Lack of Piped Water and Sewage Services is Associated with Pediatric Lower Respiratory Tract Infection in Alaska

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Objectives To determine the association between the high incidence of lower respiratory tract infection (LRI) documented among young Alaskan children and the absence of modern water service (in-home piped water/septic system or water delivered by closed haul truck) found commonly in rural Alaskan communities.

Study design A community-level analysis was performed of all 108 Alaskan communities with at least 15 children <2 years of age enrolled in Medicaid during 1998-2003. Community LRI incidence rates were determined from a Medicaid database with standard LRI billing codes. Potentially confounding community-level demographic variables were obtained, as was availability of water service.

Results During linear regression analysis, the percentage of households with modern water service in a community predicted community-level outpatient (beta = −0.53; $P < .001$) and inpatient (beta = −0.15; $P = .088$) LRI incidence rates when controlling for the degree of household crowding, unemployment, adult education, tobacco cigarette use, wood stove use, and poverty. Modest improvements in water service delivery were not shown to be associated with changes in LRI burden.

Conclusions Lack of modern water service in Alaska is associated with high pediatric LRI incidence. These communities should receive modern water service, but this intervention alone may not dramatically reduce LRI burden. *(J Pediatr 2008;152:666-70)*

Alaska Native people in Southwest Alaska have among the highest lower respiratory infection incidence rates ever reported, mainly because of bronchiolitis.[1-3] Reasons for this increase in risk are not well described. One possibility is that lack of clean water and wastewater disposal systems contribute to risk by making handwashing more difficult and thus less likely. Many small, rural, primarily Alaska Native communities lack any piped water and wastewater disposal services, and entire regions have service rates that remain below national standards. This evaluation examined the effect of modern water service on pediatric lower respiratory tract infection (LRI) incidence rates by community among Medicaid-enrolled Alaskan children age <2 years.

METHODS

Healthcare in Alaska

During the study period, health care services in Alaska were delivered through a variety of private, public, nonprofit, Native Corporation, and Indian Health Service entities. Alaska Native people constituted the state's largest racial minority and predominant rural residents and usually received services through Native Corporation and Indian Health Service facilities. Care in most small villages was provided at clinics staffed by Community Health Aides, with support provided by physicians based at regional centers. For Medicaid-enrolled persons, all in-state facilities billed Medicaid regardless of where a specific individual obtained care. During 1999-2000, approximately 94% of Alaska Native infants were enrolled in Medicaid at some point during their first 2 years of life versus 46% of non-Native infants.

Data Sources

The Alaska Division of Medical Assistance provided a master file that consisted of data for all persons younger than 2 years of age and enrolled in Medicaid from October

ICD-9	International Classification of Diseases, 9th Revision	LRI	Lower respiratory tract infection

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Supported in part by project H18 MC–00004-11 from the Maternal and Child Health Bureau (Title V, Social Security Act), Health Resources and Services Administration, Department of Health and Human Services.

Submitted for publication Jun 23, 2007; last revision received Oct 3, 2007; accepted Oct 25, 2007.

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0022-3476/$ - see front matter

10.1016/j.jpeds.2007.10.049

1, 1998, through June 30, 2003.[4] The master file was then linked to an outcomes data file containing all provider, inpatient facility, and outpatient clinic approved billing claims for International Classification of Diseases, 9th Revision (ICD-9) codes 466 (acute bronchitis and bronchiolitis), 480-487.1 (pneumonia and influenza with pneumonia), 490 (bronchitis not specified as acute or chronic), and 510-511 (empyema and pleurisy). LRI was defined as an approved billing for any of these codes. Of the total number of LRI inpatient events, 63% (928 of 1475) were due to acute bronchiolitis (ICD-9 code, 466.1) or pneumonia caused by respiratory syncytial virus (ICD-9 code 480.1), as were 50% (5186 of 10,401) of outpatient LRI events. The master Medicaid enrollment file was linked to a birth certificate database to allow evaluation of birth-related risk factors.

