# *Staphylococcus aureus* Pneumonia in Children in the Era of Community-acquired Methicillin-resistance at Texas Children's Hospital

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**Background:** Community-acquired *Staphylococcus aureus* (SA) pneumonia has increased in children, yet few studies have focused on this infection.

**Methods:** Patients with SA pneumonia (not ventilator-associated) were identified from our surveillance database. Medical records were reviewed; isolates were genotyped by PFGE and Panton-Valentine leukocidin genes detected by polymerase chain reaction.

**Results:** From August 2001 to April 2009, 117 patients had SA pneumonia. The rate of SA pneumonia per 10,000 admissions increased from 4.81 hospitalizations in year 1 to 9.75 in year 7 ($P = 0.04$). Methicillin-resistant SA (MRSA) caused 74% and methicillin-susceptible SA (MSSA) caused 26% of the infections. USA300 represented 75/82 (92%) of the MRSA and 14/28 (50%) of the MSSA isolates ($P < 0.01$). Patients with MRSA were younger (median [range], 0.8 years [0.1–16.9 years]) than patients with MSSA infections (2.5 years [0.2–20.9 years]) ($P = 0.008$). Clinical presentation was pneumonia with or without effusion in 30, empyema in 72, or lung abscess in 15 cases. Viral coinfections in 18/68 patients tested were associated with respiratory failure (72% vs. 24% [$P < 0.001$]). Thirty-five children were intubated and 68 had intensive care unit care; 89, 25, and 3 had video-assisted thoracoscopy (VATS), thoracentesis, and lobectomy, respectively. VATS was used more for USA300 than non-USA300 infections (80% vs. 57% [$P = 0.03$]). In all, 88 children received clindamycin. Improvement or cure occurred in 103 patients (88%), unscheduled visit or readmission related to the same problem in 6, respiratory sequelae in 7, and death in 1 patient.

**Conclusions:** SA pneumonia increased in frequency over the study years and most were caused by community-acquired MRSA and USA300 isolates. Viral coinfection in 15% of the cases was associated with respiratory failure. Clindamycin is an effective treatment for susceptible-SA pneumonia; VATS was more common in patients with USA300 infections.

**Key Words:** *Staphylococcus aureus*, pneumonia, empyema, lung abscess, USA300, Panton-Valentine leukocidin, methicillin resistance

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Over the past decade, *Staphylococcus aureus* (SA) has been an increasing cause of community-acquired (CA) pneumonia in children, particularly in cases of complicated pneumonia and empyema.[1–3] Nationwide empyema increased 4-fold in prevalence from 0.6 cases per 100,000 children during 1996 to 1998 to 2.5 cases per 100,000 children during 2005 to 2007 in patients <2 years and was frequently caused by SA; a similar increase in staphylococcal empyema was noted in the 2 to 4 years age group.[3] Furthermore, children hospitalized with staphylococcal pneumonia were more likely to develop empyema, in 2006 compared with 1997.[4]

USA300 has emerged as the most common pulsotype causing CA SA infection in the United States and has been associated with severe invasive infection and pulmonary involvement.[5–7] USA300 SA isolates typically carry the genes encoding Panton-Valentine leukocidin (PVL), a pore-forming toxin. PVL-positive SA strains have been associated with the development of necrotizing pneumonia affecting predominantly young immunocompetent individuals.[8]

Viral infections, especially influenza, frequently precede the development of SA pneumonia. The Centers for Disease Control and Prevention has summarized reports of deaths in children with influenza since 2004 and have emphasized complications associated with SA pneumonia.[9] Among the case fatalities in children with influenza pneumonia, SA coinfection increased 5-fold between the 2004 and 2007 influenza seasons.[10]

Few recent studies have focused on SA pneumonia in children in the era of community-associated methicillin-resistant SA (MRSA) infections.[1,10] We investigated the clinical characteristics, admission trends, and molecular epidemiology of non–ventilator-associated SA pneumonia in children at Texas Children's Hospital (TCH), including the comparative features of patients with viral coinfection and patient outcomes. We also described the management strategies for SA pneumonia in children in our hospital. We hypothesized that children with pneumonia caused by MRSA, *pvl*+ isolates, or USA300 isolates would have different clinical characteristics and outcome than those with pneumonia due to methicillin-susceptible SA (MSSA), *pvl*− or non-USA300 isolates, respectively.

