National Surveillance of Methicillin-resistant *Staphylococcus aureus* Among Hospitalized Pediatric Patients in Canadian Acute Care Facilities, 1995–2007

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Background: Information relating to the epidemiology of methicillin-resistant *Staphylococcus aureus* (MRSA) among hospitalized pediatric patients is limited. This report describes results of national MRSA surveillance among Canadian hospitalized pediatric patients from 1995 to 2007.

Methods: Surveillance was laboratory-based. Clinical and epidemiologic data were obtained by reviewing the medical records. Standardized definitions were used to determine MRSA infection. Isolates were characterized by pulsed-field gel electrophoresis, staphylococcal cassette chromosome *mec* typing and antimicrobial susceptibility testing.

Results: A total of 1262 pediatric patients were newly identified as MRSA positive from 1995 to 2007. Ages ranged from newborn to 17.9 years, 49% were infected with MRSA (51% colonized), skin and soft tissue infections accounted for the majority (59%) of MRSA infections and 57% were epidemiologically classified as community acquired (CA). The most common epidemic strain types isolated were CMRSA2/USA100/800, CMRSA10/USA300 and CMRSA7/USA400. Overall, MRSA rates per 10,000 patient days increased from 0.08 to 3.88. Since 2005, overall rates of CA-MRSA per 10,000 patient days have dramatically increased while healthcare-associated MRSA rates remained relatively stable.

Conclusions: These data suggest that the increase in MRSA among hospitalized pediatric patients is largely driven by the emergence of CA-MRSA strains with skin and soft tissue infections representing the majority of MRSA infections.

Key Words: methicillin-resistant *Staphylococcus aureus*, hospitals, pediatric, surveillance, antibiotic resistance

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Methicillin-resistant *Staphylococcus aureus* (MRSA) was first identified in Britain and Europe in the 1960s.[1–3] Initially, MRSA was recognized as an endemic pathogen in hospitals, and later it was identified in people with no known healthcare exposure.[4,5] Since the mid-1990s, MRSA strains that were epidemiologically, phenotypically and clinically unique were observed and consequently MRSA has been described as healthcare-associated (HA) and community-associated (CA) MRSA. Many studies have documented the increasing prevalence of MRSA among hospitalized pediatric patients and more specifically the increasing number of isolates with strain types typically associated with CA-MRSA.[4,6–8]

National prospective surveillance for MRSA in hospitalized patients has been conducted by the Canadian Nosocomial Infection Surveillance Program (CNISP) [The CNISP is a joint initiative involving sentinel hospitals across Canada who participate as members of the Canadian Hospital Epidemiology Committee (a subcommittee of the Association of Medical Microbiology and Infectious Disease Canada), working in collaboration with the Centre for Communicable Diseases and Infection Control, and the National Microbiology Laboratory, both of the Public Health Agency of Canada.] since 1995, and results summarizing the combined adult and pediatric population for 1995 to 2007 have been previously described.[9] We present here analysis of the clinical, epidemiologic and laboratory characterization specific to the subpopulation of children (<18 years) identified as being colonized or infected with MRSA during a 13-year period from 1995 to 2007.

MATERIALS AND METHODS

Participating Hospitals and Patients

From 1995 to 2007, the number of hospitals represented in the CNISP surveillance network that provided any inpatient pediatric care ranged from 5 to 37. From 1999, there was representation from across the country while prior to 1999 only the central and western regions of Canada were represented. Denominators (admissions and patient-days) were collected from Canadian pediatric hospitals that were able to provide separate pediatric denominator data. Rate calculations were limited to data from this group.

Data Collection, Study Definitions and Laboratory Methods

Data collection, study definitions and laboratory methods for this surveillance have been previously described by Simor et al 2010.[9] In brief, surveillance for MRSA was laboratory based, and only hospitalized patients were included. The presence of infection caused by MRSA was determined using standardized infection surveillance definitions.[10] Annual MRSA surveillance protocols

changed over time; however, all participating hospitals adhered to the same MRSA surveillance protocol in which standardized case definitions were reviewed, updated and implemented on an annual basis (MRSA surveillance protocols are available upon request by contacting the Canadian Nosocomial Infection Surveillance program: cnisp-pcsin@phac-aspc.gc.ca.).

To maintain confidentiality, a unique identifier linked to the individual patient's name was used to identify patients at participating hospital sites and was not provided to those entering or analyzing the data. The surveillance was observational, did not involve any change in patient care and was considered to be within the usual scope of hospital-based infection prevention and control programs at many of the participating hospital sites. Consequently, research ethics board approval was not required, although it was obtained at some of the participating hospitals.

