
Colonizing features of *Staphylococcus aureus* in early childhood atopic dermatitis and in mothers: a cross-sectional comparative study done at four kindergartens in Daegu, South Korea

Byung Soo Kim, MD*†; Jun Young Kim, MD‡; Hyun Jung Lim, MD‡; Weon Ju Lee, MD‡; Seok-Jong Lee, MD‡; Jung Min Kim, MD§; Moon Bum Kim, MD*†; Ho Sun Jang, MD¶; Kyung-Sool Kwon, MD*; and Do Won Kim, MD‡

Background: Colonization of *Staphylococcus aureus* is well known to be an aggravating factor for the flare-up of atopic dermatitis (AD), yet few studies have been done on its spread in families with childhood AD.

Objective: To evaluate the characteristic features of skin-colonizing *S aureus* and to identify the source of *S aureus* in early childhood AD.

Methods: Forty-four subjects with AD, 51 borderline (BD) subjects, and 36 normal controls (NC) aged 3–6 years and their mothers were recruited from four different kindergartens. After comparing the positive culture rate of *S aureus* in three different groups of children and their mothers, we determined if there is a possibility of intrafamilial transmission between the children with AD and their mothers using polymerase chain reaction and pulsed-field gel electrophoresis.

Results: A high prevalence (72.7%) of *S aureus* colonization was found in the AD group compared with the BD and NC groups. However, the prevalence rate of *S aureus* in the mothers who had children with AD was not significantly higher than in the mothers from the BD and NC groups. Based on the pulsed-field gel electrophoresis results, the cutaneous re-colonization of *S aureus* in childhood AD appears to have been primarily originating from the patients' noses, and maternal origin does not appear to substantially contribute to *S aureus* transmission in early childhood AD.

Conclusions: Since the cutaneous colonization of *S aureus* in early childhood AD predominantly originated from the patients' own noses, the maternal transmission route does not appear to contribute substantially to the colonization of *S aureus* in early childhood AD.

Ann Allergy Asthma Immunol. 2011;106:323–329.

INTRODUCTION

The colonization of *Staphylococcus aureus* is one of the most common aggravating factors of atopic dermatitis (AD) in both lesional and, to a lesser extent, nonlesional skin. The importance of *S aureus* in AD and a positive correlation between colonization with *S aureus* and clinical severity and skin barrier function has been demonstrated. Many studies have been done on the characteristics of *S aureus* in AD

patients, but studies on intrafamilial *S aureus* colonization, especially in childhood AD, and its spread within a family are lacking. Therefore after comparing the positive culture rate of *S aureus* in AD, normal control (NC), and borderline (BD) children, this study examined the distribution of toxin genes and super-antigenic exotoxins from *S aureus* colonized on the skin of the participants and determined whether there was a possibility of intrafamilial transmission between children with AD and their mothers by using polymerase chain reaction (PCR) and pulsed-field gel electrophoresis (PFGE).

METHODS

Subjects and Study Design

A total of 733 children aged 3 to 6 years who were attending 4 different kindergartens in Daegu, South Korea, were surveyed by questionnaire in May 2009 and underwent a physical examination over a 1-month period from June to July 2009. Atopic dermatitis was diagnosed according to the diagnostic criteria of Hanifin and Rajka. Severity of AD was assessed by a single investigator using the Eczema Area and

Affiliations: * Department of Dermatology and † Medical Research Institute, Pusan National University School of Medicine, Busan, South Korea; ‡ Departments of Dermatology and § Microbiology, Kyungpook National University School of Medicine, Daegu, South Korea; ¶ Mok Hye Su, Jang Ho Sun Dermatology Clinic, Busan, South Korea.

Funding Sources: This research was supported by grant from Amore-Pacific Grant in 2010.

Disclosures: The authors have nothing to disclose.

Received for publication August 3, 2010; Received in revised form December 13, 2010; Accepted for publication December 14, 2010.

© 2011 American College of Allergy, Asthma & Immunology.

Published by Elsevier Inc. All rights reserved.

doi:10.1016/j.anai.2010.12.013

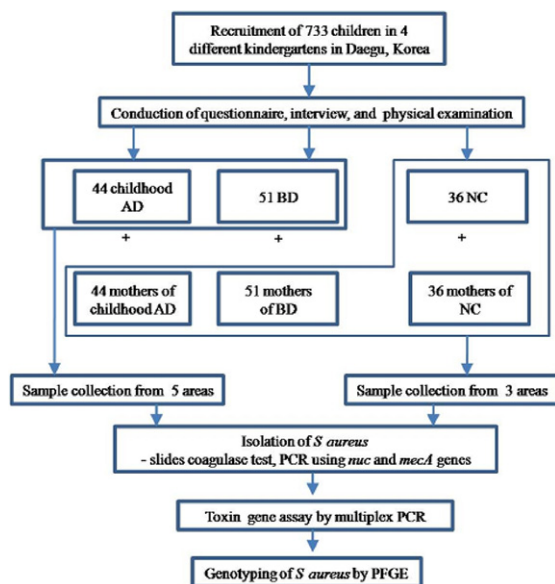


Figure 1. Flowchart of the study design and participation proportions. AD, atopic dermatitis, BD, borderline, NC, normal control, *S aureus*, PCR, polymerase chain reaction, PFGE, pulsed-field gel electrophoresis.