## PATIENTS AND METHODS

Patients admitted to TCH with the diagnosis of primary, culture-proven SA pneumonia (not ventilator-associated) and their corresponding SA isolates were identified from our SA prospective surveillance database between August 2001 and April 2009.[11,12] Study years included cases from August 1 until July 31 of the next calendar year. Study year 8 was incomplete, encompassing only 8 months.

Demographics, clinical features, laboratory and radiology results, and treatment modalities were retrospectively extracted from medical records and entered on a standardized form. The attending physicians supervised the diagnostic procedures, labora-

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tory tests, and treatment of these patients. Patient outcomes were retrospectively evaluated at least 12 months after the infection using TCH inpatient, outpatient, and laboratory records. Hospital annual admission data were obtained from the TCH admissions office. This study was approved by Baylor College of Medicine Institutional Review Board with informed consent being exempt.

## Definitions

SA pneumonia was defined by isolation of SA from blood, lung aspirate, or pleural fluid/empyema cultures, plus abnormalities consistent with pneumonia on chest imaging with or without radiologic evidence of pleural effusion or empyema and clinical signs and symptoms consistent with pneumonia. Patients with ventilator-associated pneumonia were excluded.

Empyema was defined by any of the following: loculated pleural effusion by radiologic imaging, surgical findings, and/or histologic evidence of empyema by pleural biopsy.

Lung abscess was the radiologic finding of a cavitary lung lesion.

CA and hospital-acquired infections were defined as previously.[7,12–14] Community-onset healthcare-associated (CO-HCA) is defined as the organism isolated within 48 hours of admission but the patient having an underlying illness that predispose to frequent health care contact, hospitalization, or surgery within the prior year or an indwelling device.[7]

Viral coinfection was the isolation or detection by rapid testing (lateral-flow immunochromographic assays [BinaxNow, Inverness Medical Innovations, United Kingdom]) of a viral pathogen from respiratory secretions (nasal wash/swab or tracheal aspirate) during the hospitalization.

During hospital stay, fever was ≥100.4°F.

Outcomes were defined as cure or improvement if the patient had resolution or improvement of symptoms, was discharged home, and no additional unscheduled visits related to the initial infection were documented. Unscheduled visits with symptoms related to the initial infection and readmissions were identified. Chronic sequelae included chronic lung disease with obstructive or restrictive pattern attributed to lung scarring.

## Microbiology and Molecular Methods

All isolates underwent susceptibility testing to antibiotics, including clindamycin (including inducible macrolide-lincosamide-streptogramin B resistance), erythromycin, oxacillin, trimethoprim-sulfamethoxazole, and vancomycin by disk diffusion, according to the Clinical and Laboratory Standards Institute.[15] Available isolates were genotyped by pulsed-field gel electrophoresis and PVL genes (*luk*-F and *luk*-S PV) were detected by polymerase chain reaction.[7]

## Statistics

Data were analyzed by $\chi^2$, Fisher exact test, $\chi^2$ for trend, or Mann-Whitney *U* test using STATA 10 (College Station, TX).

# RESULTS

## Clinical Characteristics of All Children With SA Pneumonia

During the study period, 117 patients with SA pneumonia were identified. Median age was 0.9 years (range, 0.05–20.9 years). Of 117 patients, 70 (59.8%) were male. In total, 23% of the patients were white, 27.4% were black, 38.5% were Hispanic, and 0.8% were Asian. In 10.3% of the cases, ethnicity was unknown or not specified. In all, 81% of the patients were previously healthy. Underlying illnesses included respiratory conditions/asthma, 9 (7.8%); immunosuppression, 8 (6.8%); neuromuscular disorders, 2 (1.7%); prematurity, 1 (0.85%); and other, 2 (1.7%) (Table, Supplemental Digital Content 1, http://links.lww.com/INF/A789).

