The role of *Staphylococcus aureus* in atopic dermatitis: microbiological and immunological implications

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**Abstract**

**Introduction:** Atopic dermatitis (AD) is an inflammatory disease characterised by chronic and recurrent course. Its predominant symptom is skin pruritus. Therefore, many AD patients have recurrent skin infections and are susceptible to the colonisation of apparently healthy skin and nasal vestibule by *Staphylococcus aureus* (*S. aureus*). Some *S. aureus* strains are capable of producing exotoxins.

**Aim:** To assess the relation between the total IgE (tIgE) and asIgE targeted against SEA (SEA-sIgE) and SEB (SEB-sIgE), as indicators of the severity of the course of AD, and the presence of *S. aureus* on apparently healthy skin, in skin lesions and in the nasal vestibule.

**Material and methods:** The research was performed in a population of 134 AD patients (61 men and 73 women) aged 2–86 years. Three smears were collected for microbiological investigations: from the nasal vestibule, from the skin where lesions appeared at the moment of investigations and from the skin which was free from the eczema. On collection the material was cultured on solid and broth mediums. After incubation each medium was thoroughly analysed for the presence of *S. aureus*.

**Results:** There was a statistically significant correlation between healthy skin colonisation by *S. aureus* and increased SEA-sIgE. The same correlation was proved between healthy skin colonisation by *S. aureus* and increased SEB-sIgE. There was a statistically significant correlation between colonisation of the nasal vestibule by *S. aureus* and the SEA-sIgE and SEB-sIgE serum concentration.

**Conclusions:** It seems that the colonisation of the lesioned skin, healthy skin and the anterior nares by *S. aureus* is related with higher tIgE serum concentration, which translates to more severe course of the disease. Significantly increased SEA-IgE and SEB-IgE concentrations were observed in the patients whose tIgE serum concentration was statistically higher.

**Key words:** atopic dermatitis, *Staphylococcus aureus*. 

Introduction

Atopic dermatitis (AD) is an inflammatory disease characterised by chronic and recurrent course. Its predominant symptom is skin pruritus [1]. It is often related with the positive family history of atopy [2]. Disrupted epidermal barrier mechanisms seem to play a significant role in the AD pathogenesis [3].

During the course of an acute phase of AD we can observe imbalance between Th1 and Th2 cells, the latter being more numerous [4]. In consequence, there is an intensified humoral response and reduced cellular immunity, which leads to higher susceptibility to infections [2, 5]. Therefore, many AD patients have recurrent skin infections and are susceptible to the colonisation of apparently healthy skin and nasal vestibule by *Staphylococcus aureus* (*S. aureus*). The pathogen is commonly thought to exacerbate the dermatological condition [8].

Some *S. aureus* strains are capable of producing exotoxins, such as staphylococcal enterotoxins A (SEA),
The nasal vestibule and/or apparently healthy skin and/or diseased skin to sterile swabs which had been moistened with sterile saline for better adsorption of microorganisms from the surface of the mucosa and/or skin. On collection the material was cultured on solid and broth mediums provided by bioMerieux and Argenta. Culture was carried out on the Columbia agar with 5% sheep blood and Chapman’s medium. After incubation each medium was thoroughly analysed for the presence of S. aureus. The strains were identified and their sensitivity to antibiotics was assessed by means of the Vitek 2 system (bioMerieux).

Apart from that, about 10 ml of venous blood was collected from each patient. The serum samples were stored at a temperature of −75°C until analysis. The tIgE and asIgE were measured by means of the fluoro-immuno-enzymatic method, according to the manufacturer’s instructions (UniCAP, Phadia). The asIgE values greater than 0.7 kU/l (i.e. class 2) were regarded as a considerably higher level of antibodies. The Mann-Whitney test was used for comparison of the tIgE serum concentration, SEA-sIgE and SEB-sIgE as well as the frequency of S. aureus incidence on apparently healthy skin, in skin lesions and in the anterior nares.

Fisher’s exact test was used to examine the relation between the incidence of S. aureus on apparently healthy skin and in skin lesions and the high tIgE serum concentration according to the age norm.

Results

The mean tIgE in the patients with S. aureus on apparently healthy skin was 2,695 ±2,249.1 kU/l. When the culturing from apparently healthy skin gave negative results, the mean tIgE was 1,428 ±1,830.8 kU/l.

