Final Performance Report

Beryllium Disease Natural History and Exposure-Response

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Chronic Beryllium Disease Among Beryllium-Exposed Workers

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LIST OF ABBREVIATIONS

BeS - Beryllium Sensitization
CBD - Chronic Beryllium Disease
BeLPT - Beryllium Lymphocyte Proliferation Test
BAL - Bronchoalveolar lavage

SIGNIFICANT FINDINGS TO DATE

BeS progresses to CBD at a rate of 7- 11% per year. Beryllium-sensitized patients merit medical counseling and surveillance for signs of progression to disease.

Medical surveillance identifies individuals with CBD of whom 22% progress to treatment with steroids. Parameters that seem to best predict progression specific to CBD are changes in forced vital capacity (FVC) over time and changes in A-a gradient with exercise.

More than 50% of the beryllium machining particles in the breathing zone were less than 10 μm in aerodynamic diameter. This small particle size may result in beryllium deposition into the deepest portion of the lung and may explain elevated rates of sensitization among beryllium machinists. A high percentage of the particles generated during machining are less than 0.6μm in aerodynamic diameter and from 8% to 10% of the aerosol generated may be deposited in the deep portions of the lung.

Measurable beryllium contamination on workers hands and inside their vehicles indicates that take-home beryllium exposure is still a significant risk.

Worker risk notification programs can positively affect workers self-protective attitudes and behaviors.

USEFULNESS OF FINDINGS

This is the first natural history study to determine the progression from beryllium sensitization to disease, as well as the progression from subclinical to clinical beryllium disease. In understanding how beryllium sensitization and disease progresses we will be better able to advise patients on their prognosis and advise industry on the impact that this disease has on their employees. In addition, understanding the natural history allows us to explore medical treatments for this disease. Characterizing exposures based on particle size distribution, particle number, and surface area allow us to study the factors influencing the deposition and retention of beryllium particles in the respiratory tract and the subsequent biological response in individuals. Understanding the tracking of beryllium outside the plant clarifies the need to monitor take-home exposures. In turn, this information will allow us to more fully understand exposures in the workplace and how we can control these exposures in an effort to reduce the occurrence of this occupational lung disease.

SPECIFIC AIMS

The granulomatous lung disorder chronic beryllium disease (CBD) occurs in beryllium workers who develop a cell-mediated immune response to beryllium. Cases continue to occur in the modern beryllium industry, despite efforts to reduce exposure. Workplace screening for beryllium sensitization using the blood beryllium lymphocyte proliferation test (blood BeLPT) identifies workers with (a) clinically significant, symptomatic CBD that has been misdiagnosed or gone undetected, (b) asymptomatic subclinical granulomatous lung disease, and (c) asymptomatic beryllium sensitization with no lung disease at the time of clinical evaluation (BeS). Some individuals with BeS progress to CBD and some with subclinical CBD develop clinical disease, although the frequency with which this occurs is not known. Several surveillance studies using the blood BeLPT to screen beryllium-exposed workforces found process-related risks of BeS and disease as well as genetic risk factors. While the blood BeLPT has proven to be a sensitive biological marker of effect and disease, decisions regarding its broad use in worker screening hinge ultimately on answers to the following questions: Does early detection of sensitization or of subclinical disease change the clinical outcome for affected individuals (secondary or tertiary prevention)? Are there specific exposure-related risk factors that, if remedied, could improve primary prevention of BeS and CBD? To answer these questions, first it was important to establish: (1) the natural history of BeS and of subclinical CBD, and (2) the characteristics of beryllium exposure that confer risk. Thus, we proposed these specific aims:

1) **To determine the natural history of beryllium sensitization (BeS).** To do this, we tested the following hypothesis:

Most beryllium-sensitized workers will develop granulomatous lung disease within a four-year follow-up period.