To determine community-level outpatient and inpatient LRI incidence rates, all children born from October 1, 1998, through June 30, 2001, were followed up through the Medicaid database from birth through 2 years of age. Incidence rates were then calculated for each community by summing the number of events and dividing by the sum of the number of days of follow-up (not all children were enrolled continuously during a given year). Rates were calculated only for communities that had at least 15 children enrolled in Medicaid during the study period to eliminate instances where small numbers of events dramatically altered community-level values. A file was created with 1 record for each community, and that included outpatient and inpatient LRI incidence rates. This file then was linked to a file of community-level census variables provided by the Alaska Department of Labor.

Based on input from the US Centers for Disease Control and Prevention, Arctic Investigations Program, the current evaluation tested the hypothesis that the presence of modern water services in a community predicts respiratory tract infection risk. For each Alaskan community, the Alaska Department of Environmental Conservation provided data from a survey conducted during 1999, 2001, 2002, 2003, and 2005 on the proportion of households with modern water service. Modern water service included piped water delivery and septic removal from a municipal source, on-site well and septic tank with a drain field, or water delivery and septic tank evacuation by covered haul vehicles. For most communities, this proportion did not change during 1999 to 2005, and thus 2005 data were used. Twenty of the final 108 communities included in analysis experienced increases of at least 10% in the proportion of houses with modern water service during 2001 or 2002. For these communities, LRI incidences rates were calculated for the period up to the year that water service coverage changed.

Analysis

Linear regression models were created that allowed an evaluation of the independent effect of community water service on LRI incidence when controlling for potential confounding variables. Census variables entered into the model included the proportion of residents that were Alaska Native people, the average number of children younger than age 3 years per household, the proportion of residents below the federal poverty line, the proportion of adults age 16 years and older and in the labor force that were employed, the proportion of adults age 25 years and older with less than 12 years of formal education, and the proportion of households using wood fuel for heat. Additionally, the cumulative years of Medicaid enrollment among children in the community were added from the Medicaid database, and the proportion of mothers in the community that used tobacco cigarettes prenatally was entered from the birth certificate database. Because of issues with multicollinearity, regression models did not include the average number of persons per household. Potential confounding variables were removed from the models in a stepwise fashion on the basis of a P value $<.05$. All analyses were performed with SPSS version 13.0 statistical software (SPSS Inc., Chicago, Ill).

RESULTS

Descriptive Analysis

There were 263 Alaskan communities with at least 1 child age <2 years enrolled in Medicaid during the study period, of which 117 had at least 15 children enrolled during the study period. Of these, 108 had information on water service, and these communities formed the basis for all subsequent evaluations.

Among the 108 evaluated communities, the mean outpatient LRI incidence rate was 56 per 100 child-years of follow-up (median, 42; standard deviation, 41; range, 0 to 153), and the mean inpatient LRI incidence rate was 11 per 100 child-years (median, 7.0; standard deviation, 11; range, 0 to 50). The mean percentage of homes that had modern water service was 69% (median, 89%; standard deviation, 38%; range, 0 to 100%).

Communities with a low percentage of houses with modern water service were not distributed randomly in the state. Twenty-one communities had less than 20% of homes connected to modern water service, and 6 had 20% to 39% of homes connected. These 27 communities were located in just 5 of Alaska's 24 census areas, all in the Western and Northern regions. These 27 communities also were more likely to have a higher mean percentage of residents who were Alaska Native people (94% vs 54%; $P < .001$) and living in poverty (26% vs 17%; $P < .001$) and a higher mean percentage of adults with less than a twelfth-grade education (33% vs 19%; $P < 001$). They did not have a higher mean percentage of maternal prenatal tobacco use (29% vs 31%; $P = .72$).

