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A Community Intervention Trial to Promote Judicious Antibiotic Use and Reduce Penicillin-Resistant *Streptococcus pneumoniae* Carriage in Children

Edward A. Belongia, MD*; Bradley J. Sullivan, MD, PhD*; Po-Huang Chyou, PhD*; Elisabeth Madagame, MD‡; Kurt D. Reed, MD*; and Benjamin Schwartz, MD§

ABSTRACT. *Objective.* Inappropriate use of antibiotics is common in primary care, and effective interventions are needed to promote judicious antibiotic use and reduce antibiotic resistance. The objective of this study was to assess the impact of parent and clinician education on pediatric antibiotic prescribing and carriage of penicillin-nonsusceptible *Streptococcus pneumoniae* in child care facilities.

Methods. A nonrandomized, controlled, community intervention trial was conducted in northern Wisconsin Clinicians. Clinic staff received educational materials and small-group presentations; materials were distributed to parents through clinics, child care facilities, and community organizations. Prescribing data were analyzed for 151 clinicians who provided primary pediatric care; nasopharyngeal carriage of penicillin-nonsusceptible *S pneumoniae* was assessed for 664 children in the baseline period (January–June 1997) and for 472 children in the postintervention period (January–June 1998).

Results. The median number of solid antibiotic prescriptions per clinician declined 19% in the intervention region and 8% in the control region. The median number of liquid antibiotic prescriptions per clinician declined 11% in the intervention region, compared with an increase of 12% in the control region. Retail antibiotic sales declined in the intervention region but not in the control region. Among participating children in child care facilities, there were no significant differences in antibiotic use or penicillin-nonsusceptible *S pneumoniae* colonization between the intervention and control regions.

Conclusions. A multifaceted educational program for clinicians and parents led to community-wide reductions

in antibiotic prescribing, but in child care facilities, there was no apparent impact on judicious antibiotic use or colonization with drug-resistant *S pneumoniae*. Longer follow-up time or greater reductions in antibiotic use may be required to identify changes in the pneumococcal susceptibility. *Pediatrics* 2001;108:575–583; *Streptococcus pneumoniae*, antimicrobial resistance, antibiotic prescribing, health education, community interventions.

ABBREVIATIONS. PNP, penicillin-nonsusceptible pneumococci; MIC, minimum inhibitory concentration; CDC, Centers for Disease Control and Prevention.

Respiratory tract and invasive infections caused by *Streptococcus pneumoniae* are a major source of morbidity among children and older adults in the United States.^{1–3} During the past decade, the prevalence of antibiotic-resistant pneumococci has increased dramatically,^{4,5} and recent surveys indicate that approximately 16% of invasive pneumococcal isolates are fully resistant to penicillin.⁶ Multiple studies have demonstrated an association between carriage or infection with resistant pneumococci and recent antibiotic use.^{7–15} Children who are younger than 15 years have the highest rate of antibiotic use,¹⁶ and nearly half of all children with a diagnosis of upper respiratory infection receive an antibiotic despite the lack of efficacy.¹⁷

The combined impact of community-wide physician and parent education regarding judicious antibiotic use in children is unknown, although physician education by peers and patient education each seem to have some influence on prescribing behavior.^{18–20} In addition, it is not known whether a reduction in unnecessary antibiotic use will lead to measurable changes in prevalence of penicillin-nonsusceptible pneumococci (PNP) in children. To address these questions, we conducted and evaluated a

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Fig 1. Location of intervention and control regions for a Wisconsin community intervention to promote judicious antibiotic use in children.