Infections were classified as CA, 92 (78.6%) cases; community-onset healthcare-associated, 22 (18.8%); and hospital-acquired, 3 (2.6%). Clinical presentation was pneumonia with or without effusion in 30 (25.6%), pneumonia with empyema in 73 (62.4%), or lung abscess in 14 (12.0%). Thirteen children did not have a fever in the hospital. The median duration of fever in 104 patients in the hospital was 5 days (range, 1–18 days). Bacteremia for a median of 1 day (range, 1–7 days) occurred in 19 of 105 (18.1%) patients from whom a blood culture was obtained. Median hospital stay was 14 days (range, 5–206 days).

A total of 96 (85.7%) children required supplemental oxygen; 68 (58.1%) required intensive care unit care for a median of 8.5 days (range, 1–206 days). Intubation and ventilatory support was required by 35 (30.7%) patients for a median of 8 days (range, 1–206 days).

## Microbiology and Molecular Analysis

Among the 117 patients, bacterial cultures were obtained from pleural fluid of 104 (88.9%) patients, chest tube drainage of 2 (1.7%), lung aspirate by interventional radiology of 4 (3.4%), lung tissue from lobectomy of 3 (2.6%), or from lung biopsy of 2 (1.7%) patients. In addition, 18 (15.4%) children had SA isolated from a tracheal aspirate and 19 (18.1%) from blood cultures.

MRSA isolates caused 87 (74%) of the infections and MSSA, 30 (26%).

Clindamycin resistance was observed in 9 (7.7%) of the isolates; 6 MRSA and 3 MSSA. Molecular analysis could be performed on 110 isolates. USA300 genotype accounted for 75/82 (91.5%) of the MRSA isolates and 14/28 (50%) of the MSSA isolates. Significant differences between MRSA versus MSSA infections and between USA300 versus non-USA300 infections included younger age, community acquisition of the infection, and lack of underlying medical conditions ($P < 0.001$) (Table, Supplemental Digital Content 1, http://links.lww.com/INF/A789).

Overall, 95.5% of the isolates carried PVL genes (*pvl*+). In all, 79 of 82 (96.3%) MRSA isolates and 26 of 28 (92.3%) MSSA isolates were *pvl*+ ($P = 0.60$). Of the 89 USA300 isolates, 87 (97.8%) carried PVL genes compared with 18 of 21 (85.7%) non-USA300 isolates ($P = 0.05$). As only 5 isolates were *pvl* negative, comparisons between *pvl*+ and *pvl*− infections were not performed.

A trend for an increase of USA300 pulsotype was observed among the MSSA isolates over the study period ($P = 0.05$, $\chi^2$ for trend). Although the overall percentage of USA300 isolates increased from 77.8% to 85.7% between study years 1 and 7, this difference was not significant ($P = 0.33$, $\chi^2$ for trend).

## Radiologic Features

All patients underwent chest radiographies; 57 (48.7%) had a chest ultrasound and 30 (25.6%) had computed tomography of the chest. Radiographic findings included unilobar consolidation in 53 (45.3%); multilobar consolidation in 63 (53.9%); pleural effusion in 105 (89.7%); diffuse interstitial infiltrates in 16 (13.7%); pneumothorax in 20 (17.1%); and pneumatoceles/cystic or cavitary lesions in 32 (27.4%) patients. The comparative radiographic features between MRSA and MSSA and USA300 and non-USA300 isolates are shown in Table, Supplemental Digital Content 2, http://links.lww.com/INF/A790. USA300 infections tended to present more commonly with pneumatocele/cystic or cavitary lesions consistent with necrotizing pneumonia ($P = 0.06$).