2) **To determine the natural history of subclinical CBD.** To do this, we tested the following hypothesis:

Many subclinical CBD cases will develop abnormal physiology, abnormal radiology indices, or require medical treatment.

3) **To assess exposure-response relationships for beryllium sensitization and disease.** To do this we tested the following hypothesis:

Although sharing similar mass concentrations of beryllium, machining exposures differ from exposures in lower-risk processes in: (i) particle size distribution within the respirable range, (ii) particle numbers within the respirable range, (iii) particle surface area,

COOPERATIVE PROJECTS WITH NIOSH

1) Beryllium Contamination Inside Vehicles of Machine Shop Workers – in collaboration with Wayne Sanderson and Paul Henneberger

2) Impact of a Worker Notification Program: Assessment of Attitudinal and Behavioral Outcomes – in collaboration with Dorothy Tan-Wilhelm, Kim Witte, Wayne Sanderson and Paul Henneberger

PROGRESS TOWARD ACHIEVEMENT OF SPECIFIC AIMS

1) **Natural history of beryllium sensitization**: All data collection is complete. Preliminary analyses are complete. Analysis of clinical data is in progress. Manuscript is being prepared for submission.

2) **Natural History of subclinical CBD**: All data collection is complete. Data analysis is in progress. Completion of analysis and manuscript submission anticipated in Spring/Summer of 2002.

3) **Dose-response relationship for beryllium sensitization and disease.** Project completed with two manuscripts published and one in preparation.

Cooperative Projects. Projects completed with two publications

MANUSCRIPTS

Published:

1. Martyny JM, Hoover MD, Mroz MM, Ellis K, Maier LA, Sheff KA, and Newman LS. Aerosols generated during beryllium machining. J Occup Environ Med. 1999
2. Kelleher PC, Martyny JW, Mroz MM, Maier LA, Ruttenber JA, Young DA, Newman LS. Beryllium particulate exposure and disease relations in a beryllium machining plant. J Occ Environ Med 2001; 43:238-49.
3. Sanderson WT, Henneberger PK, Martyny J, Ellis K, Mroz MM, Newman LS. Beryllium contamination inside vehicles of machine shop workers. Appl Occ and Environ Hyg 1999;14:223-230.
4. Tan-Wilhelm D, Witte K, Liu W, Newman L, Janssen A, Ellison C, Yancey A, Sanderson W, Henneberger P. Impact of a Worker Notification Program: Assessment of Attitudinal and Behavioral Outcomes. Am J Ind Med 2000;37:205-213.

In Preparation:

1. Newman LS, Mroz MM, Maier LA,. Progression from Beryllium Sensitization to Chronic Beryllium Disease.
2. Newman LS, Mroz MM, Maier LA, Zhang L, Murphy J. Natural History of Chronic Beryllium Disease Identified Through Workfare Surveillance.
3. Ellis K, Buchan R, Hoover M, Martyny J, Bucher Bartelson B, Mroz M, Newman L. A comparison of the particle size distributions for aerosols generated during wet grinding and dry deburring of beryllium.
4. Rita A. Lundgren, Diane L. Fairclough, Lisa A. Maier, Richard H. Jones, David A. Young, and Lee S. Newman. Addressing Mistimed and Missing Pulmonary Physiologic Data in an Observational Longitudinal Study. In preparation for submission.

STUDY RESULTS

1) To determine the natural history of beryllium sensitization (BeS).

METHODS

To achieve the general goal of this descriptive portion of the study it was important that we: (a) maximized the number of study participants who met our case definition of BeS and (b) conducted methodical clinical follow-up of these individuals at regular intervals for as long as possible or until they are shown to have developed CBD. We proposed to perform clinical assessments of BeS cases every two years during the five-year study period.

Cases for this study would include all patients with BeS presently followed at National Jewish who had not yet developed CBD, plus as many other BeS subjects as could be included within the years of this cooperative agreement.