Higher inpatient and outpatient LRI incidence rates also tended to occur in communities with high proportions of Alaska Native people, more poverty, and a less educated population (Table). Inpatient and outpatient LRI incidence rates decreased as modern water service increased (Figure). Of the 27 communities with <40% of homes connected to modern water service, the mean inpatient LRI incidence was

Table. Community characteristics and community level incidence of inpatient and outpatient LRI among Medicaid-enrolled children age <2 years; Alaska, 1998–2003

	Inpatient LRI incidence ≥15 per 100 child-years			Outpatient LRI incidence ≥90 per 100 child-years		
Community characteristic	Yes (n = 32)	No (n = 76)	*P* value	Yes (n = 30)	No (n = 78)	Risk ratio (95% confidence interval)
Mean percent Alaska Native	93%	52%	<.001	93%	53%	<.001
Mean percent living in poverty	25%	16%	<.001	26%	16%	<.001
Mean percent of persons 25 years or older with <12 years of education	34%	18%	<.001	34%	19%	<.001
Mean percent of mothers reporting prenatal tobacco use	19%	35%	<.001	17%	35%	<.001

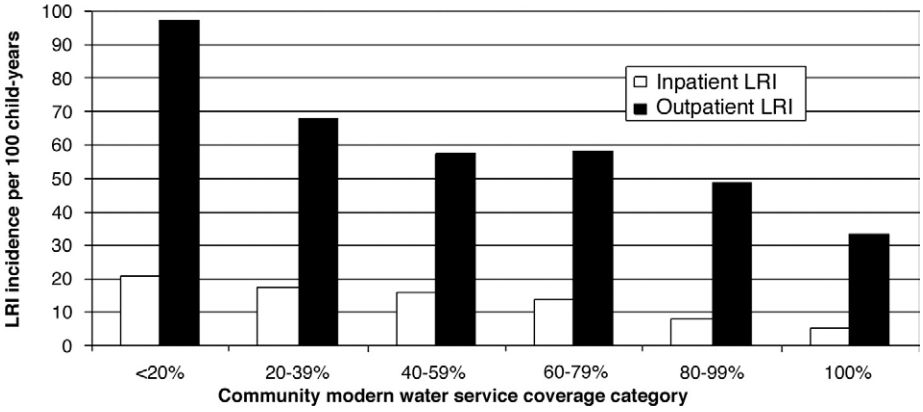

Figure. Incidence of community-level inpatient and outpatient LRI in children younger than 2 years of age by percentage of households in community with modern water service; Alaska, 1998-2003.

20 per 100 child-years compared with 8.5 per 100 child-years for the remaining 81 communities ($P < .001$); the analogous values for mean outpatient LRI incidence were 91 and 45 per 100 child-years, respectively ($P < .001$).

Multivariate Analysis of Risk Factors

During linear regression analysis, predictor variables that remained in the final model for community-level outpatient LRI incidence rate included the proportion of households with modern water service ($\beta = -0.53$; $P < .001$), the proportion of adults with less than 12 years of education ($\beta = 0.46$; $P < .001$), and the proportion of mothers of study subjects who used prenatal tobacco ($\beta = -0.74$; $P < .001$). The final model contained an interaction term created as the product of the water and tobacco use variables ($P = .002$). No interaction was noted between the other independent variables in the model. The r^2 for the final model was 0.60.

Predictor variables that remained in the final model for community-level inpatient LRI incidence rate were identical and included the proportion of households with modern water service ($\beta = -0.15$; $P = .088$), the proportion of adults with less than 12 years of education ($\beta = 0.57$; $P < .001$), and the proportion of mothers of study subjects who used prenatal tobacco ($\beta = -0.36$; $P < .001$). No interaction between variables was noted, and thus no interaction terms were entered. The r^2 for the final model was 0.54.

Changes in Modern Water Service and LRI Incidence

During 1999 versus 2002, the mean outpatient LRI incidence rates across all 108 villages were 46 versus 34 per 100 child-years, and inpatient LRI incidence rates were 15 versus 4 per 100 child-years. Of communities with increases in modern water service of at least 10%, 85% were located in 5 Western and Northern Alaska census areas. For the 54 study communities in these 5 census areas, univariate regression analysis showed that the percentage improvement from 1999 to 2002 in the number of homes with modern water service did not predict changes in outpatient ($\beta = 0.10$; $P = .47$) or inpatient ($\beta = 0.22$; $P = .12$) LRI incidence rates over the same time period.