Chest ultrasonography revealed the presence of a complex, loculated, or septated effusion in 43/57 (75.4%) patients and a free flowing effusion in 14/57 (24.6%) patients. In addition to pulmo-

nary infiltrates consistent with pneumonia, findings on chest computed tomography included cavitary lesions/pneumatoceles, lung mass, or lung abscess in 14 patients, loculated effusion/empyema in 12, pulmonary nodules/septic pulmonary emboli in 3, hydropneumothorax/pneumothorax in 4, isolated lung consolidation in 2, and a chest wall fluid collection in 1 patient. Six patients had more than 1 finding.

The last chest radiograph documented in the medical records was obtained at a median of 17 days (range, 3–1952 days) after initial presentation. In 63 patients (53.9%), the last chest radiograph showed improved residual pleural thickening and or infiltrate; 11 (9.4%) showed complete resolution of findings. Thirteen (11.1%) patients had changes consistent with scarring or chronic lung disease; 15 (12.8%) had pneumatoceles. Fourteen (12%) patients had unchanged radiographic abnormalities on last follow-up chest radiograph at a median of 11 days (range, 6–122 days). Only 1 patient had worsening of radiologic findings at 15 days after the initial presentation but was discharged home with clinical improvement and no additional hospital visits were documented. Most patients (61, 52.1%) underwent their follow-up chest radiography before discharge but 56 (47.9%) of the patients underwent a chest radiography at TCH for follow-up or other unrelated medical concerns after discharge.

Thirteen patients had an echocardiogram which was abnormal in 3 patients: one each with an atrial septal defect, severe mitral valve regurgitation, and a large pericardial effusion.

## Laboratory Results

No significant differences were observed in white blood cell count or neutropenia at the time of presentation or peak white blood cell count between patients with MRSA and MSSA infections or between USA300 and non-USA300 infections. Only 12 (10.3%) of the patients had an erythrocyte sedimentation rate documented; the median was 62 mm/h (range, 26–98 mm/h). Seventeen (14.5%) patients had C-reactive protein measured with a median of 11.1 mg/dL (range, 1.8–46.3 mg/dL). Seven patients underwent immunologic screening with normal results.

Thirteen (11.1%) patients had a pleural histopathologic specimen, all of which demonstrated features consistent with empyema.

## Viral Coinfection

Overall, 68 patients (58.1%) had a respiratory viral culture performed. In addition to viral cultures in these 68 children, rapid testing was performed in 62 (91.2%) for influenza, in 60 (88.2%) for respiratory syncytial virus (RSV), and in 7 (10.3%) for adenovirus In patients without viral cultures, rapid testing was negative in 2 for influenza and in 3 for RSV. The majority (n = 43, 63.2%) of the viral cultures was obtained from a nasal wash, 2 (2.9%) were from nasal swabs, 1 from a lung biopsy, 1 from pleural fluid, and in 30 (44.1%) the type of respiratory sample was not specified. In addition to a nasal wash or nasal swab, 2 patients had a tracheal aspirate collected and 1 patient a lung aspirate for viral culture.

Viral copathogens were detected in 18/68 patients tested and included parainfluenza, 6 (32%); influenza, 5 (26%) (3 influenza A, 2 influenza B); rhinovirus, 4 (21%); adenovirus, 2 (11%); and RSV, 1 (5%); and enterovirus, 1 (5%). One patient had 2 viruses (adenovirus and parainfluenza 3) isolated. All the viral coinfections due to influenza were identified between October and March. Parainfluenza virus was isolated from viral cultures throughout the year. Testing for viral coinfection occurred more often between the months of October and January.

Among patients tested, those with viral coinfections were more likely to present with pneumonia (10/18 vs. 9/50, $P = 0.002$), respiratory failure (13/18 vs. 12/59, $P < 0.001$), and to have longer intensive care unit stay (median [range], 20 days [6–120 days] vs. 9 days [2–121 days]; $P = 0.008$) compared with children without a viral copathogen (Table 1).