Severity Index (EASI). On the basis of clinical severity, children were classified into 3 groups, AD, BD, and NC, and were included for further bacteriological examination. The clinical criteria for BD were subjects whose symptoms were insufficient for a diagnosis of AD but who had an eczematous skin lesion plus at least one or more major or minor features of AD. Healthy volunteers without a personal or family history of AD or of any other skin or allergic diseases were allocated to the NC group. The healthy mothers of all subjects were also included in the investigation. Any child or mother with a recent inpatient hospital admission history or who had received antibiotics or immunosuppressive treatment via any route within 4 weeks before the study was excluded. Voluntary informed consent in written form was obtained from all the participants' legal guardians, and all the study protocols were reviewed and authorized by Kyungpook National University Hospital institutional review board. Figure 1 summarizes the selection process and the design of the study.

Sample Collection

For AD and BD subjects, samples were obtained from 5 areas (2 lesional skin areas including the flexural aspects of the limbs,

nonlesional skin, subungual regions, and anterior nares), whereas for all the NC participants and all the mothers, 3 areas (nonlesional skin, including the flexural aspects of the upper limbs, subungual spaces, and anterior nares) were collected. All the samples were taken on the day of the diagnosis with a sterile cotton-tipped swab stick moistened with sterile water.

Laboratory Analysis of *S aureus* Isolates

Isolation of *S aureus*. Bacterial cultures were grown using standard laboratory techniques. Colonies that grew on blood agar plates for 24 hours at 37°C were tested for coagulase activity.

The number of colony-forming units (CFU) of *S aureus* were classified into 4 categories (no growth: 0 = CFU/10 cm²; few: 0 < CFU/10 cm² < 10; moderate: 10 ≤ CFU/10 cm² < 1,000; many: 1,000 ≤ CFU/10 cm²). The identity and methicillin resistance of *S aureus* were confirmed via PCR using primers for the *nuc* and *mecA* genes, as previously described.¹

Toxin gene detection in *S aureus*. Multiplex PCR was done to identify the presence of the following staphylococcal toxin genes carried by *S aureus* strains: staphylococcal enterotoxin (*se*) *a*, *seb*, *sec*, *sed*, *see*, exfoliative toxin (*et*) *a*, *etb*, and toxic shock syndrome–like toxin (*tsst*)–1.

Genotyping of *S aureus*. To investigate the possibility of intrafamilial transmission, isolated strains were typed by PFGE. Chromosomal DNA was digested with *Sma*I and electrophoresed using program 2 of the GenePath system (Bio-Rad Laboratories Inc, Hercules, California), as previously described.² Isolates showing 6 or fewer band differences by PFGE were viewed as the same group of pulsotype.³ Similarities between all pairs were assessed using Dice correlation coefficients, and the unweighted pair group clustering method was used to construct a dendrogram.

Statistical Analysis

To analyze the frequency of the differences, dichotomous variables were examined using the χ^2 Independence Test in SPSS windows version 17.0. Statistical significance was accepted for *P* values less than .05.

RESULTS

Classification of Participants and the Assessment of AD Severity

Of the children recruited from 4 different kindergartens, 44 were classified as AD and 51 as BD. In addition, 36 healthy

Table I. Frequency of *S aureus* Colonization in Children According to Body Location

	AD (n = 44)	BD (n = 51)	NC (n = 36)	<i>P</i> value ^a
Skin	27 (61.4%)	9 (17.6%)	5 (13.9%)	
Lesions	18 (40.9%)	4 (7.8%)	—	<.0001
No lesions	9 (20.5%)	2 (3.9%)	1 (2.8%)	.0047
Subungual spaces	17 (38.6%)	5 (9.8%)	4 (11.1%)	.0013
Anterior nares	20 (45.5%)	14 (27.5%)	7 (19.4%)	.0111
Total colonization frequency	32 (72.7%)	17 (33.3%)	10 (27.8%)	<.0001

^a χ^2 independence test using SPSS Windows version 17.0 (SPSS Inc, Chicago, Illinois).