All MRSA isolates were initially identified and laboratory confirmed at participating hospitals and a unique (nonrepeated) isolate recovered from each patient was sent to the National Microbiology Laboratory for further characterization. From 1995 to 2005, isolates recovered from all patients were submitted; in 2006 and 2007, only clinical (nonscreening) isolates recovered from patients with suspected infection were submitted. Submitted isolates were confirmed as MRSA by detection of *nuc* and *mecA* genes by use of polymerase chain reaction (PCR).[11] Advanced laboratory characterization was conducted on all submitted isolates in 1995 and 1996, but reduced to a geographically representative subset for each subsequent year of the surveillance. Antimicrobial susceptibility testing was done by broth microdilution, and detection of inducible clindamycin resistance in macrolide-resistant strains was done by the disk approximation D-zone test.[12]

Molecular typing of isolates was done by pulsed field gel electrophoresis using BioNumerics software (version 5.10; Applied Maths, Austin, TX),[13,14] following DNA extraction and digestion with *Sma*I.[13] Strains designated as pulse field gel electrophoresis types CMRSA7 and CMRSA10 resemble CA genotypes USA400 (multilocus sequence type 1; clonal complex 1) and USA300 (ST8; CC8), respectively; CMRSA1 resembles USA600 (ST45; CC45) and CMRSA2 resembles USA100/800 (ST5; CC5).[14] Typing of the staphylococcal cassette chromosome *mec* (SCC_{mec}) was done by the use of PCR and previously described primers and methods.[15] All isolates submitted in 2006 and 2007 were tested for the presence of the Panton-Valentine leukocidin (PVL) gene by the use of PCR.[16] Patients with MRSA were reported only once unless a new strain of MRSA was acquired.

Statistical Analysis

Statistical differences between categorical data were assessed using Pearson's χ^2 test or Fisher's exact test. Trends over time for proportions were assessed using the χ^2 test for trend. All tests were 2-tailed and $P < 0.05$ was considered to be statistically significant. Surveillance years were divided into 3 time periods, surveillance period 1 (1995–1999), surveillance period 2 (2000–2003) and surveillance period 3 (2004–2007). These analyses were performed using SPSS 17.0 (Armonk, NY), EpiCalc 2000, version 1.02 (Brixton, UK) and Excel 2007 (Redmond, WA).

RESULTS

In total, 48 individual hospitals participated at some point in time from 1995 to 2007. General demographic features are reported on the whole population, while rates were calculated from 8 pediatric hospitals that were able to provide denominator data. A total of 1262 pediatric patients were newly identified as MRSA positive from 1995 to 2007. Ages ranged from newborn to 17.9 years and 45% were female. The median age was 1.3 years and the mean was 5 years. Almost half of the MRSA-positive children (48%) were <5 years, and children aged between 1 month and 2 years represented just over one-third (36%) of all MRSA positives. Of those where ethnicity was captured (n = 785), 25% were First Nations (Table 1). Of 1246 children where infection or colonization could be determined, 49% (n = 606) were infected with MRSA (Table 1).

During the 3 surveillance periods, MRSA infections significantly increased from 47% (1995–1999) to 51% (2004–2007) ($P = 0.04$) (Table, Supplemental Digital Content 1, http://links.lww.com/INF/B208) while the proportion colonized with MRSA decreased.

Rates of MRSA were calculated for 363 cases from 8 pediatric hospitals able to provide denominator data. Overall, MRSA rates per 10,000 patient days increased from 0.08 (1995) to 3.88 (2007). A similar pattern was observed with both the infection and colonization rates, which went from 0.00 to 2.69 and from 0.08 to 1.19, respectively (Fig. 1). Since 2002, HA-MRSA infection rates have more than tripled from 0.10 in 2002 to 0.37 in 2007 per 10,000 patient days (Fig. 2) while CA-MRSA infections have shown the most dramatic increase: 0.05 in 2002 to 1.86 in 2007 per 10,000 patient days (Fig. 3). Overall rates of CA-MRSA per 10,000 patient days increased dramatically (0.44–2.53) from 2005 to 2007 (Fig. 3) while HA rates decreased (1.09–0.79) (Fig. 2).

Overall, skin and soft tissue infections accounted for the majority (59%) of MRSA infections followed by respiratory infections (13%), surgical site (11%), bacteremia (10%) and urinary tract infections (4%). The proportion of skin and soft tissue infections significantly increased over time from 43% in 1994–1999 to 64% in 2004–2007 ($P < 0.001$). The proportion of surgical site infections and respiratory infections significantly decreased over time, whereas the proportions of urinary tract infections and bloodstream infections remained relatively unchanged (Table, Supplemental Digital Content 1, http://links.lww.com/INF/B208).

The proportion of patients with MRSA identified by admission screening compared with those identified by clinical specimens significantly increased over time from 11% in the first 5 years (1995–1999) to 30% in the last 4 years (2003–2007) while identification of MRSA through the collection of clinical isolates decreased from 89% (1995–1999) to 70% (2004–2007) ($P < 0.001$)) (Table, Supplemental Digital Content 1, http://links.lww.com/INF/B208).

Of all MRSA cases where MRSA was determined to be HA or CA (n = 966), through the use of a standardized epidemiological case definition, 55% were classified as HA. However, the proportion of MRSA cases identified as HA significantly decreased over the surveillance period while the proportion of CA cases increased. Considering only infections (n = 461), 57% (263) were classified as CA with the proportion significantly increasing over time ($P < 0.001$) while the proportion of those classified as HA decreased. The same pattern as seen in MRSA infections is seen with MRSA colonizations where the proportion classified as CA significantly increased over the surveillance period. The proportion of HA-MRSA bloodstream infections and skin and soft tissue infections significantly decreased over time, whereas that of surgical site infections, respiratory and urinary tract infections remained relatively unchanged (Table, Supplemental Digital Content 2, http://links.lww.com/INF/B209).