The mean tIgE in the patients with S. aureus in skin lesions was 2,460 ±2,190.7 kU/l. In the group of patients without S. aureus in skin lesions, the mean tIgE was 939 ±1,229.4 kU/l.

In the group of patients carrying S. aureus in the nasal vestibule, the mean tIgE was 2,483 ±2,159.1 kU/l. In the patients who did not carry S. aureus, the mean tIgE was 927 ±1,542.8 kU/l.

The statistical analysis of the results of tIgE measurements in the patients’ serum showed that there was a statistically significant relation between the presence of S. aureus in different locations and the tIgE level (Table 1).

As far as SEA is concerned, in the patients with S. aureus in skin lesions, the mean SEA-sIgE was 1.65 ±3.742 kU/l. In those without S. aureus in that location, the mean SEA-sIgE was 1.60 ±0.914 kU/l (Table 2).

In the patients with negative S. aureus cultures on apparently healthy skin, the mean SEA-sIgE was 2.55 ±4.909 kU/l. In those with negative cultures, the mean SEA-sIgE was 0.604 ±0.914 kU/l (Table 2).

If the patients carried S. aureus in their nasal vestibule, the mean SEA-sIgE was 2.14 ±4.397 kU/l. The mean
SEA-sIgE in the patients without \textit{S. aureus} in their anterior nares was $1.362 \pm 3.802$ kU/l (Table 3).

As far as SEB is concerned, the mean serum SEB-sIgE values amounted to $1.13 \pm 1.804$ kU/l in the patients with \textit{S. aureus} in skin lesions. If \textit{S. aureus} was not found, the SEB-sIgE value was $0.417$ kU/l.

If \textit{S. aureus} was found on apparently healthy skin, the SEB-sIgE values amounted to $2.15 \pm 3.849$ kU/l. If \textit{S. aureus} was not found, the SEB-sIgE value was $0.417$ kU/l.

### Table 1. The mean tIgE in the AD patients’ serum, allowing for the presence of \textit{S. aureus} in different locations, and the results of statistical analysis

| tIgE [kU/l] | Staphylococcus found | Staphylococcus not found | Statistical significance |
|------------|----------------------|--------------------------|-------------------------|
| Skin lesions: | n = 64 | n = 15 | $p = 0.0316^*$ |
| Mean tIgE ± SD | 2,460 ±2,190.7 | 939 ±1,229.4 | |
| Median | 2,103 | 479 | |
| Min.–max. | 2.63–5,001 | 10.3–3,857 | |
| Healthy skin: | n = 48 | n = 31 | $p = 0.0272^*$ |
| Mean tIgE ± SD | 2,695 ±2,249.1 | 1,428 ±1,830.8 | |
| Median | 2829 | 848 | |
| Min.–max. | 2.63–5,001 | 12.1–5,001 | |
| Anterior nares: | n = 67 | n = 12 | $p = 0.0216^*$ |
| Mean tIgE ± SD | 2,483 ±2,159.1 | 927 ±1,542.8 | |
| Median | 2,263.0 | 191.0 | |
| Min.–max. | 2.63–5,001 | 10.3–5,001 | |

*Mann-Whitney test.

### Table 2. The tIgE results exceeding the age norm, with reference to the presence of \textit{S. aureus} in different locations, and the results of statistical analysis

| Skin lesions | tIgE greater than normal – age norm interpretation | Statistical significance |
|--------------|-----------------------------------------------|-------------------------|
| S. aureus found | S. aureus not found |
| Healthy skin | 56/64 (83.6%) | 11/15 (73.3%) | $p = 0.2269^{**}$ |
| Anterior nares | 42/48 (87.5%) | 25/31 (80.7%) | $p = 0.5238^{**}$ |
| S. aureus found | S. aureus not found |
| Healthy skin | 58/67 (86.6%) | 8/12 (66.7%) | $p = 0.1031^*$ |
| Anterior nares | 58/67 (86.6%) | 8/12 (66.7%) | $p = 0.1031^*$ |

*Mann-Whitney test, \**Fisher’s exact test.