Table 2. Frequency of *S aureus* Colonization in Mothers According to Body Location

	AD (n = 44)	BD (n = 51)	NC (n = 36)	P value ^a
Skin	11 (25.0%)	11 (21.6%)	13 (36.1%)	
No lesions	4 (9.1%)	2 (3.9%)	1 (2.8%)	.1996
Subungual spaces	10 (22.7%)	9 (17.6%)	12 (33.3%)	.3043
Anterior nares	10 (22.7%)	8 (15.7%)	6 (16.6%)	.4625
Total colonization frequency	16 (36.4%)	18 (35.3%)	17 (47.2%)	.3548

^a Chi-square independence test using SPSS Windows version 17.0.

children were recruited as NC to undergo further bacteriological examination. The EASI score in AD children estimated by a single dermatologist was 4.5. Most AD children (34/44, 77.3%) had remarkably low EASI scores (<5).

Colonization of *S aureus*

Colonization rates in children. The results for the colonization of *S aureus* by the different groups are shown in Table 1. Overall, 32 (72.7%) of the 44 AD children retained *S aureus* on either the skin or anterior nares, whereas BD children (17/51, 33.3%) and NC children (10/36, 27.8%) had much lower colonization rates ($P < .0001$). Eczematous lesions (AD, 40.9%; BD, 7.8%) were more frequent in *S aureus* retaining areas than in nonretaining areas (AD, 20.5%; BD, 3.9%) in AD and BD patients ($P < .0001$). AD children showed a higher percentage of *S aureus* positivity than BD or NC children on lesions ($P < .0001$) and nonlesions ($P < .0047$). The prevalence of *S aureus* in the subungual regions was 38.6% in AD children, 9.8% in BD children, and 11.1% in the healthy controls ($P = 0.0013$). The colonization rate of *S aureus* in the anterior nares was 45.5% in AD children, which was higher than in the other groups (BD, 27.5%; NC, 19.4%; $P = .0111$).

Colonization rates in mothers. Sixteen of the 44 (36.4%) mothers with AD children were positive for *S aureus*, 18 of the 51 (35.3%) mothers with BD children, and 17 of the 36 (47.2%) mothers with NC children ($P = .3548$). No significant differences in the cutaneous culture rates were found among the mothers in the three groups ($P = .1996$). Furthermore, no significant differences were found between the mothers in terms of the subungual culture rates ($P = .3043$) and nasal carriage ($P = .4625$) (Table 2).

Quantification of cultured *S aureus* in children. The number of CFU/cm² observed in the AD children was higher than that in the children of the other two groups (Table 3). In

the AD children, 31.8% of the lesional skin swabs resulted in the formation of “many” CFU, of which 2.3% were from the nonlesional skin, 9.1% from the subungual spaces, and 22.7% from the anterior nares. In the BD group, only 2.3% of the lesional skin swabs resulted in “many” CFU, of which none were from the nonlesional skin, 2.0% from the subungual spaces, and 11.8% from the anterior nares. In the NC group, no nonlesional skin or subungual space swab resulted in “many” CFU, and only 11.1% showed “many” from the anterior nares.

Identification of methicillin resistance in *S aureus*. Of the 44 enrolled children with AD, 4.5% ($n = 2$) of the children and 11.4% ($n = 5$) of their mothers were colonized by methicillin-resistant *S aureus* (MRSA) on either the skin or the anterior nares (Table 4). They did not have a protracted history of eczema. Both groups, the children and their mothers, of the colonized patients had not received multiple or long-term course of corticosteroids or antibiotics of any kind. In addition, the worsening of the skin lesions had never progressed to the extent that it required hospitalization. The differences in the MRSA colonization rates in the BD children and their mothers (5.9% and 3.9%) and in the NC children and their mothers (8.3% and 5.6%) were insignificant compared with those of the AD children and their mothers (4.5% and 11.4%) ($P = .4857$ and $P = .2395$, respectively).

Distribution of Toxin Genes Carried by *S aureus*

Toxigenic *S aureus* strains were found more frequently in the AD children than in the BD and NC children (Table 5) ($P = .0018$). Of the 44 AD children, 22 (50.0%) were found to have a toxin gene. Conversely, staphylococcal toxin genes were found in 17 of the 51 BD children (33.3%) and in 6 of the 36 NC children (16.7%). The detection rates for staphylococcal toxin genes in the mothers of children from each group were similar ($P = .9642$). Of all the staphylococcal strains found in all children, the most frequent virulence factor was *sea* ($P = .0012$) (Table 6), which was identified in 69.9% of the strains from the

Table 3. Quantitative Comparison of *S aureus* Colonization Between the Three Study Groups

