As soon as the patient woke up, a nurse would remove the SMs and put the switch off.

This time only data from the right hand (the SM No.2) were used to analyze scratch movements. If a subject was left-handed, the SM No.2 was installed on the left hand.

### Statistical analysis

Statistical analysis was performed with Stat View (Abacus Concepts, Inc., Berkeley, CA, 1996). Group comparisons were analyzed by the Student's *t*-test, and intergroup comparisons were analyzed by the paired *t*-test. All *p* values were two-sided and were considered significant when they were less than 0.05.

## RESULTS

### Sensitivity test results

The average number was  $22.1 \pm 9.4$ , and sensitivity was 0.74 (male 0.65, female 0.83). We found that the number of scratch movements recorded by the SM had a large dispersion. We considered the following as causes of this dispersion: 1. differences in hand size; 2. minute differences in the position of the pressure sensor; 3. differences in the strength of the taping; and 4. differences in the method of scratching.

Patients with atopic dermatitis scratch in various ways, which are not always registered by the SM correctly. For instance, if the subject scratches with only his/her thumb and the sensor does not sense the change in pressure, the SM cannot record the movement.

We developed the SM to replace the scratch movements with a numerical value to permit evaluation of the itch, rather

than to measure the correct frequency of the scratch movements.

But in spite of these weak points, we concluded that the SM would register the scratch movements with sufficient exactitude to permit analysis of nocturnal scratching and to make clinical application worthwhile.

Patients with atopic dermatitis complain of itching in the daytime less frequently than at night. Therefore, we consider that the analysis of nocturnal scratching is equal to that of nocturnal itching or itching, since there is no restraint on itching.

### Presentation of the typical pattern

Typical patterns from patients with atopic dermatitis with severe and intermediate symptoms and healthy controls are presented in Fig. 2 a, b, and c, respectively. The horizontal axis shows the time course, after the installation of the SM, in 1-min units. The vertical axis shows the number of scratch movements counted every minute. The expressed number is one tenth the actual number.

The pattern exhibited by the healthy controls illustrates very scattered and low peaks, which indicates that the movements of his/her hand is sporadic and sparse during sleep, compared with those of patients with atopic dermatitis. This result shows that the SM counts very few movements in a healthy control.

On the other hand, the pattern exhibited by a patient with a severe form of the disease obviously illustrates much denser and higher peaks than that exhibited by an intermediate patient, which indicates that the former moves his hands or fingers more frequently than the latter. We believe that a series of extremely high peaks, which are caused by grasping fingers and are regarded beyond the ability of scratching, indicates that the patient is awake, since when we asked these patients, most of them answered that they had been awake around that time.

### Definitions in the analysis of scratch movements (Table I)

In order to evaluate the nocturnal itching of atopic dermatitis with a numerical value, we have to define some terms. "Pre-asleep time" shows if the subject falls asleep easily. "Scratch rate" is used to compensate for the low specificity and sensitivity of the SM. If the number of scratch movements itself is unreliable, the rate of the total scratching time in the sleeping period can be substituted for the number of scratch movements. "Minute scratch records" is a numerical value including the demerits of the SM. It tends to be affected by high values continually recorded when subjects wake up in the middle of sleeping.

Many patients are often disturbed during sleep by itching. We regard sleep disturbance as another expression of the degree of itching. "Sound sleep rate", "hourly awake number" and "awake rate" show the level of sleep disturbance. We divide "sleeping time" into three equal parts (early, mid and late periods) to analyze differences of scratch movements between sleeping periods.

### Comparison between patients with atopic dermatitis and healthy controls (Table II)

"Sleeping time" was 469.5 min in patients with atopic dermatitis and 412.6 min in healthy controls, but this difference was

