The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

A Clone of Methicillin-Resistant *Staphylococcus aureus* among Professional Football Players

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ABSTRACT

BACKGROUND

Methicillin-resistant *Staphylococcus aureus* (MRSA) is an emerging cause of infections outside of health care settings. We investigated an outbreak of abscesses due to MRSA among members of a professional football team and examined the transmission and microbiologic characteristics of the outbreak strain.

METHODS

We conducted a retrospective cohort study and nasal-swab survey of 84 St. Louis Rams football players and staff members. *S. aureus* recovered from wound, nasal, and environmental cultures was analyzed by means of pulsed-field gel electrophoresis (PFGE) and typing for resistance and toxin genes. MRSA from the team was compared with other community isolates and hospital isolates.

RESULTS

During the 2003 football season, eight MRSA infections occurred among 5 of the 58 Rams players (9 percent); all of the infections developed at turf-abrasion sites. MRSA infection was significantly associated with the lineman or linebacker position and a higher body-mass index. No MRSA was found in nasal or environmental samples; however, methicillin-susceptible *S. aureus* was recovered from whirlpools and taping gel and from 35 of the 84 nasal swabs from players and staff members (42 percent). MRSA from a competing football team and from other community clusters and sporadic cases had PFGE patterns that were indistinguishable from those of the Rams' MRSA; all carried the gene for Panton–Valentine leukocidin and the gene complex for staphylococcal-cassette-chromosome *mec* type IVa resistance (clone USA300-0114).

CONCLUSIONS

We describe a highly conserved, community-associated MRSA clone that caused abscesses among professional football players and that was indistinguishable from isolates from various other regions of the United States.

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N Engl J Med 2005;352:468-75.

Contact sports such as American football inevitably lead to skin and soft-tissue injuries that place players at increased risk for infection.[1,2] Skin infections, particularly those caused by *Staphylococcus aureus*, are common among sports participants. Recent reports have described an increasing number of community-associated methicillin-resistant *S. aureus* (MRSA) skin infections in persons without links to health care institutions.[3-6] These infections differ from those due to health care–associated MRSA in that they are resistant predominantly to β-lactam and macrolide antimicrobial agents and in that they result in the formation of skin abscesses. Cases of community-associated MRSA infection have previously been reported among football players and other sports participants; however, little is known about factors associated with the emergence of community-associated MRSA strains that may cause outbreaks in various geographic regions and community settings.

In September 2003, cases of large skin abscesses caused by MRSA were first noted among members of the St. Louis Rams, a professional football team in Missouri. Additional cases among team members and subsequent cases in members of an opposing team suggested that competitive play might be causing transmission. On November 6, 2003, the Centers for Disease Control and Prevention (CDC) was invited to investigate the transmission of MRSA among the Rams football players, to recommend prevention and control measures, and to characterize the staphylococcal isolates.

METHODS

EPIDEMIOLOGIC INVESTIGATION

We defined a case of MRSA infection as any skin or soft-tissue infection in a player or staff member of the St. Louis Rams during the 2003 football season (August 1 through November 30) from which MRSA was isolated on culture. To identify potential activities that might have led to the transmission of MRSA, we performed an observational study of on-field and off-field activities and hygiene practices during competition and training at the Rams facility. In addition, a retrospective cohort study of the players was conducted to identify risk factors for infection. Using a standardized data-collection form, we collected information about players' field positions, demographic characteristics, health care exposures, antimicrobial use, close contact with other persons with skin infections, skin-abrasion management, hygiene practices, and use of saunas, whirlpools, and training and therapy equipment. We also evaluated antimicrobial use among the Rams players by reviewing the team pharmacy log and calculating the average number of antimicrobial prescriptions per player per year. We compared this rate to sex- and age-specific rates in the general population, as determined by national surveys.[7,8]

ENVIRONMENTAL AND LABORATORY INVESTIGATION

To determine whether other Rams players were colonized with the outbreak MRSA strain, we performed a nasal-carriage prevalence survey among all players and staff members and obtained swabs of uninfected skin abrasions. To identify any environmental sources of exposure, we sampled surfaces and shared items in the training facility, including weight-training equipment, towels, saunas and steam rooms, and water from whirlpools and a therapy pool. In addition, we swabbed 0.1-m^2 (1-ft^2) areas of artificial turf after a game in areas of the field that were recorded to have the highest number of tackles. All environmental sampling was performed after recommended infection-control procedures and the use of chlorhexidine-containing soap had been initiated.

