Healthcare for Obstructive Lung Disease in an Industrial Spirometry Surveillance Program

Mridu Gulati, MD, MPH
Martin D. Slade, MPH
Martha G. Fiellin, MPH
Mark R. Cullen, MD

Objective: *The efficacy of workplace spirometry surveillance programs is unclear. We examine whether aluminum industry workers with airflow obstruction (AO) received health care for obstructive lung disease.* ***Methods:*** *We performed a cross sectional analysis over 7 years of 6821 aluminum production workers. The primary outcome was the association between obstructive lung disease insurance claims and the presence of AO. We also examined whether the presence of claims was associated with increasing AO severity.* ***Results:*** *Although workers with AO more frequently had claims, 60% of workers with AO, most frequently those with mild and borderline obstruction, had no claim.* ***Conclusions:*** *Workers with AO, particularly borderline and mild obstruction, frequently do not receive health care despite respiratory surveillance. Further investigation is needed to determine if workers with undiagnosed AO are symptomatic or have accelerated losses in lung function over time.* (J Occup Environ Med. *2009;51:336–342*)

Occupational exposures account for 20% of obstructive lung disease (OLD)—including asthma and chronic obstructive pulmonary disease (COPD).[1,2] Although many workplaces have spirometry surveillance programs to detect early disease, their efficacy is unclear. Indeed, while several regulatory agencies recommend respiratory surveillance for workers exposed to different respiratory toxicants, such as asbestos, silica, cadmium, and coke oven emissions, these guidelines do not dictate mandatory intervention.[3–14] Spirometric airflow obstruction (AO) often goes undiagnosed. In the general population, data from the Third National Health and Nutrition Examination Survey demonstrate that over 10% of the US population has undiagnosed AO. The presence and magnitude of undiagnosed AO in the occupational setting is unclear.

Early disease identification may precipitate important interventions. For example, asymptomatic smokers with mild to moderate AO in the Lung Health Study randomized to an aggressive smoking cessation campaign experienced decreased pulmonary function decline and mortality.[15,16] Similarly, identifying relatively asymptomatic workers with AO may instigate workplace modifications, such as enhanced engineering controls and substitution of less toxic chemicals. Disease detection may lead to increased worker compliance with respiratory protection or removal of workers from toxic environments.[17–19]

We study the presence of health care for OLD among US workers

From the Yale Occupational and Environmental Medicine Program, Yale University School of Medicine, New Haven, Conn.

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Address correspondence to: Mridu Gulati, MD, MPH, 135 College Street Rm 366, New Haven, CT 06510; E-mail: mridu.gulati@yale.edu.

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employed in an aluminum production company and assess whether those with AO have received care. Workers in the primary aluminum industry may have increased risk for OLD due to exposure to respiratory toxicants such as particulate matter, coal tar pitch volatiles, sulfur dioxide, and particulate fluoride.[20–28] A recent publication from this cohort demonstrated an increased asthma incidence associated with fluoride exposure.[29]

In this cross sectional analysis, we use spirometric surveillance and insurance claims databases to examine whether workers in these aluminum production facilities with AO have received health care for OLD. We also examine whether workers with more severe AO are more likely to receive care.

Methods

Setting

This cross sectional analysis covering the 7 year period 1996 to 2002 examines whether workers at an aluminum production company with spirometric evidence of AO during surveillance, obtain health care for OLD. Workers from 14 facilities in five states including Arkansas, Indiana, New York, North Carolina, and Pennsylvania were studied. Datasets include spirometry surveillance records, insurance claims data, and human resource data.

Databases

Spirometry Database. Spirometry surveillance must be performed at least once every 3 years for employees exposed to respiratory toxicants. Spirometry is performed with OMI Sensormedic 1022 spirometers (dry rolling seal spirometers) according to American Thoracic Society standards.

Insurance Claims Database. Information regarding the diagnoses of asthma and COPD, including pharmacy and medical information, is available. Data include ICD-9 CM codes (International Classification of Diseases, Ninth Revision-Clinical Modification)[30] for disease diagnosis and National Drug Codes for prescription information.[31] Information includes service dates, provider type and service locations while spirometry is performed on-site, community physicians provide health care and drugs are obtained at local pharmacies.

Human Resources Database. A human resources database provides basic demographic information including date of birth, race and ethnicity, sex, and dates of hire.