	Lesional skin			Non-lesional skin			Subungual spaces			Anterior nares		
	AD	BD	NC	AD	BD	NC	AD	BD	NC	AD	BD	NC
No growth	23 (52.3)	23 (45.1)	—	35 (79.5)	49 (96.1)	35 (97.2)	27 (61.4)	46 (90.2)	32 (88.9)	24 (54.5)	37 (72.5)	29 (80.6)
Few	5 (11.4)	3 (5.9)	—	6 (13.6)	2 (3.9)	0 (0.0)	9 (20.5)	4 (7.8)	3 (8.3)	7 (15.9)	5 (9.8)	2 (5.6)
Moderate	0 (0.0)	0 (0.0)	—	2 (4.5)	0 (0.0)	1 (2.8)	4 (9.1)	0 (0.0)	1 (2.8)	3 (6.8)	3 (5.9)	1 (2.8)
Many	14 (31.8)	1 (2.3)	—	1 (2.3)	0 (0.0)	0 (0.0)	4 (9.1)	1 (2.0)	0 (0.0)	10 (22.7)	6 (11.8)	4 (11.1)

Total number of AD = 44, BD = 51, NC = 36. The data are presented as number of patients with percentages given in parentheses.

Table 4. Prevalence of Methicillin-Resistant *S aureus* in All Subjects

	Children				Mothers			
	AD (n = 44)	BD (n = 51)	NC (n = 36)	P value ^a	AD (n = 44)	BD (n = 51)	NC (n = 36)	P value ^a
Skin	2 (4.5%)	2 (3.9%)	2 (5.6%)		4 (9.1%)	1 (2.0%)	2 (5.6%)	
Lesions	2 (4.5%)	1 (2.0%)	—		—	—	—	
No lesions	1 (2.3%)	0 (0%)	0 (0%)		3 (6.8%)	0 (0%)	0 (0%)	
Subungual spaces	1 (2.3%)	2 (3.9%)	2 (5.6%)		2 (4.5%)	1 (2.0%)	2 (5.6%)	
Anterior nares	1 (2.3%)	3 (5.9%)	2 (5.6%)		3 (6.8%)	2 (3.9%)	1 (2.8%)	
Total colonization frequency	2 (4.5%)	3 (5.9%)	3 (8.3%)	.4857	5 (11.4%)	2 (3.9%)	2 (5.6%)	.2395

^a χ^2 independence test using SPSS Windows version 17.0.

AD children, in 80.8% of the strains from the BD children, and in 66.7% of the strains in the NC children. Among the combinations of toxin genes, *sea* alone (46.6%) and *sea* in combination with *tsst-1* (16.4%) were the major patterns in the AD group. The *seb* and *see* were not detected in this study.

Determination of Whether Intrafamilial Transmission of *S aureus* Isolates Occurs

Seventeen pairs of staphylococcal isolates were obtained for detailed analysis based on the PFGE pattern. They comprised 10 AD or BD children with a positive result for *S aureus* on both on skin and nose, 4 children with cutaneous positivity and their mothers with nasal positivity, and 3 children having *S aureus* on their skin and nose and their mothers with nasal positivity.

Analysis of the isolates from the children's skin and noses. All 10 pairs of isolates obtained from the children's skin and noses were characterized in a dendrogram in Figure 2. From the analysis, 9 of 10 (90.0%) pairs of the isolates had the same PFGE patterns. Only strains from one of the participants (subject 3) were not identical in their PFGE patterns.

Analysis of the isolates from the children's skin and their mothers' noses. All 4 pairs of isolates obtained from the children's skin and their mothers' noses were characterized using a dendrogram (Fig 3). From the analysis, 1 of 4 (25.0%) pairs of the isolates had the same PFGE pattern (strains from subject 14).

Analysis of the isolates from children's skin and noses and their mothers' noses. All 3 pairs of isolates were characterized using a dendrogram (Fig 4). From the analysis, 2 of 3 (66.7%) pairs of the isolates had the same PFGE patterns (strains from subjects 15 and 17). However, isolated strains from the skin and nares of subject 16 also had identical PFGE patterns.

DISCUSSION

Recent understanding of the complex interaction between gram positive bacterium and skin inflammation has led to the realization that *S aureus* is an important factor that triggers AD.⁴ However, the source of the *S aureus* strains colonizing atopic skin has not been fully determined. One possibility is that they are acquired by contact. Thus, in preschool children with AD, the source of *S aureus* should be confined to just family members, especially mothers. Although a recent report contended that the anterior nares may be a reservoir of *S aureus*,⁵ this study undertook further investigation by examining the characteristic features of *S aureus* isolated from AD children and their mothers to determine whether intrafamilial transmission is another source of *S aureus*.