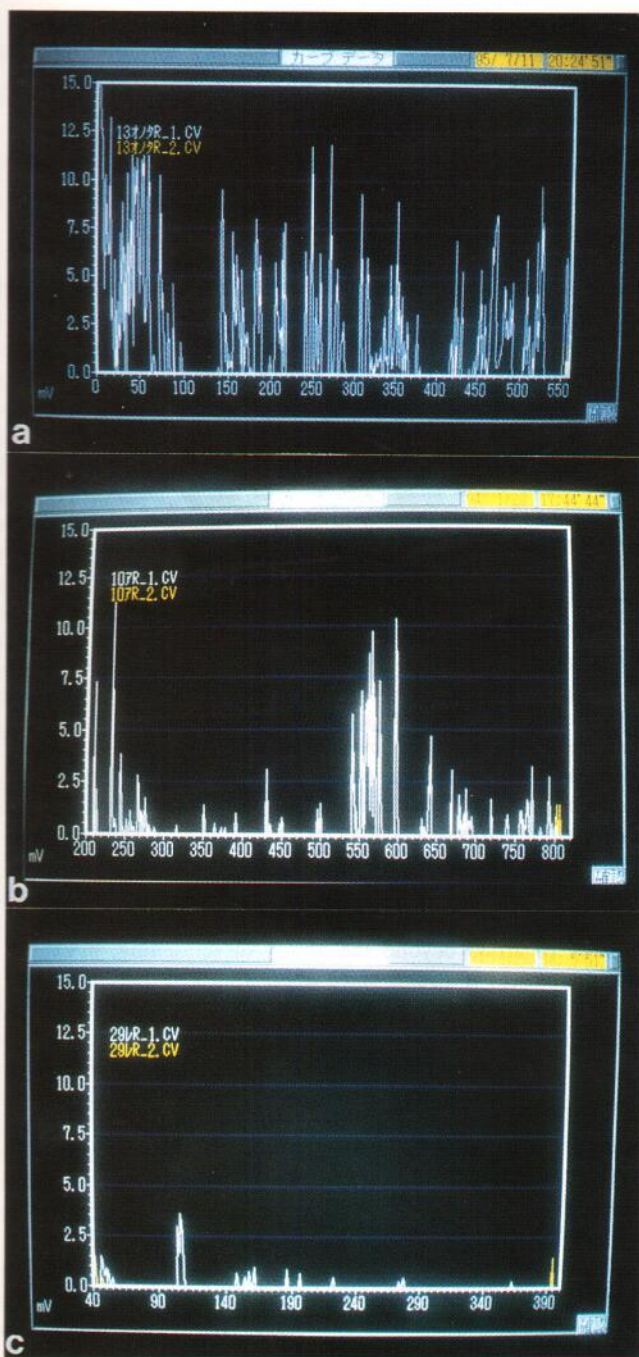


Fig. 2. Typical patterns from a patient with atopic dermatitis with severe symptoms (a), a patient with atopic dermatitis with intermediate symptoms (b) and a healthy control (c). The horizontal axis shows the time course (its unit is a minute) after the installation of the SM. The vertical axis shows the number of scratch movements counted every minute. The expressed number is one tenth the actual number.

not statistically significant. "Pre-asleep time" was longer in patients with atopic dermatitis (99.3 min) than in healthy controls (15.8 min), with a significant difference, which indicated that patients with atopic dermatitis needed more time to fall asleep.

"Scratch rate" was 0.228 in patients with atopic dermatitis and 0.054 in healthy controls, that is, the former was significantly higher than the latter. As in "scratch rate", a significant

Table I. Definition of the terms in the analysis of the SM

1. "Asleep" = the first time the SM records zero for 10 or more min, the beginning of zero
2. "Awake" = the point when scratch records other than zero begin just before the removal of the SM
3. "Sleeping time" (min) = time from "asleep" to "awake"
4. "Pre-asleep time" (min) = time from the attachment of the SM to "asleep"
5. Three phases of the sleeping period (the early, mid and late period) = three equal parts of sleeping time from "asleep" to "awake"
6. "Scratch rate" = total time with scratch records other than zero (min) / "sleeping time" (min)
7. "Minute scratch records" (no./min) = total scratch records / "sleeping time" (min)
8. "Sound sleeping state" = when the SM records zero continuously for more than 10 min
9. "Sound sleep rate" = sum of time in the sound sleeping state (min) / "sleeping time" (min)
10. "Awake bouts" = when a series of scratch records other than zero contains more than fifty or a number other than zero continues for more than 5 min
11. "Hourly awake number" (no./h) = number of "awake bouts" / "sleeping time" (hours)
12. "Awake rate" = sum of time in the "awake bouts" (min) / "sleeping time" (min.)

Table II. Results of the analysis of all patients and healthy controls

	Atopic dermatitis	Healthy control
Sleeping time (min)	469.5 ± 86.7	412.6 ± 84.2
Pre-asleep time (min)	99.3 ± 74.8*	15.8 ± 15.6
Scratch rate	0.228 ± 0.116*	0.054 ± 0.033
Minute scratch records	6.36 ± 4.96*	0.69 ± 0.65
Sound sleep rate	0.556 ± 0.152*	0.864 ± 0.091
Hourly awake number	0.912 ± 0.522*	0.079 ± 0.104
Awake rate	0.135 ± 0.129**	0.008 ± 0.011

\*  $p < 0.0001$ , \*\*  $p = 0.0003$ .

difference was found in "minute scratch records", which were 6.36 in patients with atopic dermatitis and 0.69 in healthy controls. "Sound sleep rate" showed 0.556 in patients with atopic dermatitis and 0.864 in healthy controls, a significant difference. A significant difference was also found in "hourly awake number" and "awake rate".