On-Site Clinic Database. The Onsite Occupational Health Clinics maintain medical surveillance records including smoking status information but do not provide health care. A separate variable for unknown smoking status was created.

Study Population

The study population consisted of all workers enrolled in a company insurance plan who had spirometry surveillance performed at least once within the 2 year period 1996 and 1997. Seven thousand thirty workers had at least one spirometry (total 8572 spirometries). Seventy nine workers were excluded due to missing demographic or human resources information, such as missing information on date of hire, work location or date of birth. One hundred twenty-two workers had incomplete spirometric data. Eight workers were minors. The remaining 6821 workers had 8301 (5410*1; 1345*2; 63*3; 3:4) spirometries during the 2 years and had sought health care in some form during the time period between 1996 and 2002.

Definition of Obstruction and Severity of Obstruction

Per company policy, the definition of AO was based on modified 1991 American Thoracic Society criteria and Knudson reference equations. Obstruction was defined as a ratio of forced expiratory volume in one second (FEV_1) divided by forced vital capacity of less than the lower limit of normal (LLN). Severity of obstruction was defined using FEV_1: 1) Borderline: FEV_1 percent predicted greater than or equal to the FEV_1 LLN; 2) Mild: FEV_1 percent predicted between 60% and the LLN; 3) Moderate: FEV_1 percent predicted between 41% and 59%; 4) Severe: FEV_1 percent predicted of less than or equal to 40%.[32]

The company's internal policy requires that workers with an FEV_1/forced vital capacity and an FEV_1 less than LLN be assessed individually. For workers with more than one spirometry between 1996 and 1997, at least two spirometries with obstructive physiology were required to be classified as obstructed.

Definition of Claims Diagnosis of OLD

COPD and asthma are frequently conflated and overlap; therefore, we assessed for the presence of health care for all OLD, including asthma and COPD. Any single OLD insurance claim, including a pharmacy claim OR medical claim between the period January 1, 1996 and December 31, 2002, was sufficient to document the presence of care. This included;

1. Any medical claim with an ICD-9 code for OLD, including: 493 (asthma); 491 (chronic bronchitis); 492 (emphysema) and 496 (chronic AO).
2. Any pharmacy claim with an National Drug Codes code for a drug prescribed for OLD. This included: inhaled corticosteroids, inhaled cromolyn sulfate, oral leukotrienes, long acting beta agonists, methylxanthines and short acting medications including short acting beta agonists and anticholinergics. Separate sensitivity analyses was run excluding the presence of pharmacy claims for short acting medications such as short acting beta agonists and anticholinergics alone to demon-

strate presence of health care for OLD.

Statistical Analysis

The primary outcome of this study was the association of AO with the presence of health care for OLD. Any insurance claim, either a pharmacy or medical claim, for OLD between 1996 and 2002 was deemed sufficient to document the presence of health care. Secondarily, the association between increasing AO severity (with severity coded as no AO: 0) borderline, 1) mild, 2) moderate, 3) and severe, and 4) the presence of an OLD diagnosis) was examined.

Initially, variables were examined using descriptive frequencies. Workers with and without obstruction were compared. Bivariate associations were evaluated using Fisher exact tests for categorical variables and Student's *t*-tests for continuous variables. Variables examined included age, sex, ethnicity, smoking status, plant location, employment type (hourly vs salary) and employment duration.

Analyses were performed to determine if AO and increasing severity of AO were associated with an earlier insurance claim, either a pharmacy or medical claim, for OLD. First, a test of the assumptions for proportional hazards, including visual inspection of the log-log survival versus log (time) curve was studied. A Kaplan-Meier survival curve, the first one for workers with obstruction versus workers without obstruction, was conducted. Another Kaplan-Meier survival curve was conducted for workers in the various categories of obstruction. After verifying the proportional hazards assumption, bivariate and multivariate Cox proportional-hazards regression models were performed to examine whether AO was associated with health care as demonstrated by insurance claims for OLD. Similar analyses were done determining the association between increasing severity of obstruction and an earlier diagnosis. Two separate sets of analyses were repeated determining the association between increasing severity of obstruction and an earlier diagnosis for two other outcomes; 1) the presence of a medical claim, and 2) the presence of a pharmacy claim. Statistical analyses were performed with SAS version 9.1. The study was approved by the Yale Human Investigations Committee.