In this study and previous studies, a higher prevalence (32/44, 72.7%) of *S aureus* colonization among the AD children was found than among the BD (17/51, 33.3%) and NC (10/36, 27.8%) children (Table 1). This overall prevalence rate included cutaneous carriage as well as carriage in the subungual regions and anterior nares.

The general population of healthy individuals has a considerable prevalence rate of *S aureus* on the epithelial surface, and the anterior nares are considered the most frequent carriage site.⁶ Persistent nasal carriage is known to be present in up to 35% of normal adults.⁷ Furthermore, in adult AD patients, the anterior nares are known to act as an important endogenous reservoir, with a colonization prevalence of 39 to 82%.⁶ Lebon et al⁶ showed that a high prevalence of *S aureus* nasal colonization at 6 months of age was associated with the occurrence of AD during the first and second years of life.

Table 5. Detection Rate of Staphylococcal Toxin Genes in the Isolated Strains

	Children				Mothers			
	AD (n = 44)	BD (n = 51)	NC (n = 36)	P value*	AD (n = 44)	BD (n = 51)	NC (n = 36)	P value*
Skin	19 (43.2%)	8 (15.7%)	3 (8.3%)		8 (18.2%)	8 (15.7%)	7 (19.4%)	
Lesions	13 (29.5%)	4 (7.8%)	—		—	—	—	
No lesions	7 (15.9%)	1 (2.0%)	1 (2.8%)		4 (9.1%)	2 (3.9%)	1 (2.8%)	
Subungual spaces	12 (27.3%)	4 (7.8%)	2 (5.6%)		7 (15.9%)	8 (15.7%)	6 (16.7%)	
Anterior nares	14 (31.8%)	14 (27.5%)	5 (13.9%)		6 (13.6%)	4 (7.8%)	2 (5.6%)	
Total colonization frequency	22 (50.0%)	17 (33.3%)	6 (16.7%)	.0018	10 (22.7%)	12 (23.5%)	8 (22.2%)	.9642

* χ^2 independence test using SPSS Windows version 17.0.

Table 6. Virulence Factor Profiling and Isolated Patterns of Staphylococcal Toxin Genes

Staphylococcal toxin genes	AD (%)	BD (%)	NC (%)
<i>sea</i>	51 (69.9)	21 (80.8)	8 (66.7)
<i>sea</i> only	34 (46.6)	14 (53.8)	6 (50.0)
<i>sea, sec</i>	5 (6.8)	0 (0)	0 (0)
<i>sea, tsst-1</i>	12 (16.4)	7 (26.9)	1 (8.3)
<i>sea, sed, tsst-1</i>	0 (0)	0 (0)	1 (8.3)
<i>tsst-1</i> only	0 (0)	3 (11.5)	0 (0)
Total number of isolated strains	73	26	12

This study also showed that nasal colonization by *S aureus* had a potentially pathophysiological role in the development of AD. In the current study, the intranasal colonization of *S aureus* was observed in 20 (45.5%) of the AD children, which was significantly higher than in the BD (14/51, 27.5%) and NC (7/36, 19.4%) children ($P = .0111$). These isolate rates agree with previous cutaneous *S aureus* isolate results. Because of the tendency of AD patients to scratch, Nishijima et al⁸ asserted that the subungual spaces of the hands are also an important reservoir of *S aureus* in AD. Similarly, the results of this study showed that the subungual spaces in the AD children harbored significantly more *S aureus* than in the BD and NC children ($P = .0013$). Therefore, like the previous

reports,^{8,9} these findings stress the importance of both the nares and subungual spaces as the preferential location for *S aureus*, and thus, these areas should be included for anti-staphylococcal therapeutic strategies.

Many previous studies have shown that the cutaneous colonization of *S aureus* correlates significantly with AD severity,^{10,11} and the results of this study confirmed this because the cutaneous infection rate for AD (61.4%) was higher than that of BD (17.6%). In addition, the cutaneous colonization rate in the current study was substantially lower than in previous reports, in which the prevalence of *S aureus* colonization was found to be 80% to 100%.⁹ This could be attributable to the selection criteria used in the current study (mild clinical severity in AD subjects).

The density of *S aureus* on AD lesions has been shown to be correlated with the severity of the dermatitis.¹² Staphylococcal colonization density is significantly lower in healthy individuals than in patients with AD, and bacterial counts on unaffected skin areas are lower than on affected skin areas.¹³ Similarly, quantitative comparisons between the BD and NC groups and the AD group in the current study showed a significantly higher density of colonization by *S aureus* on both the skin and in the anterior nares in AD children (Table 3).