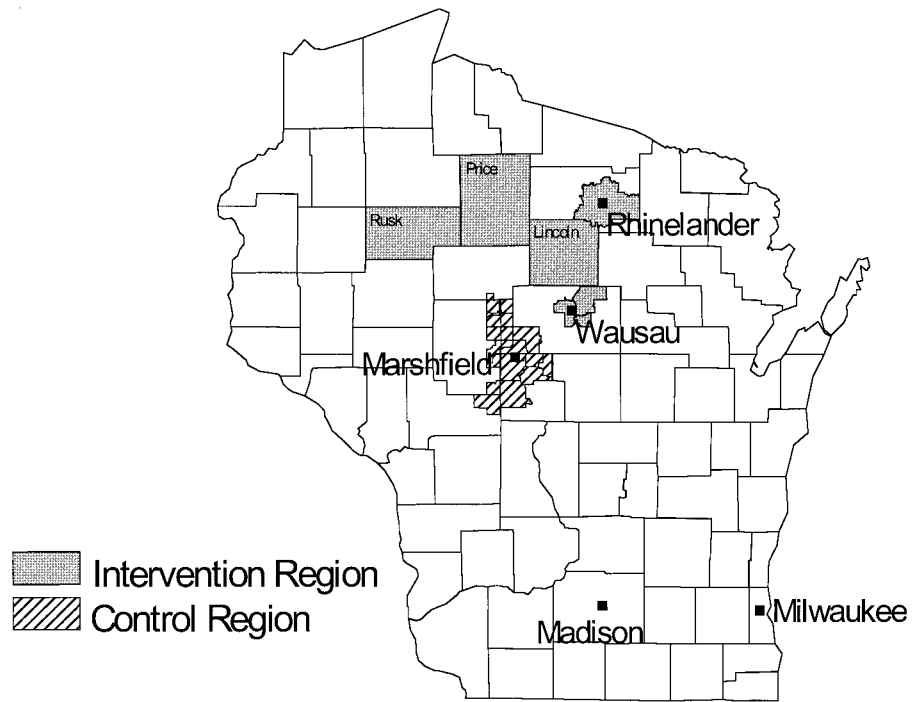


TABLE 1. Comparison of Intervention and Control Regions

	Intervention Region	Control Region
Total population	107 884	58 439
Primary care clinicians		
Family practice	83 (62.4%)	13 (25.0%)
Internal medicine	10 (7.5%)	0
Urgent/emergency care	22 (16.5%)	16 (30.8%)
Pediatrics	18 (13.5%)	23 (44.2%)
Primary care provider type		
Physician*	105 (79.0%)	42 (80.8%)
Physician assistant or nurse practitioner	28 (21.0%)	10 (19.2%)

* Resident physicians excluded.

community intervention to promote judicious antibiotic use among parents and primary care clinicians who provide pediatric care in northern Wisconsin.

METHODS

We conducted a nonrandomized, controlled, community intervention trial. The baseline observation period was January through June 1997, and the postintervention period was January through June 1998. The intervention region included Price, Rusk, and Lincoln counties in northern Wisconsin, and the adjacent cities of Wausau and Rhinelander (Fig 1). The control region was a 14–zip code area surrounding the city of Marshfield, Wisconsin. The regions were selected for their relative geographic isolation and because the Marshfield Clinic regional network was a major provider of medical care. The intervention region had a larger population and a greater number of primary care clinicians providing pediatric care compared with the control region (Table 1). Multiple competing practice organizations provided primary health care for children in the intervention region. In the control region, nearly all residents received medical care from the Marshfield Clinic regional network.²¹ Approximately half of the population in the control region was enrolled in a managed care organization, and most of the remainder had fee-for-service coverage. The regions were geographically distinct, and patients would not normally travel from one region to another for primary care services.

Nonsusceptible Pneumococcal Carriage in Child Care Facilities

Licensed child care facilities in the intervention and control regions were contacted in early 1997 and 1998 to collect nasopharyngeal swabs from children to assess the prevalence of PNP carriage (Fig 2). According to Wisconsin statute, facilities that are licensed for 8 or fewer children are classified as family day cares, and those licensed for 9 or more children are classified as group day cares. The cities of Wausau and Rhinelander were added to the intervention region during the baseline period when PNP prevalence in Price, Rusk, and Lincoln counties was found to be too low at baseline to measure any additional reduction resulting from the intervention. Facilities in these 3 counties were not revisited in the postintervention period, and they were excluded from the analysis of changes in PNP prevalence. Twenty licensed family child care facilities and 5 group child care facilities in Wausau and Rhinelander participated during the postintervention period but not during the baseline period.

Children were eligible to participate if they attended child care at least 4 hours per week and were younger than 48 months on January 1 of each year. All eligible children were recruited at participating facilities during the baseline period and the postintervention period. The child care facility operators distributed consent forms and self-administered questionnaires to parents to assess recent antibiotic use and other potential risk factors for PNP carriage. The latter included frequency of child care attendance, number of siblings, exposure to environmental tobacco smoke, recent antibiotic use, and type of health insurance. Nasopharyngeal swabs were collected from all children with parental consent from late January through May of each year, and visits to intervention and control facilities were evenly distributed throughout this time period to avoid seasonal bias. When necessary, facilities were visited more than once to obtain samples from children who were absent during the initial visit.

Nasopharyngeal specimens were collected by gently inserting a swab into the nasopharynx for at least 3 seconds. The swabs were inoculated immediately onto blood agar plates, and *S pneumoniae* was identified using standard procedures.²² Pneumococcal isolates were tested for susceptibility to penicillin using the E test.²³ According to National Committee for Clinical Laboratory Standards, a penicillin minimum inhibitory concentration (MIC) of 0.1 $\mu\text{g}/\text{mL}$ to 1.0 $\mu\text{g}/\text{mL}$ was classified as intermediate resistance, and an MIC of 2.0 $\mu\text{g}/\text{mL}$ or greater was classified as full resistance.²⁴ The result was rounded up to 2.0 $\mu\text{g}/\text{mL}$ if the E test yielded an MIC of 1.5 $\mu\text{g}/\text{mL}$. Isolates with either intermediate- or high-level resistance were classified as PNP.