After initial screening for oxacillin resistance, all available MRSA isolates from Rams players' skin abscesses and suspected MRSA isolates from skin abrasions, nasal swabs, and environmental sources were tested for antimicrobial susceptibility by means of broth microdilution, according to interpretive criteria of the Clinical and Laboratory Standards Institute (formerly the National Committee for Clinical Laboratory Standards).[9] The antimicrobial agents tested were ciprofloxacin, clindamycin, erythromycin, levofloxacin, oxacillin, penicillin, tetracycline, trimethoprim–sulfamethoxazole, and vancomycin. In addition, an antimicrobial-susceptibility disk test to study inducible clindamycin resistance (i.e., a D-test) was performed.[10,11] All *S. aureus* recovered from skin abscesses, the environment, nasal swabs, and skin-abrasion specimens were tested by a polymerase-chain-reaction assay for the staphylococcal-cassette-chromosome *mec* (SCC*mec*) resistance complex, as described by Katayama et al.,[12] and for the gene encoding Panton–Valentine leukocidin cytotoxin.[13,14]

After digestion of chromosomal DNA with restriction endonucleases (*Sma*I for initial digestion

and *Eag*I, *Sac*II, *Nar*I, *Apa*I, or *Nae*I for subsequent digestion of subtype USA300-0114), restriction products were analyzed by pulsed-field gel electrophoresis (PFGE).[15] The gels were analyzed with BioNumerics software (Applied Maths) and interpreted according to criteria published elsewhere.[16] To determine the relatedness of the outbreak strain to other strains, we compared the PFGE patterns of isolates from the Rams with those of MRSA isolates from Team A, a professional football team that competed with the Rams and members of which subsequently had abscess development. In addition, we compared the PFGE patterns of both teams' isolates with all 3241 isolates of *S. aureus* in the CDC PulseNet database[17] to identify the clonal complex to which the isolates belonged. To compare the patterns, we calculated percentage similarities with Dice coefficients by the unweighted pair-group method with arithmetic averages.[17] Multilocus sequence typing was performed on pulsed-field type USA300 isolates.[18]

STATISTICAL ANALYSIS

All univariate and bivariate analyses were performed with SAS software, version 9.0. Chi-square or Fisher's exact tests were used to analyze the relationships between categorical variables, and t-tests were used to analyze the relationship between categorical and continuous variables. All reported P values are two-sided. Multivariate analysis was not performed because of the small number of cases.

RESULTS

EPIDEMIOLOGIC INVESTIGATION

From September 1 through December 1, 2003, eight MRSA infections occurred in 5 of the 58 Rams players (9 percent) (Fig. 1). The infections developed in offensive and defensive linemen and a linebacker at sites of skin abrasions (turf burns) on elbows, forearms, or knees. All the infections rapidly progressed to large abscesses 5 to 7 cm in diameter and required surgical intervention with incision and drainage. The mean age of the players with MRSA infections was 27 years (range, 23 to 33). Various antimicrobial agents were administered; two of the players received intravenous antimicrobial agents (vancomycin and ceftriaxone) before the initiation of oral antimicrobial therapy, and all five players received three oral agents (cephalexin, trimethoprim–sulfamethoxazole, and rifampin) alone or in combination. Most of the infections resolved within 10 days after the initiation of treatment. Recurrent infections developed in three of the five players. Although none of the players required hospitalization, three of them missed 1, 4, and 12 days of games or practice, respectively, for a total of 17 missed days due to infection.