### Table 3. The mean SEA-sIgE in the AD patients’ serum, allowing for the presence of \textit{S. aureus} in different locations, and the results of statistical analysis

| SEA-sIgE [kU/l] | S. aureus found | S. aureus not found | Statistical significance |
|----------------|-----------------|---------------------|-------------------------|
| Skin lesions: | n = 65 | n = 15 | $p = 0.2071^*$ |
| Mean SEA-sIgE ± SD | 1.65 ±3.742 | 1.69 ±5.318 | |
| Median | 0.5 | 0.34 | |
| Min.–max. | 0.004–27.6 | 0.04–20.9 | |
| Healthy skin: | n = 49 | n = 31 | $p = 0.0103^*$ |
| Mean SEA-sIgE ± SD | 2.55 ±4.909 | 0.604 ±0.914 | |
| Median | 0.34 | 0.34 | |
| Min.–max. | 0.004–27.6 | 0.004–3.89 | |
| Anterior nares: | n = 69 | n = 12 | $p = 0.0271^*$ |
| Mean SEA-sIgE ± SD | 2.14 ±4.397 | 1.36 ±3.802 | |
| Median | 0.5 | 0.34 | |
| Min.–max. | 0.004–27.6 | 0.004–13.4 | |

*Mann-Whitney test.
If the patients carried *S. aureus* in their nasal vestibule, SEB-sIgE was 1.84 ±3.426 kU/l. SEB-sIgE in the patients without *S. aureus* in their anterior nares was 5.54 ± 18.348 kU/l (Table 4).

There was a statistically significant correlation between healthy skin colonisation by *S. aureus* and increased SEA-sIgE. The same correlation was proved between healthy skin colonisation by *S. aureus* and increased SEB-sIgE. There was a statistically significant correlation between colonisation of the nasal vestibule by *S. aureus* and the SEA-sIgE and SEB-sIgE serum concentration. There was no statistically significant correlation between the colonisation of skin lesions by *S. aureus* and the SEA-sIgE value. The correlation between the colonisation of skin lesions by *S. aureus* and the SEB-sIgE serum concentration was within the significance limit.

The skin colonisation of *S. aureus* was very similar in both children (45%) and adults (49%). Nasal carriage also occurred at a very similar level – children 47% and adults 53%. The difference occurred only in the colonisation of the healthy skin (children 27% and adults 41%).

In total, 55 out of 134 patients (41%) had positive SEA-sIgE or SEB-sIgE results. 44 out of 134 patients (32.8%) had positive SEA-sIgE results. The same number of patients, i.e. 44 out of 134 (32.8%) had positive SEB-sIgE results. In 107 out of 134 patients (79.8%) the tIgE

| Antibodies | SEA-sIgE (%) | SEB-sIgE (%) | SEA-sIgE or SEB-sIgE (%) | SEA-sIgE and SEB-sIgE (%) | tIgE (%) |
|------------|--------------|--------------|-------------------------|---------------------------|---------|
| Patients   | 44/134 (32.8)| 44/134 (32.8)| 55/134 (41)             | 33/134 (24.6)             | 107/134 (79.8) |

| Table 6. A comparison of data of four patients with the highest SEA-sIgE and SEB-sIgE levels |
| Parameter | Patient 1 | Patient 2 |Patient 3 | Patient 4 |
|-----------|-----------|-----------|-----------|-----------|
| Sex       | Female    | Male      | Male      | Female    |
| Age       | 25        | 39        | 28        | 6         |
| Total IgE [kU/l] | 3857 | > 5000 | > 5000 | > 5000 |
| SEA-sIgE [kU/l] | 20.9 (class 4) | 27.6 (class 4) | 4.48 (class 3) | 13.4 (class 3) |
| SEB-sIgE [kU/l] | 2.45 (class 2) | 2.27 (class 2) | 21.3 (class 4) | 63.8 (class 5) |
| SA on AS | No        | Yes       | Not achieved | Not achieved |
| SA on UAS | Not achieved done | Yes | Yes | Not achieved |
| SA in AN | Not achieved done | Yes | Yes | No |

*SA – Staphylococcus aureus, AS – affected skin, UAS – unaffected skin, AN – anterior nares.*