DISCUSSION

This study found a strong association between modern water services in a community and outpatient LRI incidence rates among children <2 years of age; a weaker association

existed for inpatient LRI incidence. Children living in communities with the lowest levels of modern water service had LRI incidence rates 3- to 4-fold higher than those found in communities with the highest levels of modern water services. Many of the communities had LRI incidence rates substantially higher than the 6.3 and 20.7 per 100 per year reported for U.S. children age younger than 5 years.[5] This high burden of disease is compounded by the frequent long-term chronic respiratory problems experienced by children who have had severe LRI during early childhood.[6,7] Although specific LRI disease syndromes were not evaluated in this study, a recent evaluation of risk factors for avian influenza A (H5N1) infection in Vietnam found an association between infection and lack of an indoor water source.[8] This raises the possibility that lack of modern water services puts Alaskan populations at increased risk of contributing to pandemic influenza spread.

The mechanism by which in-home water could decrease respiratory infection risk remains unknown, but the most likely explanation is that it increases the ease and thus the frequency of handwashing. Two recent reviews found that handwashing decreases the risk of respiratory tract infection; however, both evaluations noted the paucity of rigorous studies.[9,10] A more recent and methodologically sound randomized trial in Pakistan noted a protective effect of handwashing, with households that received plain soap and handwashing promotion reporting a 50% lower incidence of pneumonia compared with control subjects.[11] The stronger association with outpatient than inpatient LRI incidence in this study supports this hypothesis. Lack of handwashing is likely to increase the risk of acquiring an infection and presenting to an outpatient clinic, and factors such as maternal education, health care access, and background level of health may contribute more to determining whether an LRI, once acquired, results in hospitalization.

The State of Alaska's Department of Environmental Conservation, Indian Health Service, U.S. Environmental Protection Agency, and Alaska's Tribal Health Organizations have successfully increased the mean proportion of households in Alaskan communities with modern water service to 69%. Much work remains to be done, however. In 27 of the 108 evaluated communities, less than 40% of households had access to modern water services.

Equally important as the continued low level of modern water service availability in many Alaskan communities is the distribution of these communities. Mirroring what was found for communities with high LRI burden, communities with poor access to modern water service were located mainly in the rural Western and Northern parts of the state, had predominantly Alaska Native residents, and had more impoverished and less educated populations. In addition to modern water services, these same communities have had inadequate investment in schools, transportation infrastructure, and job creation. Not unexpectedly, these communities have high rates of many diseases, both infectious[12-14] and noninfectious.[15,16]

No relationship was identified between modest changes over time in modern water service delivery and LRI incidence, emphasizing the lack of a simple relationship between these factors. Changes in LRI incidence over time may have been effected by temporal changes in the geographic distribution of yearly influenza and respiratory syncytial virus epidemics, changes in risk factors such as day care attendance and breast feeding, and changes in diagnostic and reporting biases, all factors not available for this analysis. In addition to this limitation, differences in reported outpatient LRI rates may reflect interobserver variability in the diagnosis of lower respiratory tract disease, and differences in inpatient LRI rates may reflect differences in access to hospital care.

Finally, this analysis could not control for all potential confounding variables or even all available variables because of issues of multicollinearity. Consequently, the identified association between LRI incidence and modern water service availability may not be causal. The strong and consistent association between inpatient or outpatient LRI incidence and adult education levels and maternal prenatal tobacco use underline the multifactorial nature of LRI risk. Although seemingly paradoxical, the inverse association between prenatal tobacco use and LRI risk likely reflects the practice among tobacco-using Western and Northern Alaska Native women of switching from tobacco cigarettes to chewing tobacco during pregnancy.[17] Maternal use of chewing tobacco may cause high infant tobacco exposure either inadvertently through the practice of pre-chewing food or directly by giving tobacco to the infant as a pacifier,[17] with subsequent increased LRI risk, particularly with bacterial organisms.[18]

All citizens in the United States have a basic right to clean water and sewage, but this has not yet occurred. This study found that a lack of modern water service in Alaska predicted increased LRI risk among young children. A similar association might exist for other small, rural U.S. communities as well as other communities worldwide. Even though modern water service availability may decrease LRI burden, available data did not allow estimation of the expected long-term degree of improvement.

The author acknowledges Phillip Mitchell of the Alaska Bureau of Vital Statistics and Ingrid Zaruba of the Alaska Department of Labor for provision of data.

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