Results

A total of 11.7% (797 of 6821) of workers had AO. A total of 11.7% had AO; 6.7% (454), 3.4% (229) 1.3% (89), and 0.4% (25 workers) had borderline, mild, moderate, and severe AO, respectively.

Demographics

Table 1 shows demographics for workers with and without obstruction. The workers with AO had a higher mean age (49.3 years vs 46.5 years, $P < 0.0001$) and employment duration (21.3 years vs 18.8 years, $P < 0.0001$). More hourly workers (74.5% vs 69.4%, $P < 0.0001$) and male workers (94.1% vs 91.2%, $P = 0.005$) were found in the group of workers with AO. Compared to workers without AO, there were more current smokers in the group with AO (15.7% vs 10.1%, $P < 0.0001$).

Description of Medical and Pharmacy Claims

Workers with AO were more likely to have any OLD claim ($P < 0.0001$), either a pharmacy or medical claim; 40.7% (324 of 797 workers with AO) versus 18.6% (1122 of 6024 workers without AO).

With respect to medical and pharmacy claims specifically; workers with AO were more likely to have a medical claim: 236 of the 797 workers with AO (29.6%) versus 535 of 6024 workers without AO (8.9%) had a medical claim ($P < 0.0001$) 3013 claims for OLD were present in the data set for 771 (236 with AO + 535 without AO) of 6821 workers. A total of 61.1% of claims were for asthma (ICD-9 1 493) whereas 26.2% of claims were for chronic AO (ICD-9 496). Fourteen percent-

TABLE 1
Demographics of Workers With and Without Evidence of Spirometric Obstruction

	All (n = 6821)	Not Obstructed (n = 6024)	Obstructed (n = 797)	P
Age (SD)	46.8 (9.1)	46.5 (9.1)	49.3 (8.4)	<0.0001
Gender				0.005
Female	580 (8.5%)	533 (8.9%)	47 (5.9%)	
Male	6241 (91.5%)	5491 (91.2%)	750 (94.1%)	
Ethnicity				0.20*
African-American	611 (9.0%)	530 (8.8%)	81 (10.2%)	
American Indian	40 (0.6%)	38 (0.6%)	2 (0.3%)	
Asian/Pacific Islander	21 (0.3%)	21 (0.4%)	0 (0.0%)	
Caucasian	5844 (85.7%)	5143 (85.4%)	701 (88.0%)	
Hispanic	305 (4.5%)	292 (4.9%)	13 (1.6%)	
Smoking status				<0.0001†
Current	733 (10.8%)	608 (10.1%)	125 (15.7%)	
Ever	953 (14.0%)	857 (14.2%)	96 (12.1%)	
Never	1212 (17.8%)	1139 (18.9%)	73 (9.2%)	
Unknown	3923 (57.5%)	3420 (56.8%)	503 (63.1%)	
Employment type				<0.0001
Hourly	4773 (70.0%)	4179 (69.4%)	594 (74.5%)	
Salary	2048 (30.0%)	1845 (30.6%)	203 (25.5%)	
Years of employment (SD)	19.1 (9.7)	18.8 (9.8)	21.3 (8.7)	<0.0001

*χ^2 for Caucasian and non-Caucasian.
†χ^2 comparing workers with different smoking status and excluding workers with unknown smoking status.

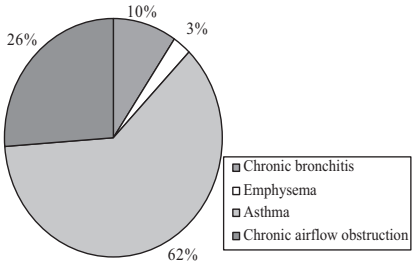

Fig. 1. Percentage of claims by diagnostic category. ICD-9 491 (chronic bronchitis): 9.5%. ICD-9 492 (emphysema): 2.7%. ICD-9 493 (asthma): 61.6%. ICD-9 496 (chronic airflow obstruction): 26.2%.

age 14.0% of workers had an asthma and a non-asthma claim. Figure 1 shows distribution of medical claims diagnoses.