Meanwhile, in the mothers of the AD children (Table 2), the prevalence rates of *S aureus* colonization from both the skin and anterior nares were not significantly higher than in

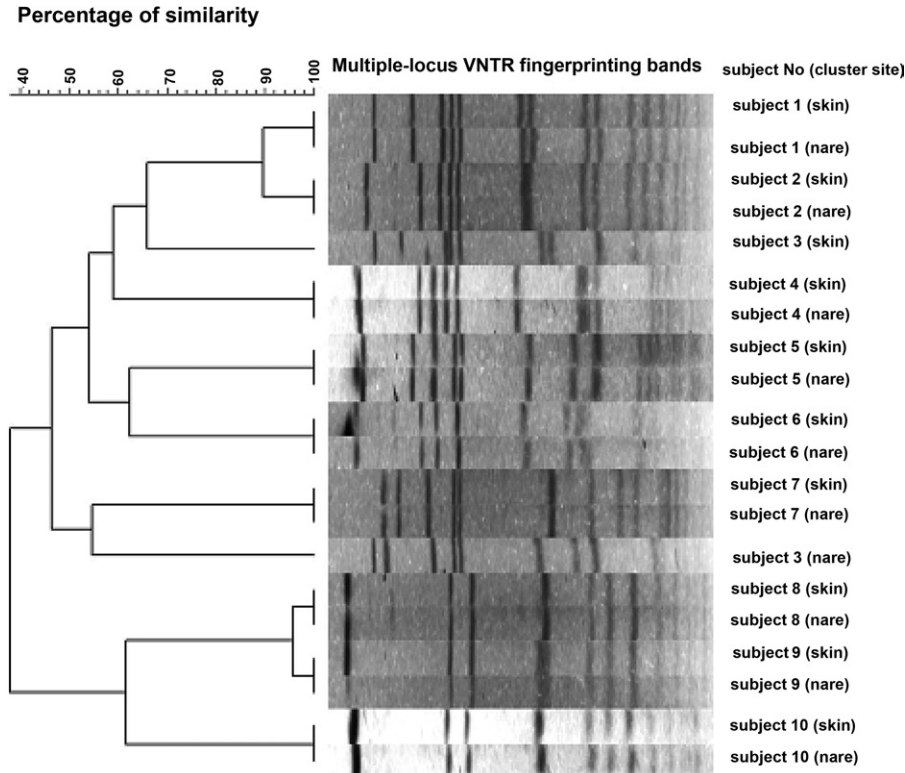


Figure 2. Dendrogram showing the results of the cluster analysis of *Smal*-generated PFGE patterns from *S aureus* isolated from the skin and noses of 10 AD children.

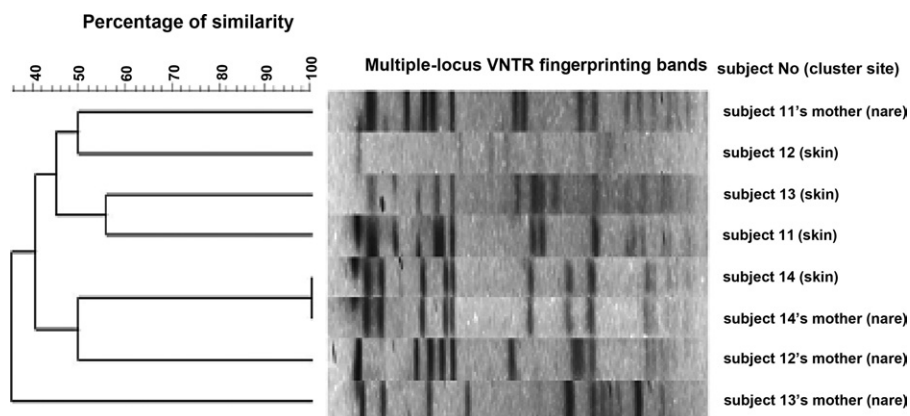


Figure 3. Dendrogram showing the results of the cluster analysis of *SmaI*-generated PFGE patterns from *S. aureus* isolated from 4 children's skin and their mothers' noses.

the mothers of the BD and NC children ($P = .3548$). This is contrary to the assertion made by Bonness et al,¹⁴ who reported a 48% prevalence of *S. aureus* colonization among parents of colonized AD children and contradicts the report by Chiu et al,¹⁵ which showed a high prevalence of *S. aureus* nasal colonization (46%) and a high concordance of *S. aureus* isolate indices with patients and their close contacts (81% of the isolates were identical or closely related by molecular typing). Therefore, based on the results of the current study, and contrary to previous reports, the prevalence of cutaneous colonization of *S. aureus* in the healthy close contacts of atopic children may not be higher, despite the closeness of the relationship. This study, however, did not take into account simple explanations for this phenomenon such as better hygiene or current use of antibacterial soaps by the mothers. This relatively low prevalence rate among healthy close contacts may be attributable to an intact barrier function to protect against cutaneous infections. Besides, transmission of *S. aureus* among healthy family members from a child with AD may be dependent on the severity of AD.