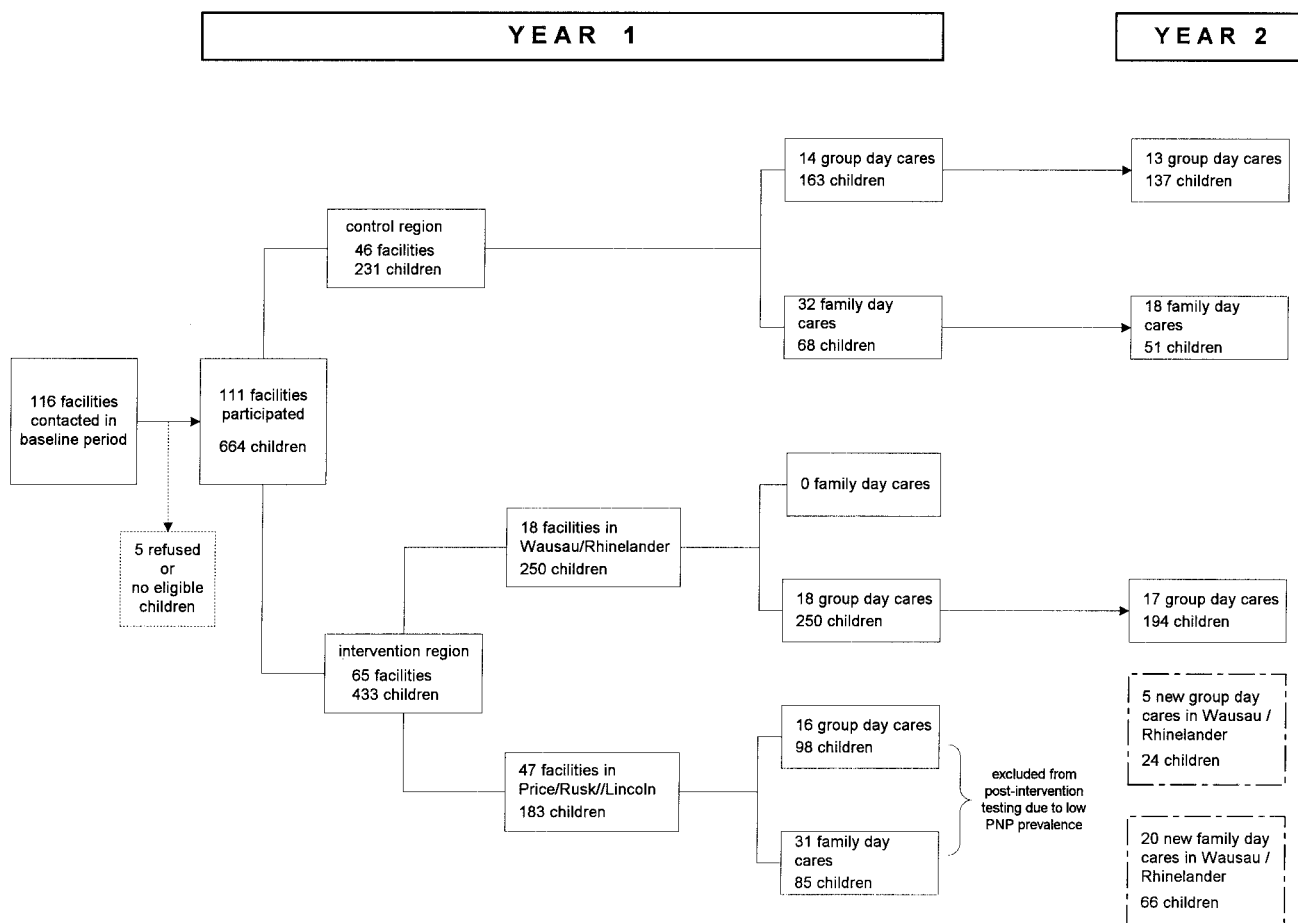


Fig 2. Participating day cares and children during the baseline period and the postintervention period.

TABLE 2. Key Educational Messages Provided to Clinicians to Promote Judicious Antibiotic Use in Children

Condition	Message
Common cold	Purulent rhinitis frequently accompanies the common cold and is not a separate indication for antimicrobial treatment.
Acute sinusitis	Antimicrobial treatment should be limited to children with <ul style="list-style-type: none"> • prolonged nonspecific upper respiratory signs and symptoms (ie, rhinorrhea and cough without improvement for >10–14 days). • more severe upper respiratory tract signs and symptoms (ie, fever $\geq 39.0^{\circ}\text{C}$, facial swelling, facial pain).
Pharyngitis	Diagnosis of group A streptococcal pharyngitis should be made using a laboratory test in conjunction with clinical and epidemiological findings.
Bronchitis	Children who have acute cough illness/bronchitis and do not have chronic lung disease warrant antibiotic treatment only for specific infections (eg, pertussis, mycoplasma).
Otitis media	Antimicrobials are not indicated for the initial treatment of middle ear effusion in the absence of AOM. Persistent middle ear effusion is expected after therapy for AOM and does not require retreatment. Uncomplicated AOM may be treated with a 5- to 7-day course of antimicrobials in low-risk children.

AOM indicates acute otitis media.

