MAJOR ARTICLE

Successful Termination of a Furunculosis Outbreak Due to *lukS-lukF*–Positive, Methicillin-Susceptible *Staphylococcus aureus* in a German Village by Stringent Decolonization, 2002–2005

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Background. Skin infections due to *Staphylococcus aureus* have recently become a public concern, mainly because of emerging resistance against widely used antibiotics and specific virulence determinants. Strains harboring the *lukS-lukF* gene (which codes for Panton-Valentine leukocidin) are frequently associated with severe furunculosis. Generally applicable strategies for the control of community outbreaks of furunculosis have not been defined.

Methods. We report the investigation and successful termination of an outbreak of furunculosis due to *lukS-lukF*–positive *S. aureus* in a German village ($n = 144$). Nasal swab specimens were obtained from village residents. A retrospective cohort study was conducted. Nasally colonized persons, persons who had current furuncles or who had experienced relapsing furuncles since 2002, and their family members underwent stringent decolonization measures using mupirocin nasal ointment and disinfecting wash solution. Multiple nasal swab specimens were obtained to monitor the long-term outcome of decolonization measures.

Results. From January 1998 through December 2004, 42 cases and 59 relapses of furunculosis were identified by active case finding. Of 140 participants tested, 51 (36%) were found to be nasally colonized with *S. aureus*. In 9 participants, the strain was positive for *lukS-lukF*. No methicillin resistance was detected. Risk of furunculosis was associated with contact with case patients (relative risk, 6.8; 95% confidence interval, 3.2–14.3) and nasal colonization with a *lukS-lukF*–positive strain of *S. aureus* (relative risk, 3.6; 95% confidence interval, 2.3–5.9). Passive surveillance implemented in January 2005 did not detect any case of *lukS-lukF*–positive, *S. aureus*–associated furuncles in this village.

Conclusion. This report describes a successful strategy for terminating the transmission of epidemic strains of *S. aureus* among a nonhospitalized population.

Staphylococcus aureus is a common cause of skin infections. Outbreaks of furunculosis were reported as early as the 1950s and 1960s [1]. *S. aureus* infection also causes severe abscesses in deeper organs and life-threatening septicemia. Humans are a natural reservoir for *S. aureus*; 30%–50% of healthy persons are nasally colonized [2, 3]. Transmission of *S. aureus* occurs predominantly by person-to-person contact, although there are reports of animal-to-human transmission [4]. The severity of an *S. aureus*–induced infection is determined by the presence of virulence factors, including several exotoxins. Panton-Valentine leukocidin—which is encoded for by the gene *lukS-lukF*—is a leukocytolytic toxin associated with severe cutaneous infections and highly lethal necrotizing pneumonia [2, 5]. The treatment of *S. aureus* infection has become increasingly complicated by the emergence of methicillin resistance in community-acquired *S. aureus* strains [6, 7], a high proportion of which (77%–97%) have *lukS-lukF* [8, 9]. In recent years, emerging community-acquired,

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methicillin-resistant *S. aureus* (MRSA) infection has become a public health problem, and rational strategies for the control of staphylococcal infection among nonhospitalized populations are required [7].

We report the investigation and control of an outbreak of infection involving furuncles and abscesses in a small village located in a rural region in northeastern Germany (population density, $\leqslant$25 inhabitants/km^2) [10]. According to anecdotal reports, furuncles first occurred among village inhabitants in the 1990s. In 2002, a local family physician observed an increase in the number of skin infections in village inhabitants. Samples obtained from patients were positive for *S. aureus,* but MRSA was not detected. Therefore, no further laboratory testing was performed. However, because cases continued to be reported, an outbreak investigation was initiated in March 2004 in cooperation with the local health department. Objectives of the outbreak investigation were to determine risk factors and routes of transmission and to stop the outbreak. Despite the lack of methicillin resistance, it was of public health importance to control the spread of infection, because the outbreak involved a nonhospitalized population. The investigation included active case finding, environmental inspection, and a retrospective cohort study that included a nasal carriage survey and a risk factor study.