The prevalence of MRSA isolates among atopic patients is increasing, and this is now posing a significant problem in terms of treatment.¹⁶ However, AD children and their mothers in the current study were no more likely to be colonized by MRSA than the BD and NC children and their mothers. This may be attributable to the comparatively mild clinical severity and shorter disease duration, because the occurrence of MRSA in AD appears to be associated with disease severity and chronicity.¹⁷ Although information is lacking in terms of differentiating community-acquired and hospital-acquired MRSA, the data indicate that MRSA isolation is not uncommon even in childhood AD (Table 4). Evidence of MRSA colonizing patients with no previous hospitalization history indicates that physicians should consider carefully the implications of a higher prevalence of MRSA in the community.

Previous studies have shown that 30% to 60% of *S. aureus* strains isolated from AD patients secrete staphylococcal enterotoxins and toxic shock syndrome toxin-1, both of which have superantigenic properties.¹⁸ Consistently, the current

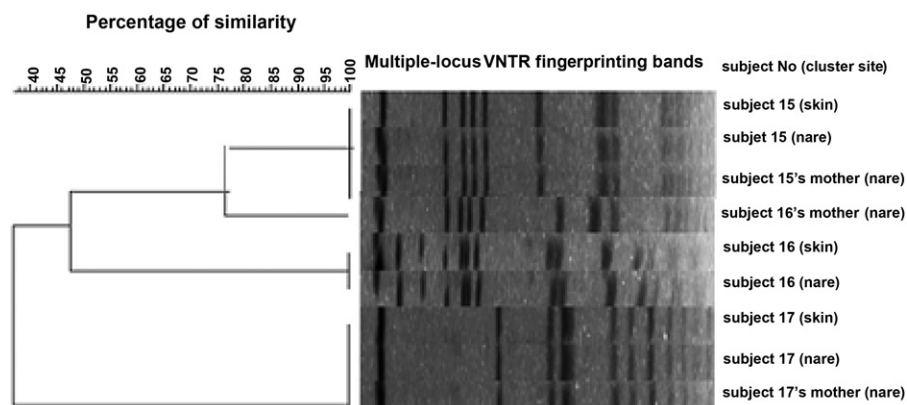


Figure 4. Dendrogram showing the results of the cluster analysis of *SmaI*-generated PFGE patterns from *S. aureus* isolated from 3 children's skin and noses, and their mothers' noses.

study showed a positive prevalence rate of superantigen-producing *S aureus* in children with AD (Table 5), and this was significantly higher than in the other groups ($P = .0018$). However, the mechanism of increased colonization by superantigen-producing *S aureus* in AD patients has not been thoroughly examined. Some studies suggest that the use of steroids or T cell immunosuppressive agents, such as tacrolimus, and cyclosporine A to manage AD, will ultimately result in the selection of *S aureus* strains with greater ability to produce diverse types and amounts of superantigens.¹⁹ However, it was interesting to find that the sea gene was the most prominent superantigenic exotoxin carried by *S aureus* in all three groups (Table 6; $P = .0012$). This is in agreement with the findings of a previous study in which the sea gene was predominantly found in adolescents and adults with AD.²⁰

In the current study, cultured isolates were examined for genotypic composition by PFGE to determine whether transmission of *S aureus* isolates between children and their mothers had taken place. The PFGE results (Figs 2 and 4) showed that 12 of the 13 (92.3%) AD and BD subjects who had *S aureus* in both nose and skin swabs were in complete concordance in terms of the genotypes of the strains (subjects 1, 2, 4 through 10, 15 through 17), indicating the occurrence of transmission between children's noses and skin. These findings suggest that the nasal carriage might be an important reservoir for self-contamination or for recolonization in patients with AD and BD. Conversely, homogenous *S aureus* strains between mothers' nares and the children's nares or skin (Figs 3 and 4) were found in only 3 of the 7 (42.9%) sample sets (subjects 14, 15, and 17). These results suggest that the possibility of *S aureus* transmission in early childhood AD is of concern to not only mothers but also other individuals in close contact. Therefore, although the initial *S aureus* infection in AD may be the result of maternal contact in infancy, the origins of *S aureus* may gradually change from the mother to other personal contacts after initial acquisition. Thus, a detailed evaluation of all family members and of the lifestyle factors of these children is necessary in future studies to determine the definitive source of *S aureus*.