The research protocol was approved by the Institutional Review Board at the Marshfield Clinic and the US Centers for Disease Control and Prevention (CDC). Written informed consent was obtained from the parents of all participating children.

Intervention

Clinician education and community education were conducted from September through December of 1997. Clinician education began with a series of "grand rounds" presentations in each of 6

communities by 1 of the authors (B.S.). This was followed by practice-based small-group meetings (academic detailing) led by 1 of 3 physician educators (B.J.S., E.M., E.A.B.). The small-group meetings typically involved 2 to 6 clinicians and lasted 30 to 60 minutes. Five key educational messages were presented regarding judicious antibiotic use for pediatric respiratory illness (Table 2). Each clinician received a folder containing clinical practice guidelines for bronchitis, upper respiratory tract infection, acute sinusitis, otitis media, and pharyngitis. These were developed by a

work group of 11 Marshfield Clinic physicians, including 4 physicians who practiced in the intervention region. The guidelines were distributed to all primary care clinicians in the intervention region, including non-Marshfield Clinic physicians. The folder also contained samples of a parent education pamphlet, parent information sheets on runny nose and otitis media with effusion, a sample letter to a child care provider (approving return to child care), and an imitation "prescription pad" to provide written recommendations regarding symptomatic management of viral respiratory illness. The clinicians also received CDC fact sheets for clinicians on 1) general principles of judicious antibiotic use, 2) the emerging threat of antibiotic resistance, 3) practice tips for reducing antibiotic use, and 4) diagnosis/management of otitis media, cough illness, pharyngitis, and sinusitis. After each small-group meeting, a thank-you letter was sent to each participant, and key messages were reinforced.

The community interventions included programs for child care providers, local public health agencies, parent groups, and community organizations. Educational materials, including pamphlets and posters developed by the CDC, were widely distributed to clinics, pharmacies, child care facilities, and schools. In addition, project nurses visited each primary care clinic and presented information to medical assistants and office staff on appropriate antibiotic use. "Cold kits" (donated by SmithKline Beecham Pharmaceuticals, Philadelphia, PA) were provided to clinics in the intervention region for distribution to adolescents and adults.

Outcome Measures

Outcome measures were compared for the baseline period (January–June 1997) and the postintervention period (January–June 1998). The primary measure of antibiotic prescribing was based on clinician-specific prescribing data from IMS Health, Inc. (Xponent database). Because patient data were not available, liquid prescriptions were used as a surrogate for pediatric use. Secondary measures of antibiotic prescribing included retail antibiotic sales data (IMS Health, Inc, DDD database) and medical record abstraction of respiratory illness visits for children who were tested for PNP carriage in child care.

Xponent prescribing data included the number and types of antibiotic prescriptions written by individual clinicians during each time period. Prescriptions for liquid and solid antibiotic formulations were evaluated separately. The Xponent database was derived from transactional data provided by 71% of all retail pharmacies in Wisconsin, including 82% of chain pharmacies and 61% of independent retail pharmacies. The prescribing data were linked to the IMS prescriber universe, a master file of prescribers derived from professional associations and other organizations. The names, addresses, and DEA numbers (if available) of primary care pediatric clinicians in the intervention and control regions were matched against the prescriber universe and linked to prescribing data. IMS prescribing data have been validated through Monte Carlo simulation studies comparing the Xponent methodology to known prescribing volumes. Confidence intervals have not been defined at the level of the individual prescriber, but aggregate data for the prescribers in this study had a sampling error of approximately 3% (Ken Copeland, IMS Health, Inc, personal communication, January 2001).

The primary outcome measure was the percent change in the total number of prescriptions per clinician for liquid and solid drug formulations. Although resident physicians attended the academic detailing sessions and received materials, they were excluded from the analysis of prescribing rates because changes in clinical responsibilities may have affected antibiotic prescribing during the study period. Clinicians who did not practice continuously or prescribe antibiotics during the study period were excluded from the prescribing analyses. Physicians who practiced primarily in a subspecialty also were excluded because the focus of the educational intervention was primary care.

Retail sales of liquid antibiotics (DDD data, IMS Health, Inc) were obtained from distributors and wholesalers that served pharmacies in both regions. The percent change in sales was calculated for the period of January through June of each year. Inpatient pharmacies, prisons, veterinarians, nursing homes, dialysis clinics, and federal government sites were excluded from the retail sales data. The DDD database captured 93% of actual retail sales.

Antibiotic use was assessed for participating children in child care by abstracting clinical data for all acute upper respiratory

illness visits during the baseline and postintervention periods. Medical records were reviewed manually to identify all visits for acute respiratory illness from January 1997 through July 1998. A structured abstraction form was used to record the diagnosis and any antibiotics that were prescribed. The medical record abstractions were performed by a pediatrician and 2 research nurses using standardized coding procedures. Ten percent of visits were abstracted in duplicate for quality assurance. Diagnoses were classified into those that usually warrant systemic antibiotic treatment (eg, acute otitis media) and those that do not (eg, bronchitis, croup).