METHODS

Setting. The affected village was inhabited by 144 persons (73 female residents and 71 male residents) in 58 households. The adults worked in farming or making handicrafts or as employees in the surrounding towns. The 30 children (age, <18 years) living in the village attended schools, kindergartens, and day care facilities in the neighboring town. Other places for group activities included a shooting club, the local voluntary fire brigade, a local citizen's group, and a soccer club. Shopping opportunities and health care services were only present in the neighboring town. One bar was located in the village and was frequently visited by the inhabitants of the village. In the neighboring towns, there were 3 family doctors, 2 surgical practices, and 2 regional hospitals.

Case finding. The family physician who first reported this outbreak of skin infection and other physicians in the region were interviewed to ascertain the number of diagnoses of furuncles and abscesses in other organs that had been made involving village inhabitants since 1998. Seven persons who no longer lived in the village but who still had close contact with relatives who lived in the village were included in the case-finding process. Detailed information regarding the history of infection in a patient and related diagnostic results was collected from physicians if informed consent was provided by the patient.

Cohort study. To obtain information about risk factors for infection, we undertook a retrospective cohort study of the residents of the village in March 2004. Every study participant was asked to complete a standardized questionnaire regarding demographic characteristics, contacts, possible risk factors, underlying diseases, and the occurrence of furuncles or abscesses in the past 12 years. The questionnaire asked about exposures that were chosen on the basis of results of explorative interviews with village inhabitants and on a wide variety of possible risk factors reported in the literature. Questions pertained to events that occurred in the year 2003 and, in affected participants, in the year before the first furuncle occurred, as well.

A case was defined as a skin abscess (furuncle) >0.5 cm in diameter or an abscess in another organ that was reported to have occurred in a village inhabitant during the period 1998–2004. Abscesses in other organs were considered to be verified only if diagnosed by a physician. A relapse was defined as a case in a person who reported the recurrence of the same symptoms after experiencing a full recovery from a previous case. Case contact was defined as exposure to a case within a person's family or household, in a friend or relative with whom time was spent or personal items were shared (e.g., clothing, towels, or toys), or in a person with whom skin contact occurred during mutual activity (e.g. while playing soccer).

Microbiological investigation and bacteriological diagnosis. Simultaneous to performing the cohort study, nasal swab specimens were obtained from every study participant and were sent to the German National Reference Laboratory for Staphylococci (Wernigerode, Germany) for isolation of staphylococci within 1 day. During the outbreak investigation, specimens of swabs of furuncles performed after surgical intervention and repeated nasal swabs performed on persons who had undergone decolonization procedures were also sent to the laboratory. All specimens were cultured on blood agar plates. After incubation for 24 h at 35°C in ambient air, colonies that were suspicious for *S. aureus* were subjected to species identification using current methods [11]. Antibiotic susceptibility was assessed using microbroth MIC [12]. PCR demonstration of *lukS-lukF* was performed using primers and conditions as described elsewhere [13]. Molecular typing was performed using *Sma*I-macrorestriction patterns according to the HARMONY protocol [14]. Of the isolates exhibiting identical patterns, 1 was further subjected to multilocus-sequence typing, as described by Enright et al. [15].

Environmental investigation. The village and the surrounding areas were inspected for any geographical or infrastructural particularities that might possibly be associated with an increased prevalence of *S. aureus* infection. This inspection included an assessment of village livestock by the regional department for veterinary care. On a routine basis, the local health department investigated the water quality of the regional bathing lakes, public outdoor pools, and private wells. Because data analysis revealed an epidemiological association between wearing fire-protective suits used by the local fire brigade and the occurrence of furuncles, the collar and axillary areas of 5 suits were swabbed for laboratory testing.