A total of 33.1% (264 of 797) workers with AO versus 15.0% (906 of 5118) of workers without AO had a pharmacy claim. One thousand one hundred seventy had 9089 pharmacy claims for any OLD medication, including short acting medications. The most frequent medications were short acting beta agonists (41.9%) and inhaled corticosteroids without a long acting beta agonist (21.0%). Figure 2 shows the distribution of pharmacy claims.

Number of Workers With Any Claim for OLD by Severity of Disease

Figure 3 shows the percentage of workers with obstruction who had any OLD claim (pharmacy or medical). Workers with AO were more likely to have an OLD claim ($P < 0.0001$), 40.7% (324 of 797 workers) versus 18.6% (1122 of 6024 workers); however, 59.3% of the 797 workers with AO did not have any claim.

Workers with more severe obstruction were more likely to have any claim, that is a medical claim or a pharmacy claim for any medication including short acting medications ($P < 0.0001$): No obstruction 18.6% (1122/6024); borderline 30.0% (136/454); mild 42.8% (98/229); moderate 75.3% (67/89); and severe 84.0% (21/25).

Bivariate and Multivariate Proportional Hazards Model

Table 2 shows the bivariate and multivariate analyses for the indicators for the presence of an insurance claim, either a medical or a pharmacy claim, for OLD. This table also demonstrates similar analyses for the presence of two other outcomes: 1) a medical claim, and 2) a pharmacy claim. In all multivariate and bivariate analyses—including those for medical claims alone, pharmacy claims alone and any claim (either a pharmacy or medical claim), increasing severity of AO was associated with an increased hazards ratio for having a claim. In the multivariate model assessing for the presence of any claim (pharmacy or medical), the hazards ratios were as follows: borderline 1.79; mild 2.63; moderate 7.47; and severe 14.92. Sex (female vs male) was associated with increased hazards ratio for having a claim in all three sets of multivariate models—the medical claim model, the pharmacy claim model and the model assessing for either a pharmacy or medical claim. Unknown smoking status was associated with a decreased likelihood of having a claim in all three sets of multivariate models—the medical claim model, the pharmacy claim model and either pharmacy or medical claim model. Increasing age was associated with an increased likelihood of having a claim in the medical claim multivariate model.

Another set of sensitivity analyses were run excluding workers whose smoking status was unknown. In this model current and ever smoking was not associated with the presence of any claim. Increasing severity of AO continued to be significantly associated with an increased hazards ratio for having any insurance claim.

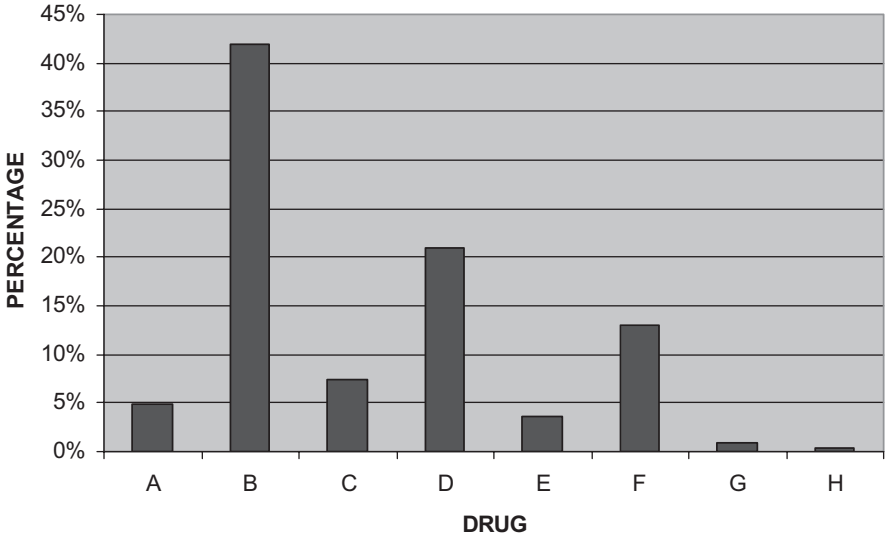

Fig. 2. Percentage of Drug Claims by Class A: Anticholinergics (short-acting)(0.4%), B: beta agonists (short acting)(41.9%), C: Anticholinergics/beta agonists (7.4%), D: Inhaled corticosteroids (21.0%), E: Inhaled corticosteroid/long acting beta-agonists (3.6%), F: Leukotriene antagonists (13.1%), G: Mast-cell stabilizers (1.0%), H: Methylxanthines (0.4%).