Of the 673 geographically representative unique MRSA isolates (53% of all MRSA cases) that were typed, the most common epidemic strain types were CMRSA2/USA100/800 (or ST5/CC5) (34%), followed by CMRSA10/USA300 (or ST8; CC8) (23%) and CMRSA7/USA400 (or sequence type 1; clonal complex 1) (18%) (Table 2). These 3 strains accounted for 75% (n = 506) of all isolates typed. However, the proportions of strain types identified

TABLE 1. Demographic and Epidemiologic Characteristics of Pediatric Patients by Age Group, 1995–2007

Variable	<1 month N (%)	1 month to <2 yr N (%)	2 to <5 yr N (%)	5 to <12 yr N (%)	12 to <18 yr N (%)	Total N (%)
Gender						
Male	124 (53)	259 (57)	69 (48)	93 (55)	142 (55)	687 (55)
Female	108 (47)	195 (43)	74 (52)	77 (45)	114 (45)	568 (45)
Total	232	454	143	170	256	1255*
Ethnicity not first						
Nations	128 (86)	203 (69)	40 (53)	68 (72)	146 (84)	585 (75)
First nations	20 (14)	92 (31)	35 (47)	26 (28)	27 (16)	200 (25)
Total	148	295	75	94	173	785*
Age						
Mean	12 days	7.6 months	3.2 yr	8.6 yr	15.7 yr	4.97 yr
Median	10 days	5.7 months	3.0 yr	8.6 yr	16.0 yr	1.3 yr
Minimum	<1 day	1 month	2.0 yr	5.0 yr	12.0 yr	<1 day
Maximum	29.2 days	1.97 yr	4.9 yr	11.9 yr	17.99 yr	17.99 yr
Region						
West	101 (43)	235 (52)	90 (63)	99 (58)	144 (56)	669 (53)
Central	118 (51)	202 (44)	51 (36)	61 (36)	100 (39)	532 (42)
East	14 (6)	19 (4)	2 (1)	10 (6)	12 (5)	57 (5)
Total	233	455	143	170	256	1258*
Surveillance periods						
1995–1999	25 (11)	56 (12)	9 (6)	15 (9)	29 (11)	134 (11)
2000–2003	28 (12)	73 (16)	31 (22)	38 (22)	68 (27)	238 (19)
2004–2007	180 (77)	327 (72)	103 (72)	117 (69)	159 (62)	886 (70)
Total	233	456	143	170	256	1258*
MRSA						
Colonized	156 (67)	239 (53)	56 (40)	59 (35)	130 (51)	640 (51)
Infected	75 (33)	213 (47)	85 (60)	109 (65)	124 (49)	606 (49)
Total	231	452	141	168	254	1246*

*Total may not equal 1262 due to missing data.