REFERENCES

- Pérez-Roth E, Claverie-Martín F, Villa J, et al. Multiplex PCR for simultaneous identification of *Staphylococcus aureus* and detection of methicillin and mupirocin resistance. *J Clin Microbiol*. 2001;39:4037–4041.
- Bannerman TL, Hancock GA, Tenover FC, Miller JM. Pulsed-field gel electrophoresis as a replacement for bacteriophage typing of *Staphylococcus aureus*. *J Clin Microbiol*. 1995;33:551–555.
- Chung HJ, Jeon HS, Sung H, Kim MN, Hong SJ. Epidemiological characteristics of methicillin-resistant *Staphylococcus aureus* isolates from children with eczematous atopic dermatitis lesions. *J Clin Microbiol*. 2008;46:991–995.
- Abeck D, Mempel M. *Staphylococcus aureus* colonization in atopic dermatitis and its therapeutic implications. *Br J Dermatol*. 1998;139:13–16.
- Chiu LS, Chow VC, Ling JM, Hon KL. *Staphylococcus aureus* carriage in the anterior nares of close contacts of patients with atopic dermatitis. *Arch Dermatol*. 2010;146:748–752.
- Lebon A, Labout JA, Verbrugh HA, et al. Role of *Staphylococcus aureus* nasal colonization in atopic dermatitis in infants: the Generation R Study. *Arch Pediatr Adolesc Med*. 2009;163:745–749.
- Noble WC, Valkenburg HA, Wolters CHL. Carriage of *Staphylococcus aureus* in random samples of a normal population. *J Hyg Camb*. 1967;65:567–573.
- Nishijima S, Namura S, Higashida T, Kawai S. *Staphylococcus aureus* in the anterior nares and subungual spaces of the hands in atopic dermatitis. *J Int Med Res*. 1997;25:155–158.
- Breuer K, Haussler S, Kapp A, Werfel T. *Staphylococcus aureus*: colonizing features and influence of an antibacterial treatment in adults with atopic dermatitis. *Br J Dermatol*. 2002;147:55–61.
- Gong JQ, Lin L, Lin T, et al. Skin colonization by *Staphylococcus aureus* in patients with eczema and atopic dermatitis and relevant combined topical therapy: a double-blind multicentre randomized controlled trial. *Br J Dermatol*. 2006;155:680–687.
- 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.
- Williams RE, Gibson AG, Aitchison TC, Lever R, Mackie RM. Assessment of a contact-plate sampling technique and subsequent quantitative bacterial studies in atopic dermatitis. *Br J Dermatol*. 1990;123:493–501.
- Monti G, Tonetto P, Mostert M, Oggero R. *Staphylococcus aureus* skin colonization in infants with atopic dermatitis. *Dermatology*. 1996;193:83–87.
- Bonness S, Szekat C, Novak N, Bierbaum G. Pulsed-field gel electrophoresis of *Staphylococcus aureus* isolates from atopic patients revealing presence of similar isolates in isolates from children and their parents. *J Clin Microbiol*. 2008;46:456–461.
- Chiu LS, Ho MS, Hsu LY, Tang MB. Prevalence and molecular characteristics of *Staphylococcus aureus* isolates colonizing patients with atopic dermatitis and their close contacts in Singapore. *Br J Dermatol*. 2009;160:965–971.
- Suh L, Coffin S, Leckerman KH, Gelfand JM, Honig PJ, Yan AC. Methicillin resistant *Staphylococcus aureus* colonization in children with atopic dermatitis. *Pediatr Dermatol*. 2008;25:528–534.
- Hon KL, Leung AK, Kong AY, Leung TF, Ip M. Atopic dermatitis complicated by methicillin-resistant *Staphylococcus aureus* infection. *J Natl Med Assoc*. 2008;100:797–800.
- Breuer K, Wittmann M, Bösch B, Kapp A, Werfel T. Severe atopic dermatitis is associated with sensitization to staphylococcal enterotoxin B (SEB). *Allergy*. 2000;55:551–555.
- Schlievert PM, Strandberg KL, Lin YC, Peterson ML, Leung DY. Secreted virulence factor comparison between methicillin-resistant and methicillin-sensitive *Staphylococcus aureus*, and its relevance to atopic dermatitis. *J Allergy Clin Immunol*. 2010;125:39–49.
- Kim DW, Park JY, Park KD, et al. Are there predominant strains and toxins of *Staphylococcus aureus* in atopic dermatitis patients? Genotypic characterization and toxin determination of *S aureus* isolated in adolescent and adult patients with atopic dermatitis. *J Dermatol*. 2009;36:75–81.

Requests for reprints should be addressed to:

Do Won Kim

Department of Dermatology

Kyungpook National University Hospital

50 Samduk 2-ga Jung-Gu Daegu

South Korea 700-721

E-mail: kimdw@knu.ac.kr