*Man–Whitney test.*

| Table 4. The mean SEB-sIgE in the AD patients’ serum, allowing for the presence of *S. aureus* in different locations, and the results of statistical analysis                                      |
| SEB-sIgE [kU/l] | *S. aureus* found | *S. aureus* not found | Statistical significance |
|----------------|-------------------|----------------------|-------------------------|
| Skin lesions:  |                   |                      |                         |
| n = 65        | 1.13 ±1.804       | 0.417 ±0.598         | *p = 0.0731*             |
| Median         | 0.35              | 0.28                 |                         |
| Min.–max.      | 0.0–12.4          | 0.02–2.45            |                         |
| Healthy skin:  |                   |                      |                         |
| n = 49        | 2.15 ±3.849       | 0.404 ±0.428         | *p = 0.0044*             |
| Median         | 0.79              | 0.34                 |                         |
| Min.–max.      | 0.0–21.3          | 0.002–1.85           |                         |
| Anterior nares:|                   |                      |                         |
| n = 69        | 1.84 ±3.426       | 5.54 ±18.348         | *p = 0.0323*             |
| Median         | 0.39              | 0.31                 |                         |
| Min.–max.      | 0.0–21.3          | 0.01–63.8            |                         |

*Mann–Whitney test.*

*S. aureus* was not found in that location, the mean SEB-sIgE was 0.404 ±0.428 kU/l.

If the patients carried *S. aureus* in their nasal vestibule, SEB-sIgE was 1.84 ±3.426 kU/l. SEB-sIgE in the patients without *S. aureus* in their anterior nares was 5.54 ± 18.348 kU/l (Table 4).

There was a statistically significant correlation between healthy skin colonisation by *S. aureus* and increased SEA-sIgE. The same correlation was proved between healthy skin colonisation by *S. aureus* and increased SEB-sIgE. There was a statistically significant correlation between colonisation of the nasal vestibule by *S. aureus* and the SEA-sIgE and SEB-sIgE serum concentration. There was no statistically significant correlation between colonisation of skin lesions by *S. aureus* and the SEA-sIgE value. The correlation between the colonisation of skin lesions by *S. aureus* and the SEB-sIgE serum concentration was within the significance limit.

The skin colonisation of *S. aureus* was very similar in both children (45%) and adults (49%). Nasal carriage also occurred at a very similar level – children 47% and adults 53%. The difference occurred only in the colonisation of the healthy skin (children 27% and adults 41%).

In total, 55 out of 134 patients (41%) had positive SEA-sIgE or SEB-sIgE results. 44 out of 134 patients (32.8%) had positive SEA-sIgE results. The same number of patients, i.e. 44 out of 134 (32.8%) had positive SEB-sIgE results. In 107 out of 134 patients (79.8%) the tIgE...
was higher than the age norm. In 33 out of 134 patients (24.6%), both the SEA-sIgE and SEB-sIgE were significantly higher (Table 5).

In the population of AD patients, the highest SEA-sIgE and SEB-sIgE values were noted in classes 4 and 3. As far as SEB-sIgE is concerned, the highest values were noted in classes 5 and 4. The group with the highest values consisted of four patients: two men and two women aged 6, 25, 28 and 39 years. All of them had higher tIgE levels than the age norm (3 patients > 5000 kU/l, 1 patient – 3857 kU/l). The patients were hospitalised at the local Clinic of Dermatology and they had erythroderma diagnosed (Table 6).

Discussion

Abeck and mempelet al. stress a big contrast between the incidence of skin colonisation by S. aureus in healthy patients (2–25%) and the incidence of the bacteria in AD patients, which ranges from 76% on apparently healthy skin to as much as 100% in oozing lesions [15].

30–60% of S. aureus strains isolated from AD patients are capable of producing exotoxins, which are superantigens [7, 9, 16, 17].

The study by Langer et al. confirmed the presence of S. aureus strains capable of synthesising exotoxins with SAg characteristics in 65% of AD patients. The clinical picture of AD was more severe in this group of patients. The researchers also proved that epidermal application of SEB caused skin inflammation [18].

Strange et al. were the first researchers to prove that SAgs caused erythema and inflammatory infiltration both in AD patients’ apparently healthy skin and in healthy patients’ skin [19].

SAgs are thought to be capable of stimulating cytokine production in T lymphocytes and macrophages [20], which results in a more intense manifestation of SAgs-mediated diseases [21].

However, many researchers question the role of SAgs in AD. Jappe et al. stress the fact that only about 50% of isolated S. aureus strains are capable of producing SAgs. On the other hand, SAgs-producing strains can be found in healthy people [22].