Case definitions. In brief, BeS cases must have at least two abnormal blood BeLPTs on two separate occasions and must have no clinical, radiographic, physiologic, or histologic evidence of CBD. CBD will be defined as two or more abnormal blood BeLPTs or an abnormal BAL BeLPT and histologic evidence of CBD on biopsy. In circumstances in which BeS subjects are unable or unwilling to undergo repeat invasive testing, we would accept as "probable CBD" cases who show evidence of new abnormalities consistent with CBD on either chest x-ray or HRCT scan Subclinical CBD versus clinical CBD distinctions are discussed below.

Frequency of follow-up assessments. We assessed the clinical status of these subjects at two-year intervals. If patients with BeS became symptomatic at any time during the study, they underwent clinical assessment prior to their two-year appointments, as a matter of clinical necessity.

Outcome measures. The principal outcome in this portion of the study was demonstration of progression to CBD. This outcome was measured in several ways, each of which has advantages and disadvantages. The "gold standard" outcome measure would be the demonstration of non-caseating granulomas and/or mononuclear cell interstitial infiltrates on lung biopsy. A second approach that has lower risk for the participant would be to rely on the BAL cell count, lymphocyte percentage, and BAL BeLPT without biopsy. In our experience, the presence of increased numbers of lymphocytes correlates highly with the presence of CBD pathology on biopsy . Furthermore, workers with BeS (by definition) have negative BAL and negative BAL BeLPT. Thus, demonstration of a positive BAL BeLPT with BAL lymphocytosis compared to baseline BAL in these BeS patients could be used as outcome criteria in this study, although less definitive than biopsy. A third less invasive approach would be to repeat the BeS subjects' chest X-ray and HRCT scan and determine if there are new abnormalities consistent with CBD . This had the obvious disadvantages of being less specific and less sensitive.

RESULTS

Sixty-seven individuals met our case criteria as having BeS without evidence of CBD at the time of initial evaluation. The 67 individuals were offered a clinical reassessment at two-year

follow-up intervals to include bronchoalveolar lavage and transbronchial lung biopsy at the time of this clinical reassessment. Ten of the 67 (14.92%) declined lung biopsy but participate in medical follow-up. Six (8.9%) were lost to follow-up, another six were unable to participate in follow-up do to other medical problems and one individual is deceased. Thus, 44 of 67 (65.7%) have been fully reevaluated including repeat bronchoalveolar lavage and transbronchial lung biopsy, with an average follow-up time from the time of initial evaluation of 3.1 Y (0.5 – 9.5Y). Follow-up evaluation duplicated the testing performed at the time of initial clinical assessment as discussed above.

Of the 44 individuals who underwent complete reevaluation, 15 (34%) developed CBD. Of the 15, 13developed granulomas and /or mononuclear cell infiltrates on repeat transbronchial lung biopsy. Two individuals were diagnosed as having CBD based on other clinical findings. One developed of lymphocytosis in bronchoalveolar lavage fluid (56% lymphocytes) and an abnormal BAL BeLPT in light of a transbronchial biopsy complicated by significant heme production and is unable to undergo further transbronchial biopsy. This patient has gone on to develop significant symptoms and decrements in other measures of physiology. Another patient was diagnosed with CBD based on an abnormal and two individuals were diagnosed as having CBD based on the development of an abnormal BAL BeLPT, and increased percentage of lymphocytes in lavage fluid.

The follow-up period from initial detection of BeS to CBD development was 3.1 years (range: 1.0-9.5Y), resulting in a conversion rate from BeS to CBD of 11% per year (Figure 1). Twenty-nine of 44 individuals (66%) remain beryllium-sensitized without evidence of progression to CBD after a follow-up time of 3.1 years (range: 0.5-7.3Y). Using an assumption that none of the 23 unevaluated patients will develop granulomatous lung disease, the estimated conversion rate from BeS to CBD would be 22.4%. Annualizing this conversion rate results in a range of conversion per year of 7% to 11%. Notably, in the period of time of follow-up, not all BeS subjects have developed CBD.