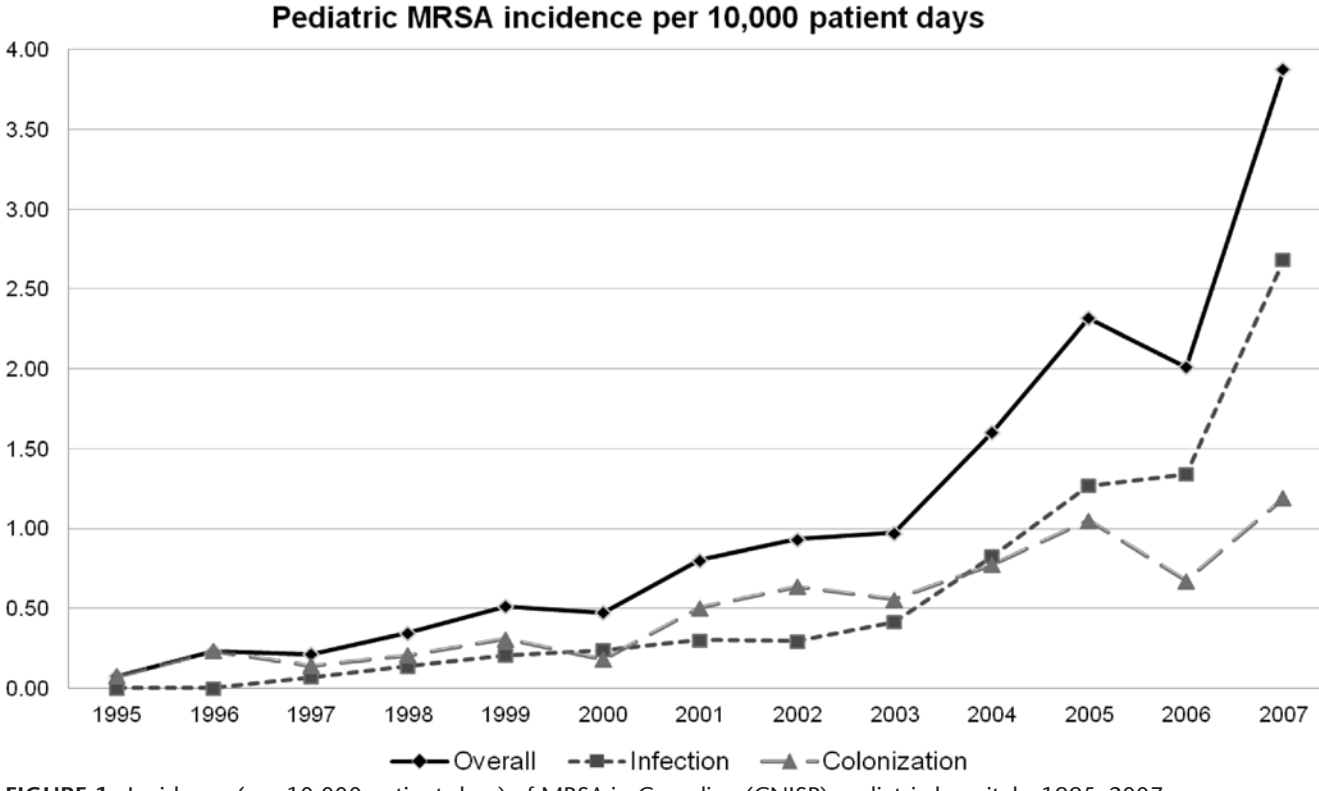

FIGURE 1. Incidence (per 10,000 patient days) of MRSA in Canadian (CNISP) pediatric hospitals, 1995–2007.

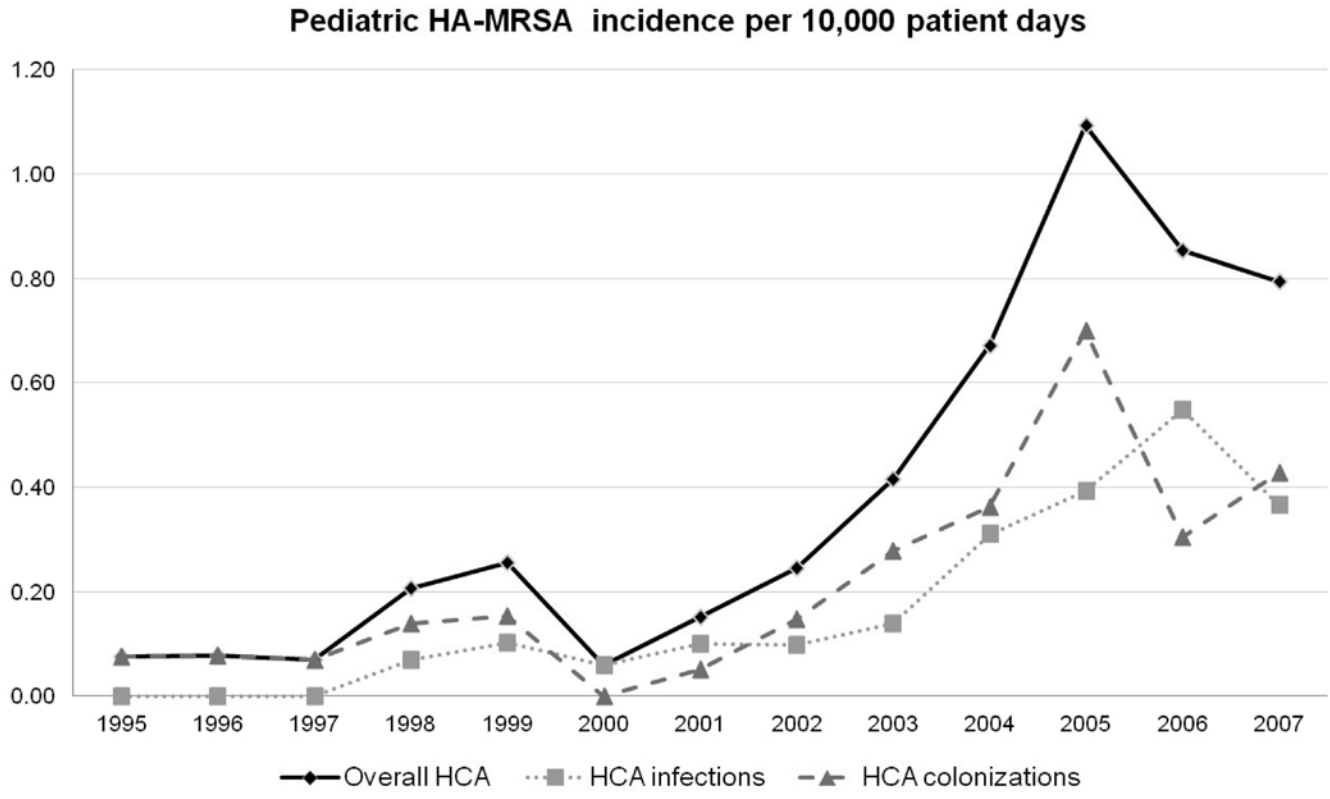

FIGURE 2. Incidence (per 10,000 patient days) of HA-MRSA in Canadian (CNISP) pediatric hospitals, 1995–2007.