When "scratch rate" was analyzed for each phase of the sleeping period in patients with atopic dermatitis, we found it to be 0.270, 0.234 and 0.183 in the early, mid and late period, respectively. The rate in the late period was found to be significantly lower than that in the early period and that in the mid period ( $p < 0.01$ ). "Minute scratch records" in the mid and late period were also observed to be significantly lower ( $p < 0.05$  and  $0.001$ ) than those in the early period (9.00, 6.26 and 3.82 in the early, mid, and late period, respectively). The sound sleep rate was the same in all periods.

Therefore, we confirmed that patients with atopic dermatitis appear to make the fewest scratch movements before daybreak. This result agrees with our experience in clinical practice. However, "sound sleep rate" showed no significant difference in the various sleeping periods.

Table III. Relation of the analyses of patients with severe and less than intermediate symptoms

	Severe	Less than intermediate	<i>p</i> -value
Sleeping time (min)	456.2 ± 74.0	482.8 ± 95.9	0.454
Pre-asleep time (min)	113.3 ± 74.1	85.3 ± 72.8	0.360
Scratch rate	0.291 ± 0.120	0.165 ± 0.065	0.004
Minute scratch records	9.15 ± 5.03	3.57 ± 2.89	0.003
Sound sleep rate	0.484 ± 0.152	0.627 ± 0.081	0.016
Hourly awake number	1.316 ± 0.397	0.508 ± 0.252	<0.0001
Awake rate	0.201 ± 0.136	0.078 ± 0.068	0.007

#### Comparison of severe and mild disease (Table III)

"Sleeping time" and "pre-asleep time" showed no differences in the severe and mild groups. But there were significant differences in "scratch rate", "minute scratch records", "sound sleep rate", "hourly awake number" and "awake rate". These results support the conclusion objectively that nocturnal itching is greater in patients with severe atopic dermatitis, who suffer from more sleep disturbance.

From the results stated above, we conclude that the SM is a useful tool for evaluating nocturnal itching in atopic dermatitis.

#### DISCUSSION

Hägermark & Wahlgren (9) have stated that itching can be recorded and assessed at three different levels: 1. by intra-neuronal recording of the activity in the C fibers using micro-neurography; 2. by recording the scratch movements during sleep; and 3. by subjective assessment of the itch sensation. The ways of recording the scratch movements during sleep have all been rather complex and require that the patient stay in a hospital bed. But our device is simple enough to be applied to outpatients as well, which indicates that it would be possible to use it in daily clinical work. Moreover, because of its ease of use, it can also be used to assess the effect of various ways of treating atopic dermatitis. We intend to report an objective evaluation of an anti-histamine agent by using the SM.

In this study, no subject dropped out because we selected only submissive patients with full compliance and avoided patients with aggressive characters. In the preliminary study, many patients, about one out of 4, were inclined to remove the SM by themselves. They told us that they had not been able to sleep well with cotton gloves and the SM or had had some pain on their hands, caused by the sensor. Therefore, in advance, we asked the subjects to go to bed with cotton gloves for some days.

Patients with atopic dermatitis often suffer from insomnia because of severe itching at night. Previously, the level of sleep disturbance has been evaluated only by a patient's complaints, scratch marks on the body or blood-stained underwear. However, these methods are not sufficient to assess the insom-

nia of a patient with atopic dermatitis with a numerical value. Our device can also evaluate sleeping conditions at night relatively easily. For instance, a long "pre-asleep time" indicates difficulty in falling asleep, while a low "sound sleep rate" indicates waking up many times during the night. These values can be compared before treatment and after treatment for atopic dermatitis.

We designed the SM to objectively evaluate scratching and its clinical application. However, regrettably the number of scratch movements recorded by the SM is not always correct for expressing scratching by a patient with atopic dermatitis. As mentioned above, one of the reasons is that a patient with atopic dermatitis has various ways of scratching. When scratch movements are monitored by a TV-video system at night, many different styles may be observed in each patient. These styles can be classified into two types of scratch movements, namely sporadic and consecutive. Sporadic scratch movements cannot be measured by the SM, which registers only the number of times from more than three consecutive changes in pressure.

The SM is a second prototype, an improvement on the first one, which had a micro-switch attached on the tip of each patient's finger stall and a pedometer for registering the data. The first type could register the sum of the number of "on" and "off" by scratch movements at night, but we could not analyze the data in detail. Therefore, we expect that improvements in technology will lead to better apparatuses of this type.

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