We observed no statistical significance in mean age, gender, race or ethnicity, or smoking status. While it is interesting to note that the individuals who progressed from BeS to CBD were all never or former smokers, this trend for progression to be linked to smoking status did not meet statistical significance. The two groups did not differ in the latency from time of first beryllium exposure to year of detection of BeS. These individuals also did not differ with regard to their employment in the nuclear weapons industry or with regard to whether they were machinists versus non-machinists, this job title having been associated in several past studies with the risk of developing CBD.

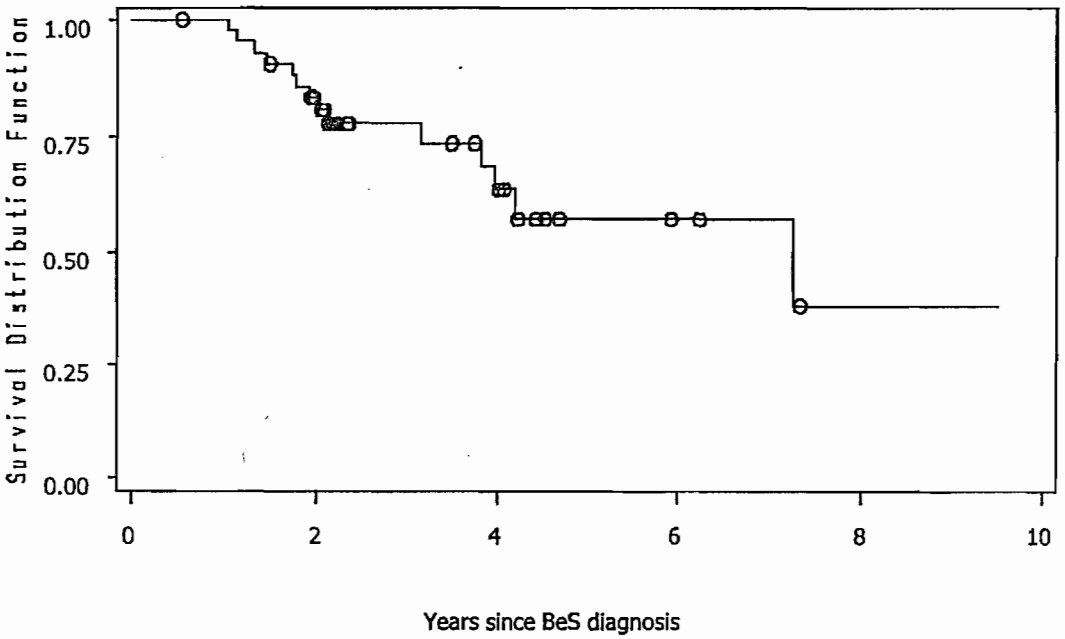
CONCLUSIONS

BeS progresses to CBD at a rate of 7- 11% per year. Beryllium-sensitized patients merit medical counseling and surveillance for signs of progression to disease.

MANUSCRIPTS

Newman LS, Mroz MM, Maier LA. Progression from Beryllium Sensitization to Chronic Beryllium Disease. In preparation for submission.

Figure 1: CBD latency from time of BeS diagnosis



Circles represent subjects who haven't progressed from BeS to CBD at their last clinical evaluation.

2) To determine the natural history of subclinical CBD.

METHODS

Cases. We estimated that we would have access to a minimum of 62 subjects meeting our case definition of subclinical CBD, coming from our past cohort of subclinical cases; new individuals who started out as BeS cases but who become subclinical cases during the course of the study; new cases referred collaborating industries as well as recently diagnosed cases identified through medical surveillance programs.

Case definition The ability to discriminate between subclinical and clinical CBD can be difficult. Therefore, we included in this study all individuals identified with CBD through worksite medical screening programs using the BeLPT and CXR. Patients identified using this definition may have upon clinical evaluation symptoms of CBD. However, none of these abnormalities had been clinically identified prior to entrance in a medical surveillance program or had been attributed to something other than CBD.