Statistical methods. Data were analysed using EpiInfo software, version 3.01 (Centers for Disease Control and Prevention), and SPSS software, version 12.0 for Windows (SPSS). Univariate analyses were performed using the complete or stratified data sets. Attack rates were determined by "number of cases" divided by "number of persons under risk" in consideration of time or possible risk factors. Relative risks were calculated to identify variables associated with the occurrence of furuncles or abscesses. To describe statistical significance, a 95% CI was computed or χ^2 and Fisher exact tests were used. A P value of <.05 was considered to be statistically significant. Backward stepwise logistic regression was initially performed using all variables that were statistically significantly associated with the occurrence of furuncles or abscesses, as well as patient sex and age.

Intervention. To control further transmission, persons colonized with *lukS-lukF*–positive *S. aureus*, persons with a current furuncle or who experienced relapsing furuncles since 2002, and their close contacts were advised to follow a stringent decolonization strategy. In the outbreak investigation, we identified 53 such persons. Control measures were initiated on 8 July 2004.

The decolonization protocol used was based on existing hospital-associated MRSA decolonization measures [16, 17]. The procedures were implemented for 5 days and included treatment with mupirocin nasal ointment 3 times daily, hand disinfection with an alcohol-based antibacterial hand sanitizer after applying nasal ointment, daily treatment of skin and hair with an octenidin-based wash solution, antiseptic treatment of the throat by gargling with 0.1% chlorhexidine solution 3 times daily, daily disinfection of personal items (e.g., comb, razor, glasses, and jewelry) and the bathtub or shower floor with an alcohol-based antimicrobial cleanser, and daily changing and washing (in water with a temperature of at least 60°C, using a laundry detergent) of towels, bedclothes, underwear, and clothing. In addition, persons were instructed to increase hand hygiene and to minimize contact with other inhabitants of the village during the 5 days of decolonization treatment. Because there was a strong epidemiological association between wearing fire-protective suits and the occurrence of furuncles, these suits were disinfected and cleaned according to local health department guidelines.

To determine the success of decolonization measures, nasal swab specimens were obtained from treated persons 3 days, 7 weeks, and 20 weeks after decolonization. Passive surveillance was implemented in January 2005. Additionally, information about the outbreak of furunculosis and *lukS-lukF*–positive *S. aureus* was provided to local physicians to promote awareness among the local medical community. This information included treatment guidelines for patients with infection or nasal colonization with *lukS-lukF*–positive *S. aureus*. Physicians were also asked to report relapsing skin infections within families and communities to the local health department and were requested to obtain a furuncle or nasal swab specimens for laboratory testing. It was requested that the regional laboratory send all *S. aureus* isolates obtained from patients with skin infections to the German National Reference Laboratory for Staphylococci to check for the presence of *lukS-lukF*.

RESULTS

Case Finding

During the period from January 1998 through March 2005, we identified 42 primary cases of furuncles or abscesses and 59 relapses in 27 persons who had experienced primary cases (figure 1). Of the 42 primary cases, 36 (86%) occurred in 7 families (that had a total of 52 family members); only 6 of the 42 primary cases presented as isolated cases. The majority of infections involved the skin. Abscesses in other organs were identified in 4 cases. Fifteen cases (36%) required hospitalization.

Cohort Study

Epidemiological descriptions. Of the 144 village residents, 141 (98%) participated in the study (73 female residents and 68 male residents). The median subject age was 39 years (range, 0–88 years); 30 participants were children (age, <18 years).

In the cohort study, 36 cases (involving 21 female subjects and 15 male subjects) met the case definition. Eight cases occurred in children (age, <18 years) and 28 occurred in adults (age, ⩾18 years). Six subjects identified by active case finding were not included in the cohort study: 2 died prior to the study, 1 did not receive a diagnosis of a furuncle until after the study (in September 2004), and 3 did not live in the village at the time the study was conducted, although they still had close contact to relatives in the village. The median age was 31 years (range, 4–53 years) for case patients and was 42 years (range, 0–88 years) for non–case patients ($P = .0075$, by Kruskal-Wallis test). Of the case patients, 23 (64%) had experienced at least 1 relapse. The overall attack rate was 26% (95% CI, 19%–34%). In persons colonized with *lukS-lukF*–positive *S. aureus,* the attack rate was 78% (95% CI, 40%–97%), and in persons colonized with *lukS-lukF*–negative *S. aureus,* it was 19% (95% CI, 8%–33%).