Discussion

This study demonstrates that in the setting of a respiratory surveillance program in an industry with known respiratory toxicant exposure, workers with AO were more likely to receive health care for OLD than those without AO. Workers with more severe AO were more likely to have received health care for OLD. However, approximately 60% percent of workers with AO did not receive any health care for OLD. The majority of these workers with undiagnosed AO had less severe forms of

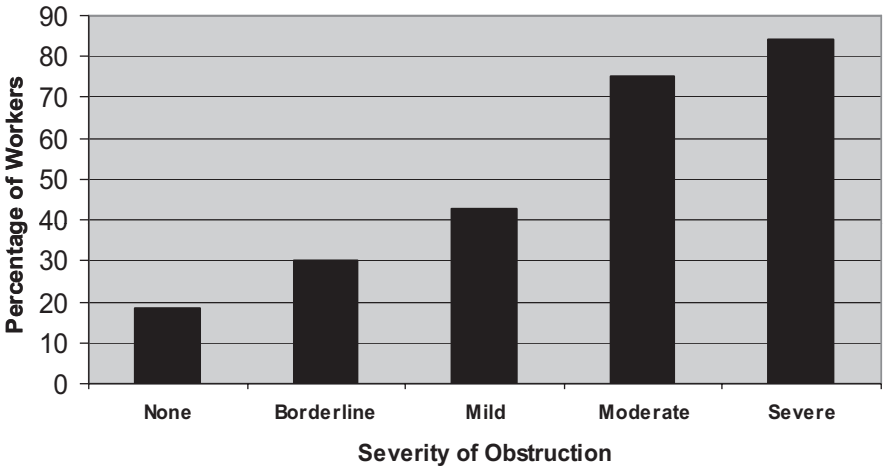

Fig. 3. Percentage of workers with any claim versus AO. No obstruction: 18.6% (1122/6024); Borderline: 30.0% (136/454); Mild: 42.8% (98/229); Moderate: 75.3% (67/89); Severe: 84.0% (21/25).

obstruction. For example, approximately 60% of workers with mild AO did not receive health care whereas only 16% of workers with severe AO did not receive health care.

What are the consequences of the undiagnosed AO, particularly in the setting of mild or borderline AO? Aluminum production workers, particularly potroom workers, may be exposed to many toxicants and may have a higher prevalence of respiratory symptoms and OLD have been reported in aluminum workers.[21,22,26,33] Furthermore, as demonstrated by the general population study National Health and Nutrition Examination Survey, undiagnosed AO is common, prevalent in approximately 10% of the population, and individuals with undiagnosed mild AO also have an increased prevalence of respiratory symptoms.[1,3] Hence, workers with undiagnosed AO in this study may also have increased respiratory symptoms and the presence of disease was not appreciated. Further investigation into the prevalence of symptoms in these undiagnosed workers is needed.

Even if workers with undiagnosed AO are asymptomatic, these workers may also continue to experience a decline in lung function over time and would benefit from changing the work environment to minimize exposure. Numerous exposures have been identified as possible toxicants including fluoride, total and respirable dust, sulfur dioxide, and coal tar pitch volatiles. In studies of aluminum workers, improvements in bronchial responsiveness and respiratory symptoms have been reported after cessation from exposures.[22,33] Even asymptomatic individuals may greatly benefit from intervention. For example, in the general population in the Lung Health Study, even relatively asymptomatic individuals with mild AO had a decrease in pulmonary function decline and mortality after an aggressive smoking cessation campaign.[15,16] Further investigation is needed to determine if workers with milder undiagnosed AO have accelerated declines in lung function.

The detection of higher prevalence of AO from surveillance programs can lead to important environmental and engineering controls to prevent disease. Other workplaces have reduced the prevalence of OLD including the detergent[34,35] and health care industry (powdered rubber latex gloves).[36,37] A surveillance program for Canadian workers exposed to diisocyanates has led to health improvement.[38]

Several issues must be considered in interpreting these results. Although as stated above, increased respiratory symptoms and accelerated rates of lung function decline have been reported in the literature for aluminum workers, it is not clear that the workers with undiagnosed AO, particularly the milder forms, in this study have an increased prevalence of respiratory symptoms. Community physicians did not have access to workers' worksite spirometries. Work sites may not have referred asymptomatic workers with mild AO for further care. Further investigation into these issues is needed.