Frequency of follow-up assessments. Surveillance-identified patients with CBD were evaluated for evidence of disease progression at two-year intervals. Some patients were seen annually.

Outcome Measures We proposed using several single, well-defined measures to identify who has progressed and who has not progressed to clinical illness. In this study design, we had the advantage of baseline physiologic and radiographic data with which to compare follow-up data. We evaluated patients with the following measures: (1) forced vital capacity (percent predicted FVC), (2) FEV_1/FVC ratio, (3) percent predicted DL_{CO}, (4) exercise tolerance ($\dot{V}O_2$), (5) resting alveolar-arterial oxygen gradient (A-a gradient), (6) maximal exercise A-a gradient, (7) median ILO profusion score, (8) physician election to treat with oral corticosteroids. We recognized that this latter factor may represent a composite of the above, and may be greatly influenced by non-objective factors and treatment biases, but nonetheless considered it a potential useful clinical marker of disease progression in a practical sense

As a means of estimating the variability in our test instruments (e.g., spirometry and exercise physiology testing), we examined the results obtained over time in our group of patients with BeS who had not progressed to subclinical CBD since these individuals presumably have normal lungs and normal physiology/radiology and will have undergone testing identical to that being performed in the subclinical CBD group.

RESULTS

Baseline clinical evaluation data was available on 131 BeS patients and 119 surveillance identified CBD patients. There were 98 BeS patients and 103 CBD patients who have serial clinical evaluation data with at least one follow-up visit (range 1 – 21 follow-up visits). For

those patients with follow-up data, time from first to last clinical evaluation ranged from 0.4 years to 14.0 years with an average of 5.4 follow-up evaluations. Of the 119 surveillance identified CBD patients, 26 (21.8%) required treatment with steroids either after their baseline evaluation or on subsequent follow-up visits. Data analysis of baseline and progression data are pending. We will compare surveillance identified BeS and CBD at baseline and over time. Using the BeS patients who do not yet have granulomas in their lungs allows us to control for changes in physiology that may be attributed to age, smoking and other workplace exposures. We anticipate that final data analyses will be completed in Spring/Summer of 2002.

CONCLUSIONS

Medical surveillance identifies individuals with CBD of whom 22% progress to treatment with steroids. Parameters that seem to best predict progression specific to CBD are changes in forced vital capacity (FVC) over time and changes in A-a gradient with exercise. Additional analyses and conclusions are pending.

MANUSCRIPTS

Newman LS, Mroz MM, Maier LA, Zhang L, Murphy J. Natural History of Chronic Beryllium Disease Identified Through Workfare Surveillance. In preparation for submission.

Additional study related to this specific aim:

In preparation of the longitudinal data for analysis we examined the effect of missing and intermittently spaced clinic visits on the analysis of these data. Abnormal spirometry and exercise physiology are expected in patients with chronic beryllium disease (CBD), but the natural course of these measures over time in CBD subjects remains unknown. This is the first study to analyze longitudinal spirometry and exercise physiology parameters in CBD subjects.

METHODS

We had up to 12 years of follow-up data available for CBD subjects, which we collected on observation during clinic visits. As is common in observational studies, this study was subject to patient drop out and intermittently spaced observations making data analysis difficult. We assumed the data were missing at random and used likelihood estimation methods for mixed models which allowed us to use all available data. An additional advantage to this method was that confounding, interacting, or otherwise interesting covariates could be evaluated for their contribution to the model. We fit three univariate mixed models using one spirometry variable - FEV_1, and two exercise physiology variables - WLM, and VO_2M, as outcome variables. Since there are noticeably fewer observations for the exercise physiology variables, and all outcomes were correlated on cross section, outcomes from spirometry and exercise physiology were modeled simultaneously in a bivariate mixed model.