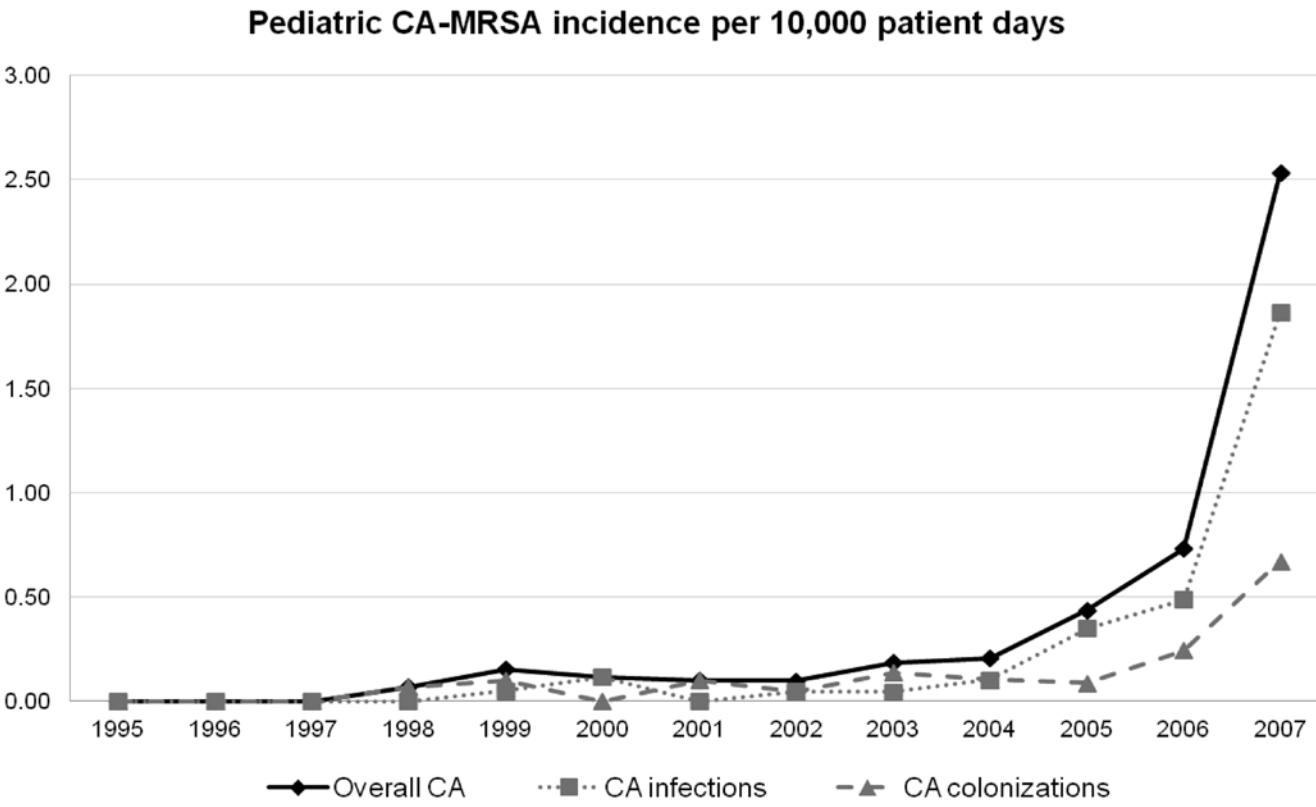

FIGURE 3. Incidence (per 10,000 patient days) of CA-MRSA in Canadian (CNISP) pediatric hospitals, 1995–2007.

TABLE 2. Laboratory Characterization of MRSA Isolates and Their Trend Over Time, 1995–2007

	1995–1999 N (%)	2000–2003 N (%)	2004–2007 N (%)	Total N (%)	χ^2	*P*
CMRSA1 (USA600; ST45; CC45)	17 (17)	18 (12)	15 (4)	50 (7)	—	—
CMRSA2 (USA100/800; ST5; CC5)	41 (41)	89 (57)	100 (24)	230 (34)	44.5	<0.001
CMRSA3/6 (ST241; ST239; CC8)	14 (14)	10 (6)	8 (2)	32 (5)	—	—
CMRSA4 (USA200; ST36)	9 (9)	5 (3)	5 (1)	19 (3)	—	—
CMRSA5 (USA500; ST8)	6 (6)	1 (1)	4 (1)	11 (2)	—	—
CMRSA7 (USA400; ST1; CC1)	3 (3)	19 (12)	102 (24)	124 (18)	28.9	<0.001
CMRSA8 (ST22)	3 (3)	5 (3)	4 (1)	12 (2)	—	—
CMRSA10 (USA300; ST8; CC8)	0 (0)	2 (1)	150 (36)	152 (23)	111.8	<0.001
Other*	7 (7)	8 (5)	28 (7)	43 (6)	—	—
Total	100	157	416	673	—	—

*Other strain types include Danish CO-MRSA (n = 1), European (n = 8), ST88 (n = 2), ST97 (n = 5), USA1000, China/Taiwan (n = 10), USA1100, SWP/Oceania (n = 10), USA700 (n = 6) and CMRSA9 (n = 1).

CC, clonal complex; ST, sequence type

changed over time. For the first surveillance period (1995–1999), CMRSA1/USA600 (ST45/CC45), CMRSA2 and CMRSA3/6 were the most common (72%), whereas CMRSA7 represented only 3% and CMRSA10 (USA300) was not detected. For the second surveillance period (2000–2003), CMRSA1, CMRSA2 and CMRSA7 represented 80% of all isolates typed (Table 2). Over time, the proportion of CMRSA10 and CMRSA7 gradually increased to become the most predominant strains isolated during the third surveillance period (2004–2007), whereas CMRSA2 significantly decreased from 41% during the first surveillance period to 24% in the third period ($P < 0.001$) (Table 2).