From our player survey and observational study of games and practices, we found that skin abrasions occurred frequently among players. Approximately two to three turf burns per week were acquired from sliding on the field during competition or practice (Fig. 2). Players reported that abrasions were more frequent and severe when competition took place on artificial turf than when it took place on natural grass. Trainers, who provided wound care, did not have regular access to hand hygiene, and alcohol-based hand-hygiene products were not available near areas where wound care or physical therapy was provided. Towels were frequently shared on the field during practice and games, with as many as three players using the same towel. Players often did not shower before using communal whirlpools. At the training facility, weight-training and therapy equipment was not routinely cleaned. Manufacturer-recommended guidelines for the routine cleaning of whirlpools, saunas, and steam rooms were not available for review.

Evaluation of potential risk factors explored in a cohort study revealed that being a lineman or a linebacker, as compared with having a backfield position, was associated with the highest relative risk of an MRSA infection (10.6 [95 percent confidence interval, 1.3 to infinity], P=0.02) (Table 1). Players with MRSA skin infection had a significantly higher body-mass index than players in whom infection did not develop. Use of antimicrobial agents during the previous year was associated with MRSA infection; however, the association was not statistically significant (relative risk, 7.8; 95 percent confidence interval, 0.5 to infinity).

According to the team pharmacy log for the 2002 football season, maintained at the training facility, a team player on average received 2.6 antimicrobial-drug prescriptions per year. This rate was greater than 10 times the rate among persons of the same age and sex in the general population (0.5 prescription per year). In their survey responses, approximately 60 percent of players indicated they had taken or received antimicrobials during the 2003 football season.

Infection-control measures were instituted at the Rams training facility during the week of Octo-

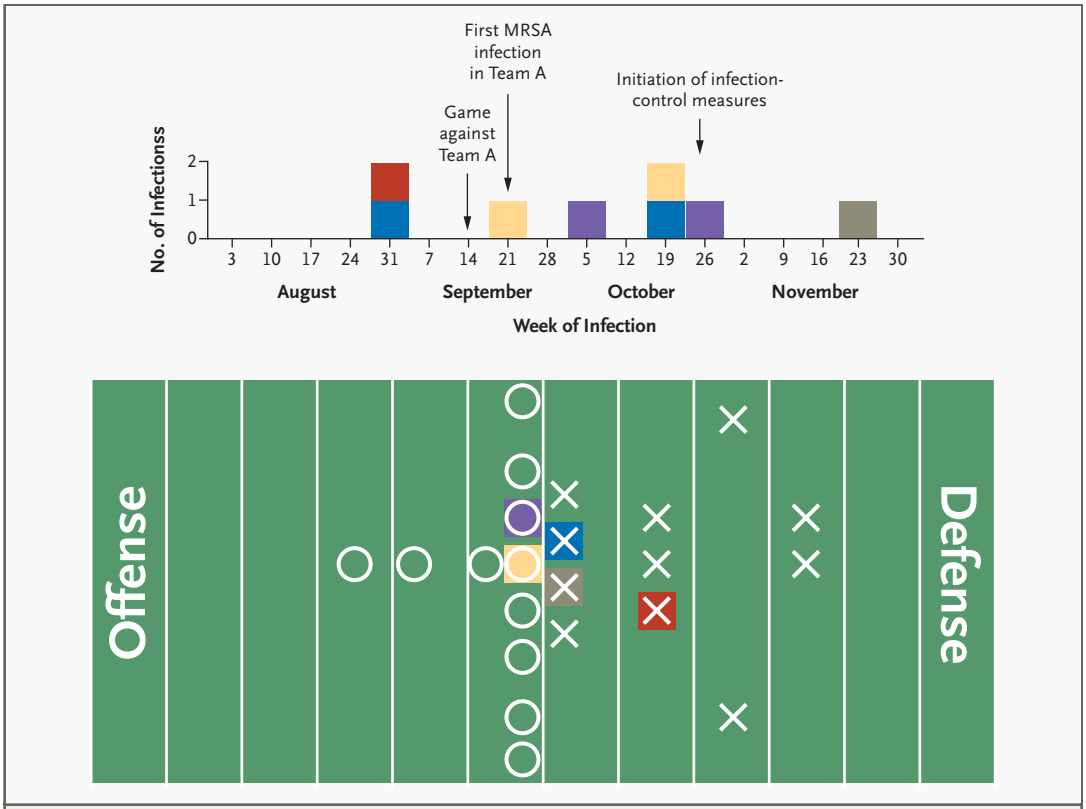

Figure 1. Epidemic-Curve Graph (Top) and Field Position Diagram (Bottom) of Cases of MRSA Infection among St. Louis Rams Professional Football Players in 2003.