Microbiological findings. Of the 140 participants who underwent testing, 51 (36%) were nasally colonized with *S. aureus.* Of these, 9 carried *lukS-lukF*–positive *S. aureus* strains. In 1 woman, a *lukS-lukF*–positive strain was detected in a furuncle swab specimen and a nasal swab specimen. Two different strains of *lukS-lukF*–positive *S. aureus* were identified: one strain was identified as multilocus sequence type ST-121 ($n = 7$), and the other was identified as ST-30 ($n = 2$). Because we detected *S. aureus* ST-30 in only 1 family, the ST-121 strain was considered to be the outbreak strain. Antibiotic resistance testing did not reveal any methicillin resistance. Of 77 tested strains, 3 (4%) were susceptible to all antibiotics tested. Antimicrobial resistance patterns of all tested strains are shown in table 1.

Epidemiological analysis. Analyses comparing exposed and nonexposed cases and noncases did not differ significantly whether exposures were considered for the year 2003 or for the year before the first furuncle occurred. Thus, only the analysis of the 2003 exposure data is presented in this report.

Univariate analysis revealed that the most important risk factors for current or past infection were contact with cases and nasal colonization with *lukS-lukF*–positive *S. aureus* (table 2). In adults, we identified additionally well-known risk factors for infection, such as smoking, drinking alcohol, and chronic skin disease (table 3).

In the multivariate logistic regression model, 6 variables were significantly associated with furuncles and abscesses (table 4). In this analysis, owning live chickens was inversely associated with infection. Being a member of the local fire brigade was the only group activity that was significantly associated with developing furuncles. Interviews revealed that the members of the fire brigade occasionally exchanged fire-protective suits with each other.

Table 1. Antimicrobial resistance pattern of 77 strains of *Staphylococcus aureus* detected (in 2004) in nasal or furuncle swab specimens following an outbreak of furunculosis (2002–2005) in a small village in Germany.

Antimicrobial resistance pattern	No. (%) of strains
Susceptible	3 (4.0)
Pen and Cip	46 (60.0)
Cip	13 (17.0)
Pen, Cip, and Ery	5 (7.0)
Pen, Cip, and Ote	3 (4.0)
Pen, Cip, and Cmp	2 (2.5)
Pen, Cip, and Oxa	2 (2.5)
Pen and Ery	1 (1.0)
Pen, Cip, Ery, and Cmp	1 (1.0)
Cip, Ery, and Fos	1 (1.0)
Total	77 (100)

NOTE. Cip, ciprofloxacin; Cmp, chloramfenicol; Ery, erythromycin; Fos, fosfomycin; Ote, oxytetracycline; Oxa, oxacillin; Pen, penicillin.

Environmental Investigation

The regional department for veterinary care did not report any abnormalities in the livestock held in the village. The water of regional lakes, public outdoor pools, and private wells was never found to be microbiologically contaminated. *S. aureus* was not isolated from any of the swabs taken from the fire-protective suits.