An evaluation survey was mailed to primary care clinicians in the intervention region in March 1998. The survey included questions to assess the usefulness of the academic detailing sessions and educational materials, and self-reported changes in antibiotic prescribing behavior after the intervention. Nonresponders received 1 or more mailed reminders and/or telephone calls.

Statistical Methods

Univariate and multivariate logistic regression analyses were conducted to assess potential risk factors for PNP carriage among participating children. SUDAAN software version 7.0 (Research Triangle Institute, Research Triangle Park, NC) was used to adjust for intracluster correlation (design effects) within child care facilities. To assess the effect of time period and region on PNP prevalence, 3 indicator variables were created for the regression analysis: control region 1998, intervention region (Wausau/Rhineland) 1997, and intervention region (Wausau/Rhineland) 1998. The control region in 1997 was defined as the referent group. The primary outcome variable for this analysis was carriage of PNP among children in the intervention region during the postintervention period compared with children in the control region during the baseline period. The analysis of PNP prevalence was restricted to 1 observation per child. To maintain independent observations, we included only the postintervention result in the logistic regression for children who were tested for PNP during both years.

SAS statistical software (SAS Institute, Cary, NC) was used to analyze changes in clinician antibiotic prescribing rates. For the Xponent prescribing data, we used the nonparametric Wilcoxon signed rank test to compare the median percent change in the number of prescriptions for each clinician. For the prescribing data based on medical record review, the Wilcoxon rank sum test was used to compare the median proportion of initial visits with an antibiotic prescription during the baseline and postintervention periods. We applied the same statistical approach to test for changes in the median percent change (treated as 2 independent samples) across the 2 regions. $P < .05$ was considered significant.

RESULTS

Ninety-six (72%) of 133 primary care clinicians in the intervention region participated in the small-group meetings. A physician educator had a telephone discussion with an additional 34 clinicians (26%) who were not available to meet in person, and folders were mailed to them. Two clinicians could not be reached, and 1 had retired. A follow-up letter was sent to all clinicians who participated in the small-group sessions to reinforce key points. No additional in-person contacts were initiated with clinicians during the educational intervention. Results regarding the impact of the educational intervention on parent knowledge and awareness have been reported elsewhere.²⁵

Impact on Antibiotic Prescribing

Prescribing data were analyzed for 109 (82%) of 133 primary care clinicians in the intervention region, and 42 (81%) of 52 clinicians in the control region (Fig 3). Thirty-four clinicians were excluded because prescribing data were not available, no liquid prescriptions were written, or the clinician was

Fig 3. Availability of prescribing data for clinicians providing pediatric primary care in the intervention and control regions.

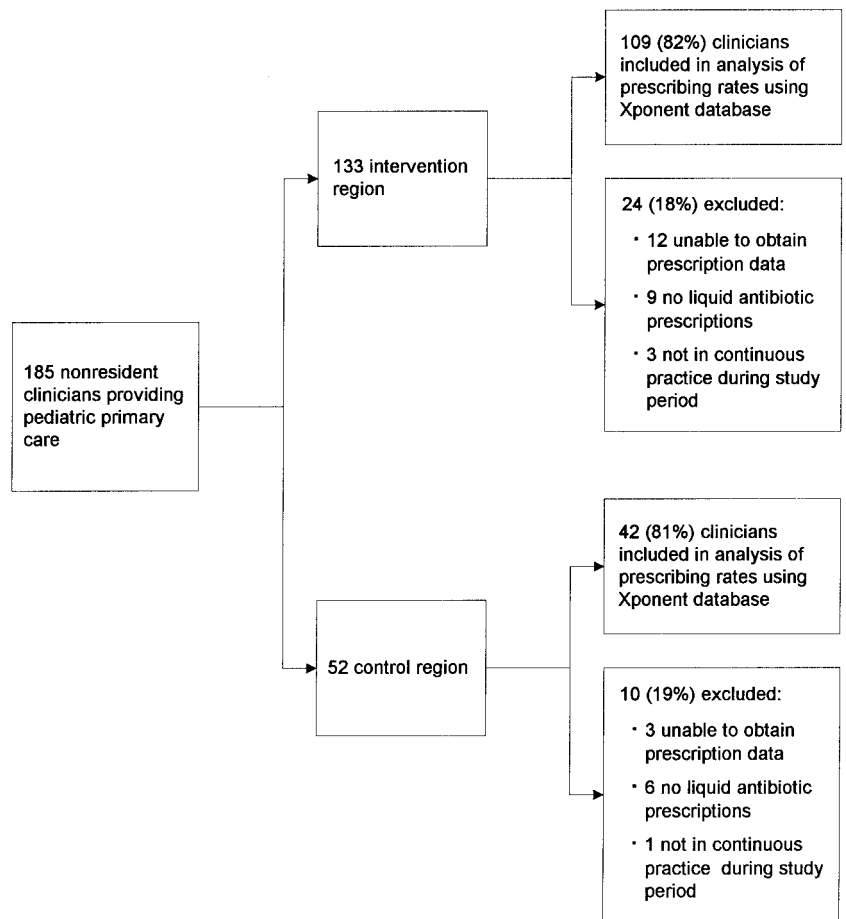


TABLE 3. Changes in the Number of New Antibiotic Prescriptions Written by Clinicians in the Intervention and Control Regions (Xponent Data)