Each box on the epidemic-curve graph and field diagram represents an MRSA infection; different colors designate different players; boxes of the same color thus represent recurrent infections. On the field diagram, X represents a defensive-player position and O an offensive-player position.

ber 26, 2003 (Fig. 1), and included installation of wall-mounted soap dispensers with chlorhexidine-containing soap for routine hand washing by players and staff members, appropriate local wound care, antimicrobial therapy targeting MRSA, and active surveillance for skin infections. After this intervention, only one additional case of MRSA infection occurred.

LABORATORY INVESTIGATION

Susceptibility testing of the MRSA causing infections in five Rams players showed that, in all cases, it was resistant to macrolides and oxacillin but susceptible to ciprofloxacin, clindamycin, tetracycline, trimethoprim–sulfamethoxazole, and vancomycin. None of the tested isolates exhibited inducible clindamycin resistance on the D-test. Isolates from the Rams and from Team A were compared with 3241 *S. aureus* isolate patterns in the CDC staphylococcus PulseNet database, which revealed that both teams' isolates were pulsed-field type USA300 (Fig. 3). After digestion with *Sma*I endonuclease, the teams' PFGE patterns were indistinguishable from one another but also indistinguishable from patterns associated with various community-associated MRSA clusters and sporadic cases in the United States. Both the teams' isolates and the indistinguishable community-associated isolates differed from other community-associated MRSA isolates (USA400) and known health care–associated isolates (USA100 and USA200).

To discriminate further among the indistinguishable PFGE patterns, digestion with five additional enzymes (*Eag*I, *Sac*II, *Nar*I, *Apa*I, and *Nae*I) was performed on MRSA isolates: two from the Rams, eight from Team A, and one representative isolate from each of nine previously investigated community clusters and sporadic cases among sports par-

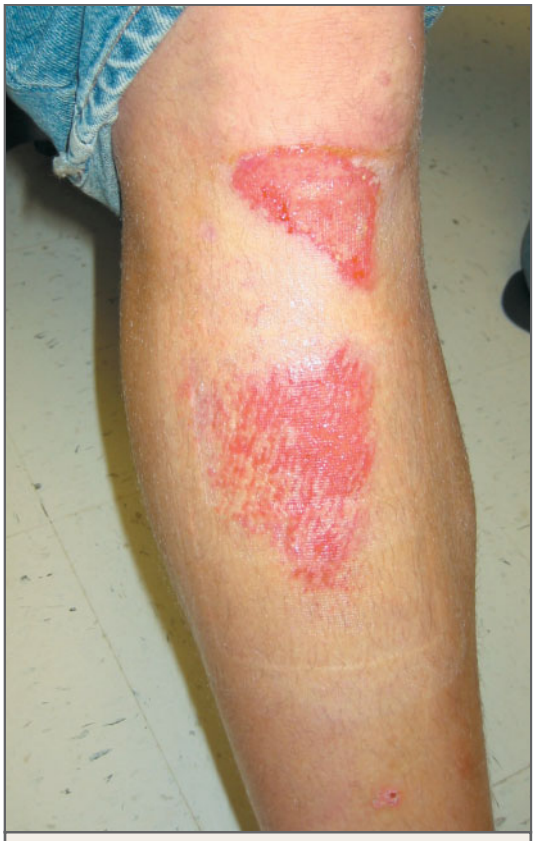

Figure 2. Photograph of an Uninfected Skin Abrasion (Turf Burn) on a St. Louis Rams Professional Football Player in 2003.

ticipants, children, prisoners, military recruits, and men who have sex with men. After each of the five additional digestions, the isolates again had indistinguishable patterns. This clonal subtype is now classified as pulsed-field type USA300-0114. All USA300-0114 isolates contained the gene for Panton–Valentine leukocidin as well as the gene complex for SCC*mec* type IVa resistance. The USA300-0114 subtype has been determined to fall within sequence type 8 on multilocus sequence typing.