## Hospitalization Trends

During the first 7 study years, there were a total of 148,102 admissions to TCH (year 8 was incomplete and excluded from the trend analysis to avoid introducing bias due to seasonality). The rate of SA pneumonia hospitalizations per 10,000 admissions increased from 4.81 in study year 1 to 9.75 in study year 7 ($P = 0.04$, $\chi^2$ for trend); in addition, the rate of USA300 SA pneumonia hospitalizations per 10,000 admissions increased from 3.38 in study year 1 to 8.36 in study year 7 ($P = 0.02$, $\chi^2$ for trend) (Fig. 1).

**TABLE 1.** Selected Comparative Clinical Features of Patients With *Staphylococcus aureus* Pneumonia With and Without Viral Coinfection

| Characteristics | Viral Coinfection n = 18 | Negative Viral Test n = 50 | *P* |
|---|---|---|---|
| Age (years) | 0.67 (0.08–15.22) | 0.79 (00.5–18.54) | 0.44 |
| Underlying illness | 1 (5.6%) | 12 (24.0%) | 0.16 |
| Clinical presentation | | | |
| Pneumonia with or without nonloculated effusion | 10 (55.6%) | 9 (18.0%) | 0.002 |
| Empyema | 7 (38.9%) | 33 (66%) | 0.045 |
| Lung abscess | 1 (5.6%) | 9 (18%) | 0.27 |
| Hospital days, median (range) | 20.5 (7–133) | 15 (6–130) | 0.08 |
| PICU days, median (range) | 14 (0–120) | 3 (0–121) | 0.02 |
| PICU days, median (range) | 20 (6–120) | 9 (2–121) | 0.008 |
| Intubation | 13 (72.2%) | 12 (24.0%) | <0.0001 |
| Days intubated | 13 (2–77) | 8 (4–94) | 0.51 |

PICU indicates pediatric intensive care unit.

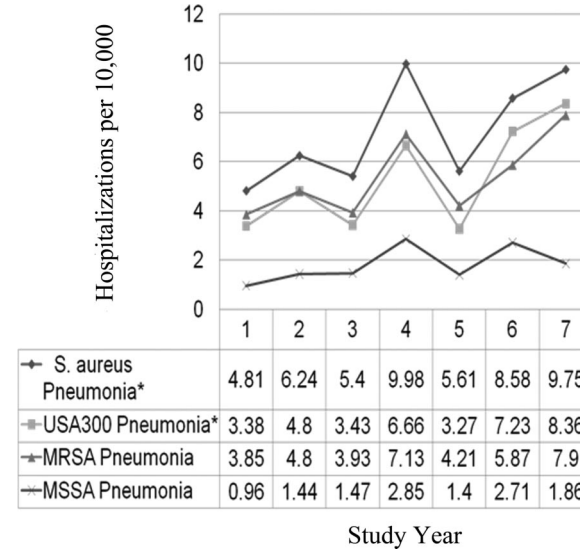


**FIGURE 1.** Trends in SA pneumonia at Texas Children's Hospital from 2001 to 2008. *$\chi^2$ for trend <0.05.

**TABLE 2.** Management Strategies of *S. aureus* Pneumonia by Methicillin Susceptibility and Genotype

| Treatment | Methicillin Resistance | | | Genotype | | |
|---|---|---|---|---|---|---|
| | MRSA n = 87 | MSSA n = 30 | *P* | USA300 n = 89 | Non-USA300 n = 21 | *P* |
| Surgical intervention | | | | | | |
| VATS | 67 (77.0%) | 22 (73.3%) | 0.68 | 71 (79.8%) | 12 (57.1%) | 0.03 |
| CT, thoracentesis | 16 (18.4%) | 5 (16.7%) | 0.83 | 13 (14.6%) | 7 (33.3%) | 0.05 |
| IR lung abscess drainage | 3 (3.4%) | 1 (3.3%) | >0.99 | 3 (3.4%) | 1 (4.8%) | 0.58 |
| Lobectomy | 1 (1.1%) | 2 (6.7%) | 0.16 | 2 (2.2%) | 1 (4.8%) | 0.47 |
| Total days of treatment | 22 (6–56) | 21 (6–50) | 0.82 | 21 (10–56) | 22 (6–42) | 0.75 |
| PO days | 7 (0–23) | 7 (0–31) | 0.86 | 7 (0–31) | 4 (0–23) | 0.63 |
| IV days | 13 (5–56) | 15 (6–42) | 0.86 | 13 (5–56) | 12 (6–42) | 0.62 |
| Clindamycin empirical treatment | 24 (27.6%) | 12 (40%) | 0.20 | 27 (30.3%) | 5 (23.8%) | 0.55 |
| Clindamycin definitive treatment with or without other antibiotics | 77 (88.5%) | 11 (36.7%) | <0.0001 | 75 (84.3%) | 8 (38.1%) | <0.0001 |
| Clindamycin-only definitive antibiotic | 65 (74.7%) | 7 (23.3%) | <0.0001 | 59 (66.3%) | 8 (38.1%) | 0.03 |