	Median Number of Prescriptions in Baseline Period	Median Number of Prescriptions in Postintervention Period	Median % Change in Number of Prescriptions*	Within-Area <i>P</i> Value†
Solid antibiotic prescriptions‡				
Intervention region clinicians	146	112	−19%	<.001
Control region clinicians	69	55	−8%	.934
Liquid antibiotic prescriptions§				
Intervention region clinicians	48	38	−11%	.096
Control region clinicians	30.5	35.5	12%	.064

* The number of prescriptions in the baseline period was subtracted from the number in the postintervention period to yield the net change for each clinician. The net change was divided by the baseline number of prescriptions to yield a percent change.

† Wilcoxon signed rank test.

‡ *P* = .042, between-area (Wilcoxon rank sum test).

§ *P* = .019, between-area (Wilcoxon rank sum test).

not in practice during the entire study period. During the baseline period, the median number of liquid antibiotic prescriptions was 48 (range: 1–1107 prescriptions) for the 109 clinicians; the median number of solid antibiotic prescriptions was 146 (range: 3–1661). The median absolute change in the number of liquid antibiotic prescriptions from baseline to postintervention was a reduction of 5 in the intervention region and an increase of 2.5 in the control region. The median percent change in liquid antibiotic prescriptions was −11% and 12% in the intervention and control regions, respectively (Table 3).

The median absolute change in the number of solid (tablet/capsule) antibiotic prescriptions was a

reduction of 21 in the intervention region and a reduction of 3 in the control region. The median percent change in solid antibiotic prescriptions was −19% and −8% in the intervention and control regions, respectively. The intervention effectiveness using Xponent data was calculated as the median percent reduction in the intervention region minus the median percent reduction in the control region. The intervention effectiveness was 23% for liquid prescriptions and 11% for solid prescriptions; both differences were statistically significant.

Within the intervention region, the proportional reductions in liquid and solid antibiotic prescribing were similar for family practice physicians compared

with other specialties ($P \geq .95$). Clinicians in the intervention region who participated in the small-group training sessions had a median reduction of 13.3% in liquid antibiotic prescriptions compared with a median increase of 4.1% among clinicians who did not attend a small-group session, but this did not achieve statistical significance ($P = .163$). For solid antibiotic prescriptions, the median reduction was 15.5% and 22.8% for clinicians who did and did not attend small-group training sessions, respectively ($P = .405$).

To assess the intervention effect as a function of baseline prescribing volume, we divided clinicians in the intervention region into quartiles on the basis of the number of prescriptions written during the baseline period. The highest quartile of solid prescribers ($n = 28$) had a median reduction of 29.7% compared with a median reduction of 6.2% for the quartile ($n = 28$) that prescribed the fewest solid prescriptions ($P = .078$). The highest quartile of liquid prescribers ($n = 28$) had a median reduction of 12.6% compared with a median increase of 17.1% for the low prescribers ($n = 28$; $P = .026$).

Within the intervention region, retail sales of liquid antibiotic formulations declined 19.6% from the baseline period to the postintervention period (Fig 4). The decline in antibiotic sales was greatest for liquid cephalosporins, for which sales decreased 32% from 103 mg per capita to 70 mg per capita. Sales of liquid amoxicillin and trimethoprim-sulfamethoxazole declined 18% and 20%, respectively. Liquid antibiotic sales were unchanged in the control region during the same time interval. Sales of antibiotics in tablet or capsule formulations declined 7.8% and 1.7%, respectively, in the intervention and control regions from January through June of 1997 to the same period in 1998.

A total of 1142 eligible visits were abstracted from the medical records of 370 children who attended child care, were tested for PNP carriage, and saw any of the 185 primary care clinicians for acute respiratory illness. During the baseline period, an antibiotic was prescribed at 57.6% and 60.1% of initial visits in the intervention and control regions, respectively ($P = .56$). During the postintervention period, an

antibiotic was prescribed at 59.5% of initial visits in the intervention region and 61.5% of initial visits in the control region ($P = .66$). For diagnoses for which antibiotics generally are not indicated, the proportion of visits at which an antibiotic was prescribed declined 5.1% (from 21.4% to 16.3%) in the control region ($P = .39$) and 3.6% (from 23.7% to 20.1%) in the intervention region ($P = .49$). The age-adjusted rate of initial visits for acute respiratory illness declined 18% for children in the control region and 10% for those in the intervention region; the difference across regions was not significant.

The evaluation survey was completed by 137 of 149 primary care prescribers (92%; including resident physicians) in the intervention region who received educational information in person or by telephone. Of these, 102 (74%) stated that they changed their antibiotic prescribing practices as a result of information and materials obtained through the intervention. The diagnosis-specific change in prescribing was greatest for bronchitis/cough illness: 84 respondents (61%) reported a change in clinical practice resulting from the intervention. Ninety-eight respondents (72%) agreed that the community education efforts had improved their patients' understanding of appropriate antibiotic use and antibiotic resistance, and 88 (66%) reported using the CDC pamphlet "Your Child and Antibiotics" to educate patients.