In the study by Zollner et al., 57% of S. aureus strains isolated from AD patients produced exotoxins with SAg properties. In the control group of healthy patients, this value amounted to 33%. The researchers observed that the presence of S. aureus strains, which were capable of producing SAgs, was related with more acute AD and a higher SCORAD (SCORing Atopic Dermatitis) score. The course of the disease was not related with the SEA-sIgE and SEB-sIgE values. What is more, the colonisation by SAgs-producing S. aureus strains was related with considerably lower tIgE values, according to the theory that a high SAg concentration inhibited IgE production [9].

Our research proved that the presence of S. aureus in different locations was related with higher tIgE in the AD patients’ serum.

IgE production in response to bacterial SAgs is secondary to the activation of B lymphocytes, which depends on the presence and activation of T lymphocytes. High SAg concentrations inhibit IgE production. It is probably caused by IFN-γ and/or IFN-α, which is produced in response to high bacterial SAg concentrations. Zollner et al. surprisingly observed that the tIgE in AD patients colonised by SAg-producing S. aureus strains was lower than in the patients with S. aureus strains incapable of SAg production. Thus, the local high SAg concentration reduces IgE production. IFN-γ induction is characteristic of chronic lesions in the course of AD [9].

Yagi et al. presented the detectability of SAg-producing S. aureus strains in different locations on AD patients’ skin. They found 40.7% on apparently healthy skin, 61.7% in non-oozing eczemas, described as excessive dryness, and as much as 75.3% in oozing lesions [23].

In view of the observations made by Zollner et al. and Yagi et al., we can suppose that the presence of a SAg-producing S. aureus strain on lesioned skin (this is, where it grows dynamically), especially in oozing lesions, will inhibit IgE synthesis and in consequence, SEA/SEB-sIgE. On the contrary, on apparently healthy skin, where the count of SAg-producing S. aureus strains is low, the production of IgE as well as SEA/SEB-sIgE is high. This might explain our observations.

Apart from that, we observed that the colonisation of healthy skin by S. aureus caused an increase in SEA-sIgE and SEB-sIgE. We also observed a significant increase in the SEA-sIgE and SEB-sIgE serum concentration if S. aureus strains were found in the nasal vestibule. We did not observe any statistically significant relation between the colonisation of lesioned skin by S. aureus and the SEA-sIgE value. As far as SEB-sIgE is concerned, the relation was within the significance limit.

There are numerous reports which show that the SEA-sIgE and SEB-sIgE serum concentration is high both in AD children and adults [24–28].

Leung et al. found SEA-sIgE, SEB-sIgE and TSST-sIgE in 57% of AD patients [24]. Tada et al. noted that in 80% of AD patients, the SEA-sIgE or SEB-sIgE values exceeded 0.35 kU/l [25]. According to Bunikowski et al., the SEA-sIgE or SEB-sIgE serum concentration was greater than 0.7 kU/l in 34% of AD children [26].

Lin et al. proved an increase in the SEA-sIgE or SEB-sIgE serum concentration in most AD children (88%) (respectively, they regarded values exceeding 0.16 kU/l and 0.7 kU/l to be positive) – SEA-sIgE was found in 70% of the children and SEB-sIgE was also found in 70% of this age group. Increased SEA-sIgE or SEB-sIgE values were very rarely observed in a group of children with dermatoses other than AD, although they were colonised by S. aureus strains producing exotoxins with SAg charac-
teristics [27]. Our research proved positive SEA-sIgE and SEB-sIgE values in AD patients (32.8% and 32.8%, respectively). There were positive SEA-sIgE or SEB-sIgE values in 41% of the patients. There were increased both SEA-sIgE and SEB-sIgE values in 24.6% of the AD patients. The researchers suggest that SEA-sIgE and SEB-sIgE may be characteristic of AD. They indicate that S. aureus induces asIgE-mediated immune response by causing an exotoxin with SAg characteristics to penetrate into the skin [27]. Like Bunikowski et al., they confirm the relation between the SEA-sIgE and SEB-sIgE serum concentration and the intensity of skin lesions [26]. However, Tada et al. did not note this relation [25].