The nasal-swab survey indicated that 23 of the 58 Rams players (40 percent) and 12 of the 26 staff members (46 percent) were colonized with methicillin-susceptible *S. aureus* (MSSA). No MRSA was identified. No environmental specimens yielded MRSA; however, MSSA isolates were recovered from a gel-applicator stick used for taping ankles and from two samples of whirlpool water collected at the end of the day. The gel and whirlpool-water isolates were indistinguishable on PFGE from MSSA recovered from the nasal swabs.

Examination of one nasal MSSA isolate revealed a two-band difference from the USA300-0114 pattern. This isolate also had the gene for Panton–Valentine leukocidin. Southern blot hybridization analysis of the outbreak MRSA isolates and the nasal MSSA isolate demonstrated that the band missing in the MSSA isolate carried the *mecA* resistance gene. The absence of the *mecA* gene may indicate either that the isolate lost the resistance gene or that this MSSA represents a strain that has not yet acquired the resistance gene.

DISCUSSION

Our investigation revealed that a cluster of skin abscesses among professional football players and other recent outbreaks of skin infection in the United States were caused by an emerging MRSA clone. This community-associated clone differed from strains of MRSA circulating in health care settings in that it was susceptible to most antimicrobial agents other than β-lactams and macrolides, it primarily caused skin infections in otherwise healthy persons, and it carried both a characteristic gene complex for methicillin resistance (SCC*mec* type IVa) and the gene for Panton–Valentine leukocidin, a cytotoxin that has been associated with severe abscesses and necrotizing pneumonia.[13] During the 2003 football season, abscesses also occurred in a competing team after a game with the Rams, suggesting that transmission of MRSA occurred during game play.

We used PFGE and five restriction endonucleases to demonstrate that MRSA isolates from both teams were indistinguishable. Further comparison with MRSA from epidemiologically unrelated outbreaks among sports participants and persons in other settings revealed that these other isolates were also indistinguishable from those of the two professional football teams and represented a clone now classified as pulsed-field type USA300-0114. These results indicate that this clone may be widely distributed in the community and thus that the two teams may have acquired the same strain independently. With currently available molecular-typing methods, it was not possible to differentiate between community and team isolates, and thus neither team-to-team transmission nor independent, community acquisition could be implicated as the primary source of MRSA among football players.

Table 1. Risk Factors for Skin Abscesses Due to Community-Associated MRSA among 53 St. Louis Rams Football Players, August 1 through November 30, 2003.*

Risk Factor	Risk Factor Present			Relative Risk (95% CI)	P Value†
	All Respondents	MRSA Infection	No MRSA Infection		
Black race — no. of players (%)	25/53 (47)	3/5 (60)	22/48 (46)	1.7 (0.3–9.3)	0.55
Mean body-mass index‡	NA	35.8	31.1	NA	0.03
Lineman or linebacker position (vs. backfield position) — no. of players (%)	27/53 (51)	5/5 (100)	22/48 (46)	10.6 (1.3–∞)	0.02
Surgery in past year — no. of players (%)	16/53 (30)	3/5 (60)	13/48 (27)	3.5 (0.6–18.8)	0.13
Hospitalization in past year — no. of players (%)	10/53 (19)	0/5	10/48 (21)	0.4 (0–3.6)	0.33
Use of antimicrobials in past year — no. of players (%)	30/51 (59)	5/5 (100)	25/46 (54)	7.8 (0.5–∞)	0.06
Turf burns covered during games — no. of players (%)	39/50 (78)	3/5 (60)	36/45 (80)	0.4 (0.1–2.2)	0.31
Shaved body other than face — no. of players (%)	9/51 (18)	1/5 (20)	8/46 (17)	1.2 (0.2–9.2)	0.89
Gloves worn during games — no. of players (%)	44/52 (85)	5/5 (100)	39/47 (83)	2.2 (0.2–∞)	0.41
Gloves used >3 times (vs. 1, 2, or 3 times) before washing — no. of players (%)	29/46 (63)	2/5 (40)	27/41 (66)	0.4 (0.1–2.1)	0.26

* The data reflect information provided by the players who responded to the survey. CI denotes confidence interval, and NA not applicable. Percentages and relative risks were calculated on the basis of the total number of responses to each question.
† P values and confidence intervals are based on Fisher's exact and chi-square analysis for categorical variables and t-testing for continuous variables.
‡ The mean body-mass index is the weight in kilograms divided by the square of the height in meters.