MRSA indicates methicillin resistant *S. aureus*; MSSA, methicillin susceptible *S. aureus*; VATS, video-assisted thoracoscopy; CT, chest tube placement; IR, interventional radiology thoracentesis.

## Management

The median durations of total and parenteral antibiotic treatment were 21 days (range, 6–56 days) and 14 days (range, 5–56 days), respectively (Table 2). Seventy-two (61.5%) children completed therapy with oral antibiotics for a median of 11 days (range, 3–31 days).

Clindamycin alone or in combination was used as definitive therapy in 88 (75.2%) and as empirical treatment in 36 (31%) cases. Ninety-three (79.5%) patients received vancomycin as part of their empirical antibiotic therapy, generally for 2 to 4 days; vancomycin was discontinued once SA was identified and the antibiotic susceptibilities were available. Vancomycin was the definitive antibiotic in 8, linezolid in 3, an antistaphylococcal $\beta$-lactam in 18, and trimethoprim-sulfamethoxazole in 5 children, the latter to complete outpatient therapy orally after parenteral vancomycin, a $\beta$-lactam, or clindamycin. Only 10 (8.6%) patients had vancomycin trough levels measured. In 4 patients, vancomycin levels were between 15 to 20 $\mu$g/mL and in 6 it was less than 15 $\mu$g/mL.

Video-assisted thoracoscopy (VATS), thoracentesis/chest tube placement, lung abscess drainage by interventional radiology, and lobectomy occurred in 89 (76.1%), 21 (17.9%), 4 (3.4%), and 3 (2.6%) patients, respectively. VATS was more commonly used for USA300 infections compared with non-USA300 infections; 71/89 versus 12/21, respectively ($P = 0.03$).

## Follow-up and Outcomes

Seventy-nine (67.5%) patients had documented follow-up for a median of 34 days (range, 3–1952 days); the remaining patients were considered cured for purposes of our analysis since no record of return to TCH was detected. A total of 103 patients (88%) were considered to be cured or improved. If only the 79 patients for whom follow-up information was available are considered, 66 (83.5%) were cured. Of 36 children, 31 who received empiric clindamycin (86%) were cured or improved.

Two patients (1.7%) had additional unscheduled hospital visits due to fever that occurred 6 and 8 days after hospital discharge, respectively. They were evaluated in the emergency center and discharged home. Four (3.4%) patients were readmitted for symptoms related to the primary infection: 1 patient required a second VATS 5 days post discharge; 1 patient developed sixth rib osteomyelitis with reaccumulation of pleural effusion/empyema 32 days after discharge; and 2 patients were readmitted for fever and worsening of radiologic pneumonia 6 days and 21 days post discharge. All ultimately had resolution of their infection. Eight patients experienced complications related to hematogenous dissemination or local extension of the disease including septic pulmonary emboli (n = 2), liver abscess (n = 1), splenic abscess (n = 1), pericardial effusion (n = 2), chest wall abscess (n = 1), and rib osteomyelitis (n = 1).