Impact on PNP Carriage in Child Care Facilities

During the baseline period, nasopharyngeal swabs and risk factor data were obtained from 433 (49%) of 885 age-eligible children who attended 65 licensed child care facilities in the intervention region, including Price, Rusk, and Lincoln counties (Fig 2). In the control region, 231 (40%) of 583 age-eligible children participated at 46 facilities. PNP was isolated from 54 children (12.8%) in the intervention region and 57 children (24.7%) in the control region. Fully resistant pneumococci were isolated from 15 children (3.5%) in the intervention region and 5 children (2.2%) in the control region at baseline. There was substantial geographic variability in PNP prevalence within the intervention region. Only 11 (6.0%) of 183 children at facilities in Price, Rusk, or Lincoln county were colonized with PNP, compared with 53 (21.2%) of 250 children in Wausau and Rhinelander. The geographic variation in prevalence could not be attributed to differences in antibiotic use, age, child care facility size, or other known risk factors for PNP.

During the postintervention period, nasopharyngeal swabs and risk factor data were collected from 284 (43%) of 660 eligible children at 42 child care facilities in Wausau/Rhineland and from 188 (37%) of 511 eligible children at 31 facilities in the control region. PNP was isolated from 34 children (12.0%) in Wausau/Rhineland and 35 children (18.6%) in the control region. The prevalence of fully resistant pneumococci was 3.2% in each region during the postintervention period.

After adjusting for the design effect of child care clustering, univariate analysis demonstrated that the following factors were associated with PNP carriage: hours per week in child care, antibiotic treatment

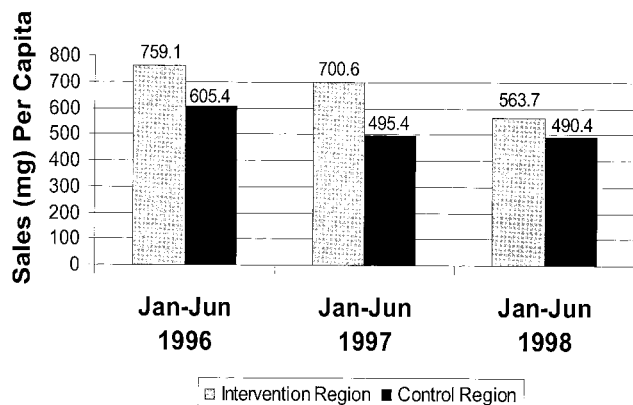


Fig 4. Per capita retail sales of liquid antibiotics in the intervention and control regions, 1996 through 1998 (first half of each year). Population denominators in each region were based on 1990 census data.

TABLE 4. Factors Associated With PNP Carriage in a Multiple Logistic Regression Model That Includes Results From the Baseline Period and the Postintervention Period (1 Observation per Child)

	Design Effect*	Odds Ratio	95% Confidence Interval	Adjusted P Value
Age (mo)	1.74	0.96	0.94–0.98	<.001
Time spent at child care facilities (h/wk)	0.71	1.03	1.02–1.05	<.001
Antibiotic treatment in past 3 mo	0.92	1.73	1.09–2.75	.021
Number of eligible children attending the facility	1.39	1.01	1.01–1.02	<.001
Region				
Intervention, 1998†	1.94	0.46	0.18–1.18	.106
Control, 1998	1.29	0.49	0.22–1.05	.067
Intervention, 1997†	1.94	0.81	0.29–2.21	.671
Control, 1997	Referent	Referent	Referent	Referent

* The design effect is the ratio of the variance of cluster sampling to the variance of simple random sampling. A design effect greater than 1 indicates a positive intracluster correlation within child care facilities. The confidence intervals and P values were adjusted in the logistic regression model to account for the design effect.

† Wausau/Rhinelanders.

during the previous 3 months, recent antibiotic treatment failure, and the number of children younger than 4 years attending the child care facility. In a multivariate logistic regression model, PNP carriage remained significantly associated with each of these variables except for recent antibiotic treatment failure (Table 4). Age was inversely related to PNP carriage. Residence in the intervention region was not significantly associated with reduced odds for PNP carriage. When the multivariate model was restricted to the subset of children colonized with *S pneumoniae* each year, PNP carriage was independently associated with younger age ($P = .009$), antibiotic treatment in the past 3 months ($P = .017$), and number of children younger than 4 years at the child care facility ($P = .001$).