CMRSA2 isolates were more likely ($P < 0.001$) to be isolated from colonized patients (over 50%) than those infected (27%), whereas CMRSA7 and CMRSA10 were more likely to be isolated from infected patients ($P \leq 0.001$), and accounted for 52% of the infection isolates compared to 19% of colonization isolates (data not shown). The most predominant strains detected in skin and soft tissue infection isolates were CMRSA7 (23%) and CMRSA10 (36%), while from all other isolates (other sites) it was CMRSA2 (Table, Supplemental Digital Content 3, http://links.lww.com/INF/B210).

SCC_{mec} typing was available for 248 isolates with SCC_{mec} type IVa found 71.0% of the time, followed by SCC_{mec} type II (12.0%). SCC_{mec} type IVa was exclusively found in CMRSA7 strains and almost all (95%) CMRSA10 strains, whereas SCC_{mec} type II was identified mostly (60%) in CMRSA2.

The PVL gene was detected in 59% (n = 274) of the 466 isolates tested. The majority of PVL-positive isolates yielded SCC_{mec} type IVa (94%) and were either CMRSA10 (55%) or CMRSA7 (37%). In addition, just over 80% (n = 225) of PVL-positive isolates were classified as infections with the majority (75%) being skin and soft tissue infections.

Antimicrobial resistance varied among the isolates tested. Susceptibility to vancomycin, linezolid, rifampin, gentamicin, trimethoprim-sulfamethoxazole, tetracycline, daptomycin and tigecycline was observed in 90–100% of CMRSA2, 7 and 10 strains. Increased susceptibility to fusidic acid compared to mupirocin was also observed. More resistance to clindamycin, ciprofloxicin and erythromycin was observed (Table 3).

DISCUSSION

To our knowledge, these surveillance results provide the most comprehensive description of the epidemiology and incidence of MRSA among hospitalized children in Canada.

In 2006, Aboriginals (First Nations, Inuit and Métis) represented 3.75% of the Canadian population.[17] Although Aboriginal peoples have higher hospitalization rates compared with non-Aboriginals,[18] the proportion of MRSA cases in these data (where ethnicity was known) suggests that Aboriginals may be overrepresented (25%) among pediatric MRSA cases. Over 50% of MRSA cases among aboriginals were classified as CA and 48.0% were pulse field gel electrophoresis identified as CMRSA7 (data not shown). These findings are in line with previously published results by CNISP (including both adult and pediatric cases), which reported an overrepresentation of Aboriginals during the 1995–2002 surveillance.[19] In addition, a 2005 position statement from the Canadian Pediatric Society reported increased CA-MRSA rates among First Nations people in Canada and suggests that "crowding, lack of quality running water and heavy antibiotic use may be additional reasons for the higher prevalence of MRSA observed in First Nations communities in Canada."[20] Other studies that have collected ethnicity data have also reported higher rates of MRSA or CA-MRSA either by case classification or typing of isolates among minority groups such as African Americans, Hispanics and Native Americans.[21–23] In general, our results indicate that CA-MRSA is on the rise, particularly the proportion of skin and soft tissue infections identified as CA-MRSA. These results are not surprising because they mirror those from different countries reporting similar increases in CA-MRSA.[7,21,22]

The proportion of MRSA cases identified as infected (49%) was much higher than the results reported previously by Simor et al[9] in 2010 (32%; which included adult cases) for the same surveillance period. Among these pediatric cases, 59% of MRSA infections were skin and soft tissue infections and showed a significant increase over time. Other studies have reported similar proportions of skin and soft tissue infections among their study populations ranging from 47% to 80%,[8,21,22] with substantial increases reported over time.[6,7,22]

The majority of CMRSA7 and 10 strains were found to carry the SCC_{mec} type IVa and were primarily PVL positive. In addition, skin and soft tissue infections represented 3 quarters of MRSA infections tested for the PVL gene. A recent study of MRSA infections in a single pediatric hospital in Detroit, MI,[24] reported similar results where the majority of USA300 (CMRSA10) strains carried the SCC_{mec} type IVa and were all found to be PVL positive.

Our data have implications for empiric antimicrobial choices for MRSA. All MRSA in this surveillance remained susceptible to vancomycin, which justifies Canadian guidelines that recommend vancomycin as empiric therapy for children admitted with severe MRSA infections.[25] Clindamycin resistance is moderate particularly for HA-MRSA strains. Although a sizeable proportion of MRSA isolates (CMRSA2, 7 and 10) remained susceptible to clindamycin, about 37% of CMRSA2 (a HA-MRSA strain) exhibited resistance to clindamycin compared to CMRSA7 and CMRSA10 strains (Table 3). Recently, it has been suggested that