Iide et al. reported that in a group of AD children increased SEA-sIgE and SEB-sIgE serum concentration amounted to 33.6%. Positive SEA-sIgE results amounted to 17.9%, whereas positive SEB-sIgE results amounted to 29.3% (values exceeding 0.7 U/ml, i.e. class 2, were considered positive). The greatest number of increased values was found in a group of schoolchildren, whereas the smallest number was noted in infants. The tIgE serum concentration was significantly higher in the group of children with positive SEA-sIgE or SEB-sIgE values. Interestingly, the researchers concluded that the percentage of positive SEA-sIgE or SEB-sIgE values in the patients whose clinical condition deteriorated in the summer months was higher than in patients whose clinical condition exacerbated in the winter. This phenomenon may have been related with better conditions for the growth of S. aureus, higher temperatures and air humidity in the summer. S. aureus was isolated in all the patients with positive SEA-sIgE or SEB-sIgE values. There was no difference between the incidence of the MRSA strain in the AD patients with positive or negative SEA-sIgE or SEB-sIgE values. Apart from that, the researchers confirmed the fact that significantly higher values corresponded with acute AD. It seems that the percentage of positive SEB-asIgE was higher than the percentage of positive SEA-asIgE. SEB is related with a local infection, whereas SEA is usually found in the toxic shock syndrome [28]. Our patients with the highest SEA-sIgE and SEB-sIgE values were characterised by more severe AD. Exacerbations required hospitalisation. The adult patients were aged 25-39 years and there was a 6-year-old girl.

Langer et al. obtained 44% of positive SEA-sIgE values and 47% of positive SEB-sIgE values (values exceeding 0.35 U/ml were interpreted as positive). The SEA-sIgE values ranged from 0.44 to 21.40 kU/l (4.07 ±5.84 kU/l, mean ± SD), whereas the SEB-sIgE values ranged from 0.38 to 89.60 kU/l (9.20 ±22.63 kU/l, mean ± SD). The researchers conducted patch tests, using different concentrations of SEA and SEB extracts in AD patients and Healthy subjects. They observed dose-dependent SEA and SEB reactions. They suggested that the reaction to patch tests resulted from the superantigen characteristics of SEA and SEB. Langer et al. proved that stimulation through SEA and SEB application caused a higher percentage of positive reactions to patch tests in comparison with the application of a single agent. In view of this fact, the colonisation by S. aureus, which is capable of SAgS production, may intensify the skin reaction to common allergens among AD patients [18].

Reefer et al. noted that the tIgE value was increased in 42% of AD patients. Apart from that, the researchers observed higher SEA-sIgE and SEB-sIgE concentrations (corresponding to values > 0.75 IU/ml) only in the patients whose tIgE serum concentration exceeded 800 IU/ml [29]. Our observations revealed higher tIgE than the age norm in 79.8% of the AD patients. 67 out of 134 patients (50%) exceeded the tIgE of 1,000 kU/l. Reefer et al. observed positive asIgE values in reaction to both toxins in 82% of the patients whose tIgE was greater than 2,000 kU/l. There was no asIgE in reaction to any bacterial products (a wide range of bacterial and fungi products were investigated) in patients with low tIgE (≤ 35 IU/ml). Reefer et al. proved that asIgE targeted against microbial allergens was very often found in AD patients with increased tIgE [29]. In our study, among the AD patients with SEA-sIgE values of class 2 or higher, there were 43 out of 44 (97.7%) patients with tIgE greater than 1,000 kU/l (there was only one patient whose SEA-sIgE value was in class 3 and tIgE amounted to 379 kU/l). Similarly, the SEB-sIgE value in 44 patients was categorised at least as class 2. They included 40 patients (90.9%) with tIgE > 1,000 IU/ml (4 patients with SEB-sIgE in class 2, the tIgE values were: 121 kU/l, 54.5 kU/l, 514 kU/l and 379 kU/l). There was one patient with the tIgE value of 379 IU/ml, SEA-sIgE in class 3, and SEB-sIgE in class 2.

Bunikowski et al. proved that in AD children with positive SEA-sIgE/SEB-sIgE results there were more episodes of S. aureus superinfection than in children with negative results [26].

**Conclusions**

It seems that the colonisation of the lesioned skin, healthy skin and the anterior nares by S. aureus is related with higher tIgE serum concentration, which translates to more severe course of the disease. It seems that the colonisation of the healthy skin and the nasal vestibule by S. aureus (not lesioned skin, though) is related with a higher asIgE concentration with reference to both staphylococcal enterotoxins. However, the phenomenon needs further research in larger groups of AD patients. Significantly increased SEA-IgE and SEB-IgE concentrations were observed in the patients whose tIgE serum concentration was statistically higher.