Seven (6%) patients developed sequelae: 2 had chronic recurrent pneumothoraces and 5 had chronic lung disease/lung scarring (>1 year post discharge) with restrictive or obstructive patterns. Of the 7 patients, 4 patients with sequelae were previously healthy and 1 required chronic ventilatory support and tracheostomy for several weeks after the infection. Three of the 7 patients had underlying illnesses; 2 had immunodeficiencies (chronic granulomatous disease and chronic neutropenia) and the other patient had a history of recurrent pneumothoraces due to Marfan syndrome.

One (0.85%) patient died as a result of the infection. He was a 1.8-year-old previously healthy male who presented with pneumonia and empyema, and developed respiratory failure requiring ventilator support and extracorporeal membrane oxygenation. He was treated with vancomycin. A clindamycin-resistant MRSA USA300 *pvl*+ isolate grew from a pleural fluid culture and a tracheal aspirate. The child also had influenza B virus coinfection.

# DISCUSSION

To our knowledge, this series of children with SA pneumonia, primarily due to MRSA, is the largest reported in the CA-MRSA era. The predominance of MRSA as a cause of SA pneumonia in previously healthy children over the past several years has been reported in several case series from the United States, in contrast with the European experience in which MSSA infection prevails.[1,9,16]

We have observed a larger proportion of MRSA isolates causing pneumonia (75%) than the proportion of MRSA causing other invasive infections like osteomyelitis (63%) or septic arthritis (38%) in children at TCH with invasive SA infections.[12] For blood culture isolates, others have reported a higher proportion of MRSA associated with pneumonia or empyema than those isolated from musculoskeletal infections.[17] This finding could represent an advantage or tropism of the MRSA isolates, especially those with

the genes encoding for PVL, to cause lower respiratory tract infections, and deserves further investigation.[18]

USA300 genotype accounted for almost all of the MRSA isolates. The proportion of MSSA isolates that were USA300 genotype significantly increased over the study period from 33% to 75%. At TCH, we have observed an increased proportion of MSSA isolates causing invasive infections being USA300, and others have reported a similar finding in CA skin and soft-tissue infections.[13,19,20]

Both MRSA and USA300 isolates causing pneumonia were associated with younger age and community acquisition. Most of the MRSA (96%) and MSSA (92%) isolates carried PVL genes. Furthermore, the proportion of MSSA isolates carrying PVL genes is higher than we have reported for other SA invasive infections at TCH (46% of MSSA organisms causing septic arthritis, and 25% of the MSSA isolates causing CA osteomyelitis).[19,21] These findings are consistent with the hypothesis that PVL contributes to the pathogenesis of SA pneumonia in children. Several reports have associated PVL with the development of necrotizing pneumonia in humans and animal models.[18,22,23]

The mortality in our study was 0.85% of all SA pneumonia patients and 5% of the patients with a viral coinfection. Viral coinfection was detected in 15% of our cases and was associated with increased severity of infection related to respiratory failure. Severe cases of SA pneumonia have been reported in relation to influenza season and associated with a prodromal viral illness in 33% to 71% of patients.[16,24–27]

VATS was more likely to be performed for SA pneumonia caused by USA300 than non-USA300 isolates. We speculate that these USA300 infections were more severe and required a more aggressive treatment approach. Our study also suggests that in children, clindamycin is an effective agent to complete treatment for MRSA pneumonia due to susceptible isolates. If SA bacteremia is present, clindamycin is administered to complete therapy once the bacteremia has been cleared. Evidence of inhibition of toxin production, including PVL, with exposure to clindamycin has been demonstrated in vitro.[28,29] These findings in conjunction with evidence from retrospective studies have led others to suggest that antibiotics that inhibit protein synthesis (like clindamycin or linezolid) should be considered for treating nonendovascular MRSA infection.[30,31]