RESULTS

The bivariate mixed models demonstrate improvement over the univariate mixed models due to the potential for improving the precision of the fixed effects estimates, and because correlation is allowed between the random effects of spirometry and exercise physiology.

CONCLUSIONS

The methods described in this paper will be useful for any longitudinal data set in which the primary interest is on the available data and the pattern of missing data is unrelated to the patients' respiratory status.

MANUSCRIPTS

Rita A. Lundgren, Diane L. Fairclough, Lisa A. Maier, Richard H. Jones, David A. Young, and Lee S. Newman. Addressing Mistimed and Missing Pulmonary Physiologic Data in an Observational Longitudinal Study. In preparation for submission.

3) To assess exposure-response relationships for beryllium sensitization and disease.

We proposed to characterize exposures in a beryllium metal machining plant in which there had been recently diagnosed CBD cases. The precision metal machining plant has used beryllium metal, albemet (a beryllium-aluminum alloy), beryllium oxide, and a beryllium metal-oxide alloy in machining operations since 1969. Machining techniques include cutting metal with a Duall saw, milling, deburring, grinding, lapping, electrical discharge machining, lathe work, and hand sanding.

Two exposure-response studies resulted from this research:

A) We examined the characteristics of beryllium machining exposures under actual working conditions.

METHODS
Stationary samples, using eight-stage Lovelace Multijet Cascade Impactors, were taken at the process point of operation and the closest point that the worker would routinely approach. Paired samples were collected at the operator's breathing zone using a Marple Personal Cascade Impactor and a 35-mm closed-faced cassette.

RESULTS
More than 50% of the beryllium machining particles in the breathing zone were less than 10 μm in aerodynamic diameter. This small particle size may result in beryllium deposition into the deepest portion of the lung and may explain elevated rates of sensitization among beryllium machinists. The exposure data has demonstrated that a high percentage of the particles generated during machining are less than 0.6μm in aerodynamic diameter and that from 8% to 10% of the aerosol generated may be deposited in the deep portions of the lung. The highest particle number per μg of beryllium was observed in ambient air and lathing samples. The theoretical surface area of the beryllium particles is related directly to the particle numbers and again to the median mass for each of the processes.

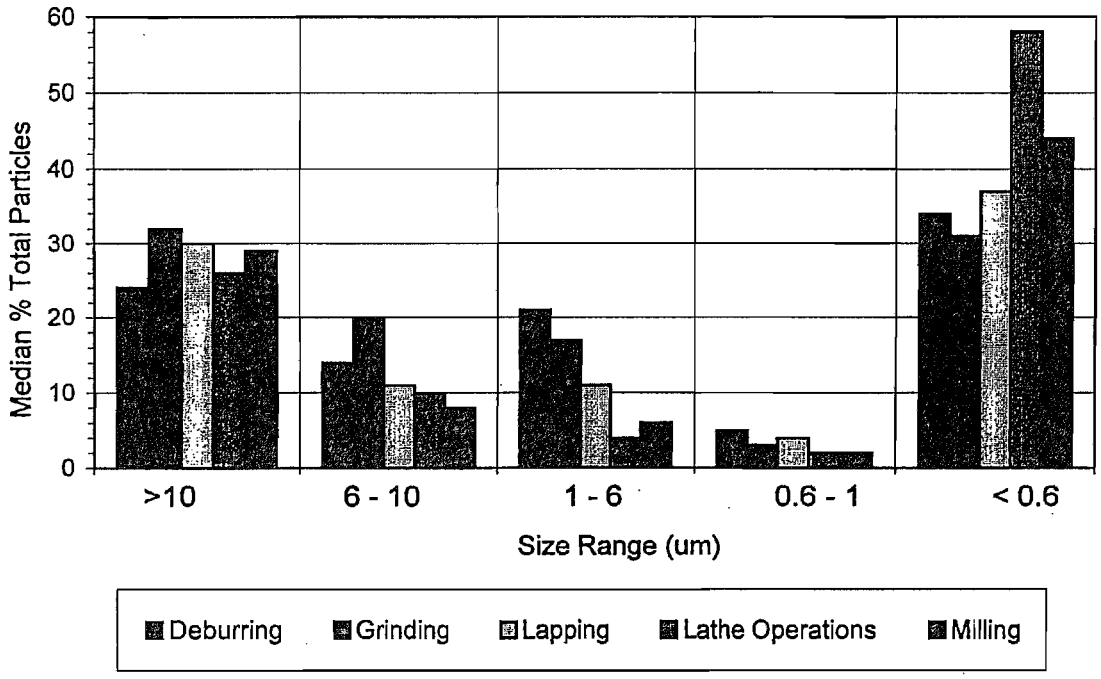
CONCLUSIONS
The small particle size from machining operations may result in beryllium deposition into the deepest portion of the lung and may explain elevated rates of sensitization among beryllium machinists.