TABLE 3. Antimicrobial Susceptibility and Epidemic Strain Type, 1995–2007

Epidemic Strain Type	Antimicrobial Susceptibility, N (%)												
CMRSA	Clindamycin	Ciprofloxacin	Erythromycin	Vancomycin	Rifampin	Gentamicin	Tetracycline	Tigecycline	Linezolid acid	TMP-SMX	Daptomycin	Mupirocin*	Fusidic Acid
2 Susceptible	53 (62)	45 (46)	14 (14)	97 (100)	94 (100)	52 (93)	91 (97)	11 (100)	59 (100)	94 (97)	11 (100)	80 (85)	82 (91)
Intermediate	1 (1)	1 (1)	4 (4)	0	0	0	0	0	0	0	0	0	0
Resistant	32 (37)	51 (53)	79 (82)	0	0	4 (7)	3 (3)	0	0	3 (3)	0	14 (15)	8 (9)
Total	86	97	97	97	94	56	94	11	59	97	11	94	90
7 Susceptible	38 (43)	82 (92)	56 (63)	89 (100)	87 (98)	83 (99)	86 (97)	40 (95)	85 (100)	85 (96)	42 (100)	37 (42)	79 (90)
Intermediate	40 (45)	1 (1)	12 (14)	0	2 (2)	0	1 (1)	0	0	0	0	0	0
Resistant	10 (11)	6 (7)	21 (24)	0	0	1 (1)	2 (2)	2 (5)	0	4 (4)	0	52 (58)	9 (10)
Total	88	89	89	89	89	84	89	42	85	89	42	89	88
10 Susceptible	61 (50)	23 (19)	11 (9)	121 (100)	121 (100)	120 (99)	117 (97)	49 (100)	121 (100)	121 (100)	49 (100)	120 (99)	120 (99)
Intermediate	43 (36)	2 (2)	0	0	0	0	0	0	0	0	0	0	0
Resistant	17 (14)	96 (79)	110 (91)	0	0	1 (1)	4 (3)	0	0	0	0	1 (1)	1 (1)
Total	121	121	121	121	121	121	121	49	121	121	49	121	121
Total	295	307	307	307	304	261	304	102	265	307	102	304	299

Among MRSA isolates tested, all were 100% susceptible to vancomycin, linezolid acid and daptomycin.
*Mupirocin susceptibility defined as having MIC ≤ 2.
TMP-SMX, trimethoprim-sulfamethoxazole.

trimethoprim-sulfamethoxazole is a viable treatment alternative for MRSA-related infections, given that resistance is low in industrialized countries (minimal resistance also found in these data) and it is cost-effective.[26] Although these data do not support clindamycin as the empiric drug of choice for all MRSA infections, there is evidence suggesting that skin and soft tissue infections may respond better to clindamycin and it may prevent recurrence.[27] However, increasing rates of resistance to clindamycin make this drug less useful as an empiric choice. Our data also show that empiric topical fusidic acid is preferable to mupirocin, especially for CMRSA7 strains because of less resistance. In general, these data emphasize the need for culture and susceptibility testing to identify the most effective antibiotic regimens.

The increases in pediatric MRSA rates occurring from 1995 to 2007 are similar to those reported by Gerber and colleagues in 2009[22] who reported an increase in United States national pediatric MRSA rates from 6.7 per 1000 patient admissions in 2002 to 21.2 in 2007. They suggested that the observed increase was most likely due to the emergence of CA-MRSA strains during this period. The results of our surveillance also indicate that the increase in MRSA rates may be due to the emergence of CA-MRSA and its consequent introduction into hospitals. Interestingly, while the rate of CA-MRSA increased in our surveillance, the rate of HA-MRSA has remained relatively stable since 2005. In addition, more than half of the children were MRSA carriers and one third were detected by screening protocols. Effective screening and isolation procedures may help to limit the spread of CA-MRSA in the hospital setting, especially when many children are asymptomatic MRSA carriers. The introduction of national, standardized admission screening and isolation procedures may help to reduce the transmission of MRSA in pediatric facilities.

This surveillance study was limited by the fact that it was unable to determine risk factors or to describe patient outcomes. The majority of hospitals participating in this surveillance were tertiary-care teaching hospitals; therefore, the results may not be representative of other healthcare facilities in Canada. In addition, although a standardized case definition for MRSA was used, there may have been some variation across participating hospitals in determining whether infection or colonization was present or in determining whether the isolate was HA-MRSA or CA-MRSA. Nevertheless, results of this study have indicated the usefulness of ongoing surveillance of MRSA in terms of providing benchmarks to compare against previous years, other countries and to identify factors and trends specific to the hospitalized pediatric population.