Limitations of this study include that the selection of the patients was based on culture positivity for SA from normally sterile sites, which improves ascertainment of cases but might bias the results toward cases severe enough to require hospitalization and to undergo procedures to establish an etiologic diagnosis.[32] As information from tracheal aspirates is not collected routinely in our surveillance study, we may have underestimated the number of cases with SA pneumonia. Additionally, rates of viral coinfection might have been underestimated as only 58% of our patients had respiratory viral cultures requested by the attending physicians who may have ordered viral cultures on children who may have appeared to be more critically ill than those patients for whom viral cultures were not ordered. Furthermore, the sensitivity of the viral tests employed may not have been as great as that for polymerase chain reaction-based tests. Follow-up information was limited to those children who had medical records available at TCH sometime after discharge. We assumed that children without any follow-up information would have been cured but they may have sought care outside of TCH for a recurrence or treatment failure after discharge. However, there is only one other children's hospital in the Houston area, and it is very likely that there would have been some indication of this occurring if several children had sought care at the other children's hospital. The retrospective nature of the study and the single-center enrollment might limit the ability to extrapolate the results to other settings.

In conclusion, SA and particularly the USA300 clone have been increasingly noted as causing pneumonia/empyema in children at TCH. Virtually all the isolates carry the *pvl* genes. Viral copathogens were noted in slightly more than 25% of patients in whom viral detection tests were performed and were associated with more severe disease. VATS was the most commonly performed procedure to manage SA empyema in our institution. In children, clindamycin is an effective antibiotic to complete therapy for SA pneumonia due to susceptible isolates. Further studies are needed to determine the optimal antibiotic therapy for SA pneumonia in children.

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# Current Abstracts

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## Surveillance for Invasive Meningococcal Disease in Children, United States–Mexico Border, 2005–2008

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Invasive meningococcal disease (IMD), caused by *Neisseria meningitidis*, is a reportable condition in both the United States and Mexico. However, only a limited number of epidemiologic descriptions of IMD, primarily from outbreaks, are available from Mexico. The goals of this study were to compare hospital-based estimates of IMD in children and serogroup distribution at Tijuana General Hospital (TGH), Mexico, with a catchment population of nearly 200,000 children <17 years of age, to reported IMD cases in children in San Diego County (SDC), with a population of 723,600 children <17 years of age. This border is the most traversed international frontier in the world.

Between October 1, 2005 and May 31, 2008, a total of 29 pediatric cases of IMD were diagnosed, 16 at TGH (an estimated 3.08 annual cases/100,000 children <17 years of age) and 13 in SDC (0.69 annual cases/100,000 children <17 years of age). Children <5 years old were accounted for most IMD cases at both sites; 9 cases at TGH, and 10 in SDC ($P = 0.24$). Overall, serogroup C was most commonly identified among the 29 cases (41.4%), followed by B (34.5%) and Y (10.3%); another 13.8% of cases were not serogrouped (2 cases each at TGH and SDC). A significant difference in serogroup was observed by site; serogroup C was most commonly identified at TGH (62.5%), whereas serogroup B was most common in SDC (61.5%) ($P = 0.005$).

*Comment:* This surveillance project describes active hospital-based surveillance and serogroup distribution of IMD in children on both sides of the United States–Mexico border. The age and serogroup distribution differed greatly between sites, with SDC demonstrating more infant cases and serogroup B, whereas TGH demonstrated more child and adolescent cases and serogroups C and Y. This study suggests that the rates of IMD at TGH, and presumably Tijuana and elsewhere in Mexico, may be substantially higher than reported.

During the study period, vaccine-preventable serogroups were more common in TGH than in SDC. This finding has potential implications for immunization with the meningococcal vaccines containing serogroups C and Y in Mexico. Widespread meningococcal vaccination has not yet been introduced in Tijuana or elsewhere in Mexico, although the monovalent meningococcal C conjugate vaccine has been licensed in Mexico. This study suggests that a substantial number of IMD cases might have been prevented with quadrivalent meningococcal vaccine (75%) or monovalent serogroup C vaccine (63%).

Establishment of a binational IMD surveillance system could provide substantial benefit in improving IMD control potentially leading to vaccination strategies in Mexico's northern border region, and perhaps elsewhere. Further IMD surveillance studies including binational systems are needed to better define the epidemiology of IMD in the northern border and other regions of Mexico and determine appropriate vaccination policies.