DISCUSSION

This study demonstrated that a multifaceted community-based educational intervention in the United States can reduce antibiotic prescribing for children. We observed a community-wide reduction in prescribing of liquid and solid antibiotics, along with a reduction in retail antibiotic sales. However, we were unable to demonstrate a reduction in inappropriate antibiotic prescribing among children who attended child care. A previous study demonstrated that an educational program for physicians and patients can reduce antibiotic prescribing for bronchitis in adults.²⁶ That study was conducted within a single, large, managed care practice, as opposed to a community setting. Other intervention studies have demonstrated successful strategies for altering physician prescribing behavior, but most have attempted to discourage use of specific drugs (eg, oral cephalosporins) rather than reduce total antibiotic prescribing.^{20,27,28} These and other studies have found that printed materials alone or continuing medical education conferences have minimal impact on physician behavior. Multifaceted activities, including peer education, succeed more often than single-intervention activities.^{18,29,30}

In this study, we included parent and community education because physician focus groups have emphasized that parental expectations for antibiotics are a barrier to more judicious prescribing.³¹ In baseline and postintervention telephone surveys of par-

ents in the intervention and control regions, we found that parental knowledge and awareness regarding indications for antibiotic use and antibiotic resistance improved in the intervention region after the educational program.²⁵ Most physicians agreed that this made it easier for them to withhold antibiotics for viral infections. Efforts to promote judicious antibiotic use are likely to have greater success if public education is included along with physician education. Specific educational interventions also are needed to promote appropriate antibiotic use for children in child care, because our community interventions had no impact on this population. Effective child care interventions may require repeated educational presentations for staff members and frequent reinforcement of key messages to parents.

Reductions in antibiotic use were documented by the 2 data sources that were most representative and complete: IMS Health Xponent (prescribing) and DDD (retail sales) databases. The absence of a reduction in antibiotic use among children in child care suggests that changes in prescribing behavior were distributed unevenly. Parents of children who were in child care may have been more likely to expect or demand antibiotics compared with parents of children who were not attending child care, and there is some evidence that child care providers may encourage this behavior.³² Selection bias also may have contributed to the apparent absence of change among children in child care. Fewer than 50% of eligible children participated in the study, and the participants may have had higher rates of respiratory illness or parents who were more likely to request antibiotics.

This study was conducted in a relatively isolated rural population, and the results may not be generalizable to more urban populations. In addition, the study had limited power to detect changes in PNP carriage because of the design effect of child care clusters. Clinicians in the intervention region had a higher volume of antibiotic prescribing at baseline compared with those in the control region, and this may partially explain the success of the intervention in that setting. This would be consistent with the observation that the greatest percent reduction in antibiotic use occurred among the highest quartile of prescribers. A similar intervention may have less

impact in a group of physicians who have already taken steps to limit unnecessary antibiotic use. The higher volume of antibiotic use in the intervention region also may be related to the greater proportion of family physicians compared with pediatricians.³³ We were unable to compare changes in antibiotic use by specialty because of the limited number of family physicians who provided pediatric care in the control region and the limited number of pediatricians in the intervention region.

Although recent antibiotic use has been associated consistently with PNP carriage or infection, little is known regarding the microbiologic impact of a community-wide reduction in antibiotic use. The spread and maintenance of resistant pneumococcal clones may be affected by factors other than antibiotic use, and the magnitude of reduced antibiotic use that is necessary to reduce the prevalence of resistance is unknown. Two other studies examined the relationship between community-wide antibiotic use and PNP prevalence^{34,35}; one of them found that PNP prevalence could be reduced by a program to promote judicious antibiotic use. In the current study, a 15% to 20% reduction in antibiotic use in the intervention region was not associated with a measurable decline in PNP prevalence after adjusting for confounders. However, there was no reduction in the rate of antibiotic prescribing for children in child care, so selection pressure for antibiotic resistance may have been maintained in the child care facilities despite community-wide reductions in antibiotic use. In addition, the time interval between the intervention and follow-up testing was short, and it may have been insufficient to alter the circulating pneumococcal clones in the community. Finally, several facilities in the intervention region participated during the postintervention period only. This could have reduced the comparability of the 2 child care facility populations over the 2 time periods, although we adjusted for individual risk factors and child care facility size in the analysis.

We identified 3 major risk factors for PNP carriage: younger age, recent antibiotic use, and attending a child care facility with a greater number of children. The first 2 risk factors were described previously.^{12,13,15,36} The finding that child care facility size is an independent predictor of PNP carriage suggests that horizontal transmission of resistant clones is important in group child care settings. Larger facilities may amplify horizontal spread by offering more opportunities for contact between carriers and susceptible children. We also observed geographic variation in PNP prevalence that could not be explained by differences in child care facility size, antibiotic use, or other known risk factors, suggesting that horizontal spread of clones contributes to the focal occurrence of PNP.

The postintervention evaluation survey demonstrated that the educational program was well accepted by clinicians, and there was strong support for the community education efforts. Several states recently initiated programs to promote judicious antibiotic use, and the results of this study should encourage professional societies, public health agen-

cies, and academic centers to work collaboratively to implement multifaceted interventions. Further work is needed to understand the complex relationship between community-wide changes in antibiotic use and carriage or infection with resistant pathogens and to assess the economic impact of antibiotic resistance and inappropriate antibiotic use.

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