A significant number of workers without AO had evidence of health care for OLD. Since asthma is reversible AO, it is certainly possible that workers without AO have disease. However, our focus in this study was whether workers with documented abnormalities, AO, were receiving health care.

Another question raised by this study is whether or not claims data sufficiently captures health care utilization. From previous investigation, it is known that over 98% of workers use this company's insurance annually, and their health care should be captured by claims data. Limited studies have suggested a specificity of 87% to 99% for OLD. In a pilot study (unpublished data) comparing claims to on-site clinic charts at one of the company's production facilities, a sensitivity of 70% and specificity of 90% were found. Workers seeking care for OLD should have either an OLD medical or pharmacy claims.

Less stringent diagnostic claims criteria were used in this study. For example, short acting medications such as beta agonists and anticholinergics, often used in the treating of acute respiratory illnesses, were deemed sufficient to demonstrate the presence of a pharmacy claim for OLD. Indeed, only 552 workers had pharmacy claims for controller medications whereas 1170 workers had pharmacy claims for controller and short acting medications. Short acting medications were included in our analyses because studies have dem-

TABLE 2
Bivariate and Multivariate Proportional Hazards Model for Prediction of Claims

	Medical Claim			Pharmacy Claims			Any Claim		
	Bi-Variate	P	Multi-Variate	P	Bi-Variate	P	Multi-Variate	P	Bi-Variate	P	Multi-Variate	P
Age	1.02	<0.0001	1.02	0.0028	1	0.72	1	0.6	1.006	0.039	1	0.29
Sex (F vs M)	1.39	0.0042	1.87	<0.0001	1.4	0.0004	1.46	0.0001	1.34	0.0008	1.48	<0.0001
Ethnicity (non-white vs white)	0.95	0.67	0.78	0.08	1.03	0.79	0.94	0.56	1	1	0.9	0.26
Years of employment	1.01	0.07	1.01	0.18	1	0.98	1.01	0.24	1	0.4524	1.01	0.13
Employment type (hourly vs salary)	1.68	<0.0001	1.61	<0.0001	1.29	0.0002	1.19	0.02	1.35	<0.0001	1.25	0.0008
Smoke (vs never)												
Current	1.5	0.0006	1.08	0.57	1.1	0.34	0.9	0.31	1.24	0.0202	0.99	0.91
Ever	1.03	0.83	0.88	0.34	0.87	0.18	0.84	0.09	0.9	0.2713	0.85	0.08
Unknown	0.96	0.69	0.78	0.03	0.79	0.0024	0.72	0.0003	0.85	0.0216	0.77	0.001
Severity (vs no AO)												
Borderline	2.3	<0.0001	2.33	<0.0001	1.62	<0.0001	1.72	<0.0001	1.73	<0.0001	1.79	<0.0001
Mild	4.21	<0.0001	4.1	<0.0001	2.61	<0.0001	2.7	<0.0001	2.61	<0.0001	2.63	<0.0001
Moderate	10.25	<0.0001	9.71	<0.0001	6.29	<0.0001	6.44	<0.0001	7.66	<0.0001	7.47	<0.0001
Severe	21.47	<0.0001	18.18	<0.0001	14.13	<0.0001	13.72	<0.0001	16.57	<0.0001	14.9	<0.0001

onstrated that individuals with asthma are often inappropriately treated. Reasons include noncompliance as well as the fact that health care providers do not always prescribe controller medications, particularly inhaled corticosteroids, appropriately.[39,40] Although further investigation is needed to understand in what settings these short acting medications were prescribed, multivariate analyses excluding short acting medications still demonstrated that severity of AO was associated with increasing likelihood of a claim for OLD.

Our diagnostic claims criteria were also lenient because we required the presence of only one claim over the 7 years to demonstrate the presence of care. This study's purpose was not to demonstrate the adequacy of care, but its presence or absence. Further investigation is needed with respect to the adequacy of care.

In conclusion, workers with AO, particularly borderline and mild obstruction, often do not receive health care for OLD. Further investigation examining the long term consequences of these abnormalities, including whether these individuals have increased respiratory symptoms or accelerated lung function declines, is needed.

Acknowledgments

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