Findings from our investigation underscore the importance of certain factors at the player level and at the team level that could have facilitated the spread of the clone in this setting. One important player-level factor was skin abrasions, or turf burns. All MRSA skin abscesses developed at sites of turf burns on areas of skin not covered by a uniform (e.g., elbows and forearms). These abrasions were usually left uncovered, and when combined with frequent skin-to-skin contact throughout the football season, probably constituted both the source and the vehicle for transmission. In our investigation, infection occurred only among linemen and linebackers, and not among those in backfield positions, probably because of the frequent contact among linemen during practice and games. We also observed a lack of regular access to hand hygiene (i.e., soap and water or alcohol-based hand gels) for trainers who provided wound care; skipping of showers by players before the use of communal whirlpools; and sharing of towels — all factors that might facilitate the transmission of infection in this setting.

We did not detect any MRSA in environmental or nasal samples; however, environmental sources yielded MSSA that matched nasal MSSA isolates — a finding that suggests that the environment may have had a role in the transmission of MRSA among team members. Previously reported investigations have identified potential transmission from contaminated surfaces and shared items.[23] In addition, recovery of MRSA from colonized persons during outbreaks has been variable, with some investigations detecting no nasal colonization with MRSA,[19,22] as was the case in our study. Treatment of infected players with antimicrobial drugs (e.g., rifampin) in our study may have eliminated the nasal colonization in these persons. In addition, institution of infection-control practices and enhancement of personal hygiene may have minimized