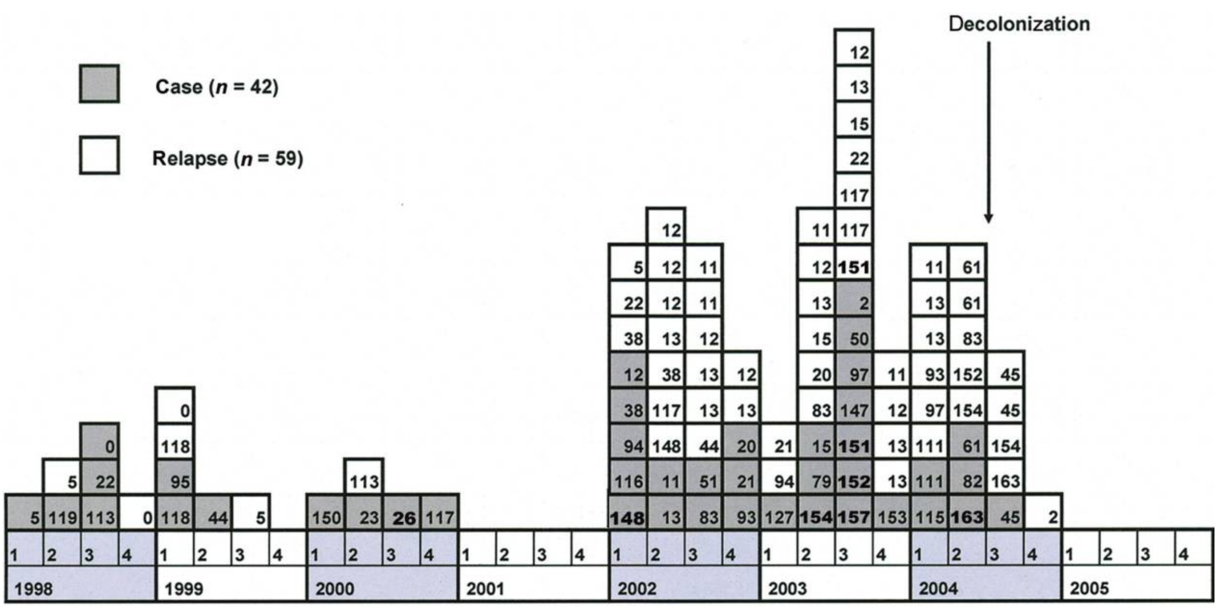

Figure 1. Epidemic curve of furuncles and abscesses in other organs that occurred in the residents of a small village in Germany from January 1998 to December 2005. The numbers 1–4 along the x-axis represent each quarter of the year indicated. The numbers in the boxes are the identification numbers assigned to the village residents for the purpose of this study. *Bold numbers,* self-reported cases of furuncles or abscess. Overall, 42 cases and 59 relapses were identified. In July 2004, decolonization was conducted in persons identified as being colonized with *lukS-lukF*–positive *Staphylococcus aureus*.

Table 2. Exposures identified as significant risk factors by univariate analysis (in 2004) using data from the cohort study of an outbreak of furunculosis (2002–2005) in a small village in Germany.

Exposure	RR (95% CI)	P[a]
Contact with case patients within or outside the family	6.8 (3.2–14.3)	<.001
Contact with case patients within the family	3.5 (1.5–8.3)	.003
Contact with case patients outside the family	3.1 (1.2–7.6)	.02
Nasal colonization with *lukS-lukF*–positive *Staphylococcus aureus*	3.6 (2.3–5.9)	<.001
Having gone swimming anywhere	2.9 (1.4–6.0)	.001
Visiting the local public outdoor pool	3.4 (2.1–5.4)	<.001
Visiting the local bathing lake	2.6 (1.5–4.6)	<.001
Being a member of the local voluntary fire brigade	2.2 (1.3–3.8)	.005
Sharing objects with neighbors[b]	1.8 (1.0–3.1)	.05
Owning live chickens	0.5 (0.2–0.8)	.009

NOTE. RR, relative risk.
[a] Determined using the χ^2 test.
[b] For example, dishes, toys, or clothes.

Surveillance after Decolonization

Consecutive nasal swab specimens were obtained from treated persons ($n = 53$) 3 days, 7 weeks, and 20 weeks after decolonization (table 5). Only 2 persons refused to provide all 3 control swab specimens. All swab specimens had negative test results after 3 days. After 7 weeks, 4 persons from 3 families were found to be colonized with a *lukS-lukF*–positive *S. aureus* strain (ST 121); 2 experienced recolonization, and 2 were considered to be newly colonized. These 4 persons received a 10-day course of treatment with rifampicin and trimethoprim-sulfamethoxazole, as described by Hoss and Feder [18]. In addition, decolonization procedures described above were repeated for the 4 colonized subjects and their families.