MANUSCRIPTS

1) Martyny JM, Hoover MD, **Mroz MM**, Ellis K, Maier LA, Sheff KA , and Newman LS. Aerosols generated during beryllium machining. J Occup Environ Med. 1999.

2) Ellis K, Buchan R, Hoover M, Martyny J, Bucher Bartelson B, Mroz M, Newman L. A comparison of the particle size distributions for aerosols generated during wet grinding and dry deburring of beryllium. (In preparation for submission)

Figure 2. Median percent of beryllium for PI samples by process for each size range.



B) We examined the relationship between exposure to beryllium and presence of beryllium sensitization and chronic beryllium disease in a cohort of workers in the beryllium precision machining facility.

METHODS

Twenty cases of BeS or CBD were compared to 206 worker controls in a case-control study. Exposure for each job title was measured using cascade impactors placed in the workers breathing zone to measure total beryllium exposure and exposure to particles < 6 μm and < 1 μm in aerodynamic diameter. Cumulative exposure was calculated as Σ (Job Title Exposure Estimate x Years in Job Title). Individual lifetime-weighted (LTW) exposure was calculated as Σ [(Job Title Exposure x Years in Job Title)/Total Years Employment)].

RESULTS

Cases were more likely to have worked as a machinist (odds ratio [OR], 4.4; 95% confidence interval [CI], 1.1 to 17.5) than controls. The median cumulative exposure was consistently greater in cases compared to controls for all exposure estimates and particle size fractions, although not statistically significant (Table 1). Median cumulative exposure was 2.9 $\mu g/m^3$-yrs in cases vs. 1.2 $\mu g/m^3$-yrs in controls for total exposure and 1.7 $\mu g/m^3$-yrs in cases vs. 0.5 $\mu g/m^3$-yrs in controls for exposure to particles less than 6 μm in diameter. With cumulative exposure categorized into low, intermediate and high exposure groups, the odds ratios were 2.4 (95% CI, 0.7 to 8.2) for the intermediate exposure group and 1.2 (95% CI, 0.4 to 4.2) for the high exposure group compared to the low exposure group. The median LTW exposure was 0.25 $\mu g/m^3$ in both cases and controls. The median LTW exposure to particles less than 6 μm was 0.20 $\mu g/m^3$ in cases compared to 0.14 $\mu g/m^3$ in controls. The differences in cumulative and lifetime-weighted exposure were not statistically significant. None of the 22 workers with LTW exposure less than 0.02 $\mu g/m^3$ had BeS or CBD. Twelve (60%) of the cases had LTW exposures greater than 0.20 $\mu g/m^3$.

CONCLUSIONS

Increased cumulative and lifetime weighted exposure to total and respirable beryllium was observed in cases of CBD and BeS compared to the controls. Despite the lack of statistical significance, these results support efforts to control beryllium exposure in the workplace.