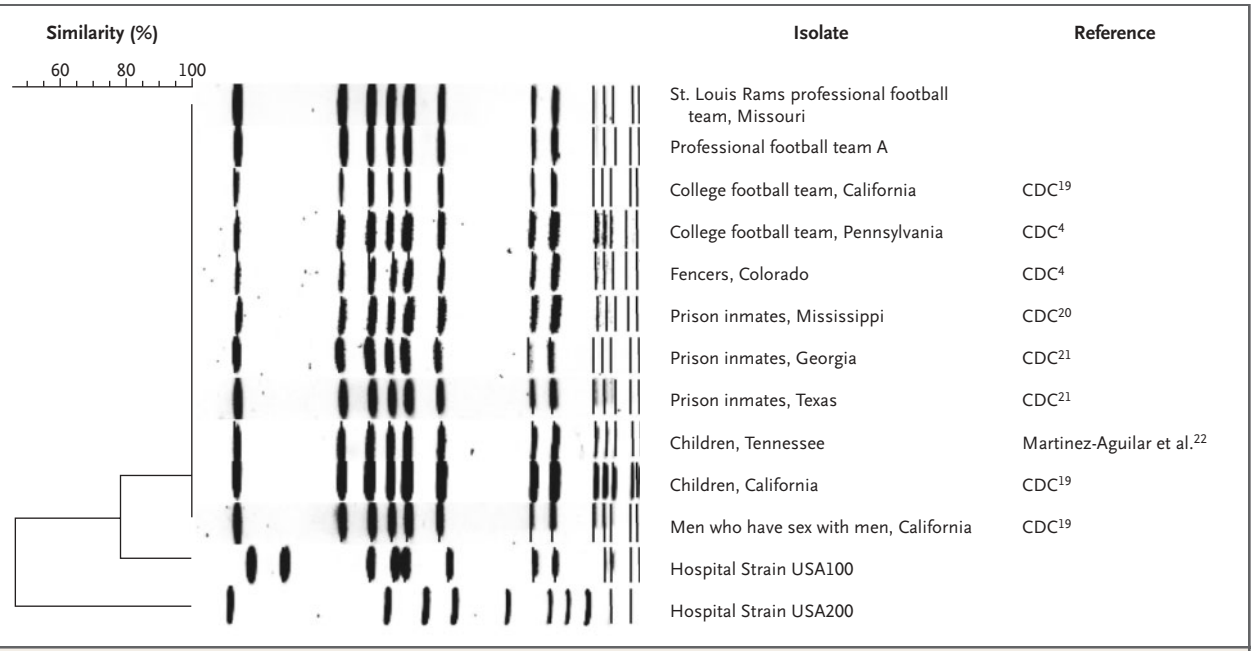

Figure 3. Pulsed-Field Gel Electrophoresis Patterns with Percentage Similarities for MRSA Isolates from Competing Football Teams (St. Louis Rams and Team A) and from Outbreaks in Various Community Settings and Geographic Locations.

The dendrogram presents only one representative MRSA isolate for each setting. All strains are from the staphylococcus PulseNet database of the Centers for Disease Control and Prevention (CDC).

colonization and transmission to other players before our nasal-swab survey.

We found the highly conserved USA300-0114 MRSA clone was present in diverse regions of the United States. This clone and other USA300 and USA400 strains appear to have caused the majority of community-associated MRSA cases characterized to date in the United States.[17] The reasons for the emergence of the clone are unclear; however, antimicrobial use in the community may have helped select bacteria that are resistant to standard empiric therapy for skin and soft-tissue infections (i.e., a first-generation cephalosporin or a penicillinase-resistant penicillin). The players in our investigation were receiving 10 times the number of antimicrobial prescriptions dispensed to the general public. Increased use of antimicrobial agents, when combined with other factors such as compromised skin, close skin-to-skin contact, close person-to-person proximity, a contaminated environment, and suboptimal hand and personal hygiene may provide the right conditions for efficient transmission among the members of a cohort and thus lead to clusters of skin infections.

On the basis of the findings of this and other investigations of outbreaks among sports participants, several recommendations can be made. First, clinicians and other personnel involved in the care of sports participants should be aware of the emergence in the community of MRSA with distinct microbiologic and epidemiologic characteristics. Infections with these organisms predominantly cause skin abscesses in otherwise healthy persons who often have no health care exposures. Obtaining cultures in suspected cases of infection and performing antimicrobial-susceptibility testing will facilitate early identification of cases and initiation of targeted treatment. Clinicians should drain abscesses and ensure that wounds are covered and contained with clean, dry dressings. Infected persons should receive guidance regarding enhanced hand and personal hygiene to prevent transmission. Frequently touched surfaces should be cleaned in accordance with manufacturer-recommended guidelines. Chlorhexidine-containing soap and nasal decolonization with mupirocin have been recommended to control outbreaks[19-23]; however, data demonstrating the independent benefit of these agents in controlling MRSA in community clusters are lacking. Some studies have reported that anti-

bacterial soap with 1.5 percent triclocarban is effective in preventing impetigo and atopic dermatitis.[24] Additional studies are needed to determine whether the use of antibacterial soap should be routinely recommended and whether decolonization and the use of body antiseptics are also needed to control transmission.

The CDC has initiated a collaboration with the National Collegiate Athletic Association in developing guidelines for the prevention and control of community-associated MRSA among college football players. The guidelines will include educational materials targeted to athletic trainers and will describe infection-control practices and measures for responding to cases or clusters of infections. To monitor the prevalence of community-associated MRSA infections, the CDC has initiated active population-based surveillance in eight geographic locations in the United States.[25] These data will help to characterize the emergence of MRSA in the community and will guide public health interventions, including strategies to prevent antimicrobial resistance.

The use of trade names and commercial sources does not imply endorsement by the U.S. Department of Health and Human Services or the CDC.

We are indebted to Laura Rose, Terri Forster, Chesley Richards, and Linda McCaig (CDC); to Dr. Bao-Ping Zhu (Missouri Department of Health and Senior Services); and to Dr. William Baine (Agency for Healthcare Research and Quality, U.S. Department of Health and Human Services) for their support.

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