In the months following decolonization, 1 person was newly affected with furuncles, and 3 other persons experienced relapses. These persons belonged to 2 families; members of 1 of these families had already been identified as being colonized 7 weeks after decolonization. The *lukS-lukF*–positive *S. aureus* strain ST-121 was identified in all affected persons from nasal ($n = 2$) or furuncle swab specimens ($n = 2$). They were treated by their personal physicians, and the respective families repeated the decolonization treatment.

Table 3. Exposures identified as significant risk factors in adults by univariate analysis (in 2004) using data from the cohort study of an outbreak of furunculosis (2002–2005) in a small village in Germany.

Exposure	RR (95% CI)	P[a]
Smoking[b]	4.4 (2.0–9.5)	<.001
Consuming alcohol daily	3.4 (1.2–10.1)	.07
Experiencing a chronic skin disease	3.1 (1.7–5.6)	.003
Buying milk, eggs, or meat in the village	2.9 (1.4–6.0)	.002
Using a private well for water	2.6 (1.4–4.9)	.002
Having children within the household	2.6 (1.4–5.1)	.003
Receiving help from a neighbor[c]	2.3 (1.1–5.0)	.07
Visiting the local bar at least once a week	2.2 (1.2–4.1)	.02
Having work-related contact with persons other than one's colleagues	2.2 (1.2–4.1)	.02
Playing card games with the neighbors	2.0 (1.1–3.7)	.04

NOTE. RR, relative risk.
[a] Determined using the χ^2 test.
[b] Defined as smoking >10 cigarettes per week.
[c] For example, in gardening, construction, or doing the daily shopping.

Table 4. Multivariate logistic regression involving variables significantly associated with furuncles and abscesses in the model (from 2004) using data from the cohort study of an outbreak of furunculosis (2002–2005) in a small village in Germany.

Exposure	OR (95% CI)
Nasal colonization with *lukS-lukF*–positive *Staphylococcus aureus*	9.2 (1.2–73.1)
Contact with case patients within or outside the family	4.7 (1.3–17.3)
Being a member of the local voluntary fire brigade	5.5 (1.6–19.0)
Sharing objects with neighbors[a]	3.6 (1.1–12.2)
Experiencing a chronic skin disease	12.3 (1.5–100.2)
Owning of live chickens	0.3 (0.1–0.7)

[a] For example, dishes or toys.

In nasal swab specimens that were obtained 20 weeks after decolonization, no *lukS-lukF*–positive strains were detected. In 2005, the year following decolonization, no cases of furuncles or abscesses due to *lukS-lukF*–positive *S. aureus* were detected in inhabitants of the village through passive surveillance.

DISCUSSION

We report the investigation and control of an outbreak of skin infections due to *lukS-lukF*–positive *S. aureus* in a small village in Germany. In a retrospective cohort study, we confirmed well-known risk factors, such as smoking, alcohol consumption, and chronic skin disease [8, 19]. The typical route of transmission was person-to-person contact and the main risk factor was nasal colonization with *lukS-lukF*–positive *S. aureus*. In addition, we identified the fire-protective suits used by the local fire brigade as a possible vehicle for transmission. We found no explanation as to why owning live chickens was inversely associated with infection.

Our study has several limitations. Recall bias is likely in a retrospective cohort study. The occurrence of furuncles was self-reported by the case patients. In routine practice, no swab specimens from furuncles were obtained, and no laboratory testing was performed. Because participants could have reported a higher or lower number of infections than the true number, the attack rate could be over- or underestimated. In the follow-up of persons who received decolonization treatment, 2 persons refused to provide all 3 control swab specimens. Furthermore, swabs were not performed for some persons on all 3 specified dates. *S. aureus* was not isolated from any of the swabbed fire-protective suits that were used by the local fire brigade. It is possible that more-effective methods of swabbing would have revealed positive results.