**Conflict of interest**

The authors declare no conflict of interest.
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References
1. Braun-Falco O, Burgdorf WHC, Plewig G, et al. Dermatologia. Czelej, Lublin 2010; 426-7.
2. Baker BS. The role of microorganisms in atopic dermatitis. Clin Exp Immunol 2006; 144: 1-9.
3. Silny W. Atopowe zapalenie skóry. Termedia, Poznań 2013; 54-61.
4. Orfali RL, Sato MN, Santos VG, et al. Staphylococcal enterotoxin B induces specific IgG4 and IgE antibody serum levels in atopic dermatitis. Int J Dermatol 2015, 54: 898-904.
5. Park KD, Pak SC, Park KK. The pathogenetic effect of natural and bacterial toxins on atopic dermatitis. Toxins 2017; 9: 3.
6. Adamek-Guzik T, Guzik TJ, Czerniawska-Mysik G, et al. Effects of combined therapy with oral antihistamines and topical corticosteroids on Staphylococcus aureus colonization in atopic dermatitis. Allergy Asthma Immunol 2002; 7: 33-43.
7. Bunikowski R, Mielke M, Skarabis H, et al. Evidence for a disease – promoting effect of Staphylococcus aureus-derived exotoxins in atopic dermatitis. J Allergy Clin Immunol 2000; 105: B1-9.
8. Hon KL, Lam MC, Leung TF, et al. Clinical features associated with nasal Staphylococcus aureus colonisation in Chinese children with moderate-to-severe atopic dermatitis. Ann Acad Med Singapore 2005; 34: 591-4.
9. Zollner TM, Wichelhaus TA, Hartung A, et al. Colonization with superantigen – producing Staphylococcus aureus is associated with increased severity of atopic dermatitis. Clin Exp Allergy 2000; 30: 994-1000.
10. Breuer K, Dubinker S, Kapp A, et al. SEB – Oktapeptide induzieren eine enterotoxinspezifische T – Zellantwort bei atopischer Dermatitis. Allergologie 2006; 29: 383-92.
11. Kim JE, Kim JS, Cho DH, et al. Molecular mechanisms of cutaneous inflammatory disorder: atopic dermatitis. Int J Mol Sci 2016; 17: 1234.
12. Hradetzky S, Werfel T, Roesner LM. Autoallergy in atopic dermatitis. Allergo J Int 2015; 24: 16-22.
13. Tang TS, Bieber T, Williams HC. Does " autoreactivity " play a role in atopic dermatitis? J Allergy Clin Immunol 2012; 129: 1209-15.
14. Hanifin JM, Rajka G. Diagnostic features of atopic dermatitis. Acta Dermatovenerol Suppl 1980; 92: 44-7.
15. Abeck D, Mempel M. Staphylococcus aureus colonization in atopic dermatitis and its therapeutic implications. Br J Dermatol 1998; 139: 13-6.
16. Chen WQ, Zhang MH, Bi Zg. A study on superantigen production by Staphylococcus aureus colonizing in skin lesion and its clinical significance in the patients with atopic dermatitis and eczema. J Clin Dermatol 2005; 34: 22-4.
17. Schlievert PM, Case LC, Strandberg KL, et al. Superantigen profile of Staphylococcus aureus isolates from patients with steroid-resistant atopic dermatitis. Clin Infect Dis 2008; 46: 1562–7.
18. Langer K, Breuer K, Kapp A, et al. Staphylococcus aureus-derived enterotoxins enhance house dust mite-induced patch test reactions in atopic dermatitis. Exp Dermatol 2007; 16: 124-9.
19. Strange P, Skov L, Lisby S, et al. Staphylococcal enterotoxin B applied on intact normal and intact atopic skin induces dermatitis. Arch Dermatol 1996; 132: 27-33.
20. Marrack P, Kappler J. The staphylococcal enterotoxins and their relatives. Science 1990; 248: 705-11.
21. McCormick JK, Yanwood JM, Schlievert PM. Toxic shock syndrome and bacterial superantigens: an update. Annu Rev Microbiol 2001; 55: 77-104.