MANUSCRIPTS

Kelleher PC, Martyny JW, Mroz MM, Maier LA, Ruttenber JA, Young DA, Newman LS. Beryllium particulate exposure and disease relations in a beryllium machining plant. J Occ Environ Med 2001; 43:238-49.

Table 1: Cumulative Beryllium Exposure for Cases Compared to Controls Based on Personal Cascade Impactor Samples, Precision Beryllium Machining Plant.

Personal Impactor Sample Exposure Estimate	Cumulative Exposure, median $\mu g/m^3$-yrs or median particle $\#/m^3$-yrs		
	Cases (n=20)	Controls (n=206)	P value
Total exposure	2.93	1.24	0.38
Particles < 6 μm	1.66	0.50	0.23
Particles < 1 μm	0.96	0.34	0.20
Particle Number ($x10^8$)	1.67	0.51	0.19

RESULTS OF COOPERATIVE PROJECTS WITH NIOSH

1) Beryllium Contamination Inside Vehicles of Machine Shop Workers

This cooperative project with NIOSH characterized the potential for workers in a beryllium machining facility to carry away beryllium from the work site.

METHODS

A cross-sectional survey was conducted to evaluate potential take-home beryllium exposures. Wipe samples were collected from workers hands and vehicle surfaces and analyzed fro beryllium content. A random sample of employees was selected representing every major job category in the plant without prior knowledge of individual work practices. Background wipe samples were collected from control vehicles.

Study participants completed an interviewer-administered questionnaire concerning work history, job duties, the wearing and handling of work clothes, showering and hand washing practices, eating and smoking habits and demographic information.

Hand wipes were obtained by study participants wiping their hands with commercial wet-wipes after they performed their normal end of shift routine. NIOSH investigators timed and monitored the wiping exercise for accuracy. Wipe samples were collected inside workers cars from the steering wheel, driver's door armrest, driver's seat, floor beneath steering wheel, front passenger's seat, front passenger's floor, dashboard and child seats. Samples were analyzed using ICP-AES according to NIOSH method 7300.

RESULTS

Results ranged from nondetectable to 40 μg/ft2 on worker's hands and up to 714 μg/ft2 inside their vehicles. The highest concentrations inside the workers vehicles were found on the driver's floor indicating that worker's were carrying out beryllium on their shoes.

CONCLUSIONS

Results from this study showed that workers were potentially carrying home beryllium on their hands, clothing and shoes. Since CBD can occur at low levels of exposure, it is prudent to reduce the potential for workers to carry beryllium away from the worksite.

MANUSCRIPTS

Sanderson WT, Henneberger PK, Martyny J, Ellis K, Mroz MM, Newman LS. Beryllium contamination inside vehicles of machine shop workers. Appl Occ and Environ Hyg 1999;14:223-230.

2) Impact of a Worker Notification Program: Assessment of Attitudinal and Behavioral Outcomes

This cooperative project developed and assessed the effectiveness of a worker notification program at a beryllium machining plant

METHODS

Self-protective attitudinal and behavioral responses of among workers in two plants were compared. The first plant received beryllium risk notification and a matched control plant did not receive notification.

RESULTS

Workers receiving notification showed more positive attitudes toward beryllium safety and stronger intentions to engage in safety behaviors. The amount of hand-soap use at the intervention plant pre-notification as compared to post-notification increased significantly.

CONCLUSIONS

Worker notification programs promote adherence to recommended safety measures. The results of the study suggest that mass presentations before a live audience may be as effective as on-on-one notification. These results support also the use of communication theories in the development of worker notification methods.

MANUSCRIPTS

Tan-Wilhelm D, Witte K, Liu W, Newman L, Janssen A, Ellison C, Yancey A, Sanderson W, Henneberger P. Impact of a Worker Notification Program: Assessment of Attitudinal and Behavioral Outcomes. Am J Ind Med 2000;37:205-213.