Our stringent intervention protocol led to cessation of the outbreak. A major strength of our study was the investigation of the long-term success of these measures in a community setting monitored by obtaining multiple nasal swab specimens from treated persons and by passive surveillance. Our protocol was based on decolonization measures used in hospital settings against MRSA [16, 17, 20]. In 2 of these reports, eradication of MRSA in colonized patients was achieved in 93% and 99% of cases. However, recolonization was observed within several weeks in 22% and 26% of cases, respectively [17, 20]. In our study, all nasal swab specimens obtained 3 days after decolonization were negative for *S. aureus*. In the following weeks, decolonization measures were repeated in 4 families, because individual members were found to be newly colonized or recolonized with *lukS-lukF*–positive *S. aureus* or experienced furuncles. At least 1 family admitted to not thoroughly following the recommended decolonization protocol. We must assume that the recommended measures were not followed by everybody. Because decolonization was implemented in the community, rather than in a hospital environment, we were unable to sufficiently monitor compliance. Nevertheless, the absence of *lukS-lukF*–positive *S. aureus* 20 weeks after the initial implementation decolonization efforts suggests that eradication of a virulent *S. aureus* strain is possible in a community setting. No furuncles due to *lukS-lukF*–positive *S. aureus* were detected by passive surveillance in the village during the year after decolonization was performed.

Outbreaks of skin infections within a defined community have been reported previously. In some reports, appropriate

Table 5. Findings from nasal control swab specimens obtained in July, August, and November, 2004, from 53 persons receiving decolonization treatment following an outbreak of furunculosis in a small village in Germany.

Control swab	Total no. of swab specimens obtained	Result of testing, no. (%) of swab specimens	
		Staphylococcus aureus positive	*lukS-lukF* positive
First[a]	43	0 (0)	0 (0)
Second[b]	48	11 (23)	4 (8)
Third[c]	46	10 (22)	0 (0)

[a] Obtained at least 3 days after decolonization.
[b] Obtained 7 weeks after decolonization.
[c] Obtained 20 weeks after decolonization.

intervention measures are described, but without any monitoring of the long-term outcome [21, 22]. Several published outbreaks have occurred in football teams or among military recruits [23–25]. Two outbreaks of furunculosis due to community-acquired MRSA that display parallels to our outbreak were observed in Alaskan villages [9, 26]. In these outbreaks, visits to steam baths and saunas were associated with furuncles. Infection control was limited to hygiene-control measures, increased surveillance of community-acquired MRSA infection, and provision of appropriate treatment guidelines to health care providers. We are aware of only 1 report on the short-term success of decolonization measures in an outbreak in Switzerland of skin infections in schoolchildren due to *S. aureus* that is resistant to penicillin and amoxicillin [27]. Affected and colonized persons and their family members received treatment for eradication that consisted of nasal mupirocin twice daily and daily chlorhexidine showers for 5 days. It was not reported whether follow-up nasal swab specimens were obtained after successful decolonization to assure that treated persons remained negative for penicillin- and amoxicillin-resistant *S. aureus* in the following months.

In summary, this is, to our knowledge, the first report of the successful termination of an outbreak of furuncles and abscesses due to *lukS-lukF*–positive *S. aureus* in a defined population of a small village, including a long-term follow-up of a stringent decolonization strategy. Because infection and colonization due to community-acquired MRSA is an emerging problem worldwide, it is a public health responsibility to identify outbreaks, to trace contacts, and to apply effective infection-control measures [7, 28, 29]. Even in the absence of methicillin resistance, *lukS-lukF*–positive *S. aureus* requires particular attention because of its capacity to cause necrotizing infections [5]. The control strategy described in our report may be helpful for others who encounter infection due to *lukS-lukF*–positive *S. aureus* in nonhospitalized populations.

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