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REFERENCES

1. Benner EJ, Kayser FH. Growing clinical significance of methicillin-resistant *Staphylococcus aureus*. *Lancet*. 1968;2:741–744.
2. Stewart GT, Holt RJ. Evolution of natural resistance to the newer penicillins. *Br Med J*. 1963;1:308–311.
3. Colley EW, Mcnicol MW, Bracken PM. Methicillin-resistant staphylococci in a general hospital. *Lancet*. 1965;1:595–597.
4. Milstone AM, Carroll KC, Ross T, et al. Community-associated methicillin-resistant *Staphylococcus aureus* strains in pediatric intensive care unit. *Emerging Infect Dis*. 2010;16:647–655.
5. 2010 MRSA Research Center. MRSA history timeline: the first half-century, 1959–2009. [The University of Chicago Medical Center website]. Available at: http://mrsa-research-center.bsd.uchicago.edu/timeline.html. Accessed February 2011.
6. Naseri I, Jerris RC, Sobol SE. Nationwide trends in pediatric *Staphylococcus aureus* head and neck infections. *Arch Otolaryngol Head Neck Surg*. 2009;135:14–16.
7. Sircar KD, Bancroft E, Nguyen DM, et al. Hospitalization of pediatric patients for methicillin-resistant *Staphylococcus aureus* skin and soft-tissue infection, 1998–2006. *Epidemiol Infect*. 2010; 138: 677–682.
8. Ochoa TJ, Mohr J, Wanger A, et al. Community-associated methicillin-resistant *Staphylococcus aureus* in pediatric patients. *Emerging Infect Dis*. 2005;11:966–968.
9. Simor AE, Gilbert NL, Gravel D, et al. Canadian Nosocomial Infection Surveillance Program. Methicillin-resistant *Staphylococcus aureus* colonization or infection in Canada: National Surveillance and Changing Epidemiology, 1995-2007. *Infect Control Hosp Epidemiol*. 2010;31: 348–356.
10. Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. *Am J Infect Control*. 2008;36:309–332.
11. Louie L, Matsumura SO, Choi E, et al. Evaluation of three rapid methods for detection of methicillin resistance in *Staphylococcus aureus*. *J Clin Microbiol*. 2000;38:2170–2173.
12. Clinical and Laboratory Standards Institute (CLSI). *Performance Standards for Antimicrobial Susceptibility Testing; Nineteenth Informational Supplement.M100-S19*, Wayne, PA; 2009.
13. Mulvey MR, Chui L, Ismail J, et al. Canadian Committee for the Standardization of Molecular Methods. Development of a Canadian standardized protocol for subtyping methicillin-resistant *Staphylococcus aureus* using pulsed-field gel electrophoresis. *J Clin Microbiol*. 2001;39:3481–3485.
14. Christianson S, Golding GR, Campbell J, et al. Canadian Nosocomial Infection Surveillance Program. Comparative genomics of Canadian epidemic lineages of methicillin-resistant *Staphylococcus aureus*. *J Clin Microbiol*. 2007;45:1904–1911.
15. Oliveira DC, de Lencastre H. Multiplex PCR strategy for rapid identification of structural types and variants of the mec element in methicillin-resistant *Staphylococcus aureus*. *Antimicrob Agents Chemother*. 2002;46:2155–2161.
16. Lina G, Piémont Y, Godail-Gamot F, et al. Involvement of Panton-Valentine leukocidin-producing *Staphylococcus aureus* in primary skin infections and pneumonia. *Clin Infect Dis*. 1999;29:1128–1132.
17. Statistics Canada. Aboriginal Peoples, 2006 Census. Catalogue Number 97–558-XCB2006007. Available at: http://www.statcan.gc.ca/bsolc/olc-cel/olc-cel?catno=97–558-XCB2006007&lang=eng. Accessed January 1, 2011.
18. Carrière G, Garner R, Sanmartin C, LHAD Research Team, Statistics Canada. Acute-care hospitalizations and Aboriginal identity in Canada, 2001/2002 [Statistics Canada website]. Catalogue Number 82–622-X no.005. Available at: www.statcan.gc.ca/pub/82–622-x/82–622-x2010005-eng.htm. Accessed February 2011.
19. Ofner-Agostini M, Simor AE, Mulvey M, et al. Canadian Nosocomial Infection Surveillance Program, Health Canada. Methicillin-resistant *Staphylococcus aureus* in Canadian aboriginal people. *Infect Control Hosp Epidemiol*. 2006;27:204–207.
20. Canadian Pediatric Society (CPS). Methicillin-resistant *Staphylococcus aureus* in First Nations communities in Canada. CPS Position Statement (FNIF 2005-02). *Pediatr Child Health*. 2005;10;557–559.
21. Jungk J, Como-Sabetti K, Stinchfield P, et al. Epidemiology of methicillin-resistant *Staphylococcus aureus* at a pediatric healthcare system, 1991–2003. *Pediatr Infect Dis J*. 2007;26:339–344.
22. Gerber JS, Coffin SE, Smathers SA, et al. Trends in the incidence of methicillin-resistant *Staphylococcus aureus* infection in children's hospitals in the United States. *Clin Infect Dis*. 2009;49:65–71.
23. Naimi TS, LeDell KH, Como-Sabetti K, et al. Comparison of community- and health care-associated methicillin-resistant *Staphylococcus aureus* infection. *JAMA*. 2003;290:2976–2984.
24. Abdel-Haq N, Al-Tatari H, Chearskul P, et al. Methicillin-resistant *Staphylococcus aureus* (MRSA) in hospitalized children: correlation of molecular analysis with clinical presentation and antibiotic susceptibility testing (ABST) results. *Eur J Clin Microbiol Infect Dis*. 2009;28:547–551.
25. Canadian Pediatric Society (CPS). Control and treatment of methicillin-resistant *Staphylococcus aureus* in Canadian paediatric healthcare institutions. CPS Position Statement (Ref No. ID06-01). *Pediatr Child Health*. 2006;11;163–165.
26. Pappas G, Athanasoulia AP, Matthaiou DK, et al. Trimethoprim-sulfamethoxazole for methicillin-resistant *Staphylococcus aureus*: a forgotten alternative? *J Chemother*. 2009;21:115–126.
27. Williams DJ, Cooper WO, Kaltenbach LA, et al. Comparative effectiveness of antibiotic treatment strategies for pediatric skin and soft-tissue infections. *Pediatrics*. 2011;128:e479–e487.

