Rocky Flats Beryllium Health Surveillance

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The Rocky Flats Beryllium Health Surveillance Program (BHSP), initiated in June 1991, was designed to provide medical surveillance for current and former employees exposed to beryllium. The BHSP identifies individuals who have developed beryllium sensitivity using the beryllium lymphocyte proliferation test (BeLPT). A detailed medical evaluation to determine the prevalence of chronic beryllium disease (CBD) is offered to individuals identified as beryllium sensitized or to those who have chest X-ray changes suggestive of CBD. The BHSP has identified 27 cases of CBD and another 74 cases of beryllium sensitization out of 4268 individuals tested. The distribution of BeLPT values for normal, sensitized, and CBD-identified individuals is described. Based on the information collected during the first 3 1/3 years of the BHSP, the BeLPT is the most effective means for the early identification of beryllium-sensitized individuals and to identify individuals who may have CBD. The need for BeLPT retesting is demonstrated through the identification of beryllium sensitization in individuals who previously tested normal. Posterior/anterior chest X-rays were not effective in the identification of CBD. — Environ Health Perspect 104(Suppl 5):981–986 (1996)

Key words: beryllium, health, surveillance, allergic, sensitization, lymphocyte

Introduction

Chronic beryllium disease (CBD) is a chronic granulomatous disorder of the lungs following inhalation of beryllium, in which a specific cell-mediated immune response plays a central role (*1–3*). The pathogenesis of CBD is believed to be a cell-mediated hypersensitivity reaction to beryllium bound to tissue proteins. Hypersensitivity to beryllium demonstrated through the beryllium lymphocyte proliferation test (BeLPT) is one of the criteria for the diagnosis of CBD (*1–3*).

Rocky Flats, 16 miles northwest of Denver, Colorado, part of the U.S. Department of Energy (DOE) nuclear weapons complex, began using beryllium in research and development operations in 1953. Beryllium production began in 1957. In June 1984, the first case of CBD at Rocky Flats was diagnosed in a beryllium machinist. The potential for occupational beryllium exposure occurred to varying degrees in a wide variety of jobs at Rocky Flats.

This article describes an ongoing voluntary program to assess beryllium sensitization and CBD in current and former Rocky Flats employees. The Beryllium Health Surveillance Program (BHSP) used the BeLPT for the detection of beryllium sensitization, B-reader* evaluated posterior/anterior chest X-rays, and medical evaluations at two major medical centers with experience in diagnosing CBD. Beginning in August 1993, the BHSP began providing BeLPT retesting for all employees who previously had tested BeLPT normal or had received an abnormal chest X-ray possibly related to CBD. The BHSP has identified beryllium sensitization in individuals who previously tested BeLPT negative. The BHSP has also demonstrated the need to confirm positive BeLPT results prior to offering a more involved medical evaluation for the diagnosis of CBD.

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Abbreviations used: BAL, bronchoalveolar lavage; BeLPT, beryllium lymphocyte proliferation test; BHSP, Beryllium Health Surveillance Program; CBD, chronic beryllium disease; COPD, chronic obstructive pulmonary disease; TLV, threshold limit value.

*B-readers are physicians trained and certified by the National Institute of Occupational Safety and Health (OSHA) in the use of the International Labor Office (ILO) system for classifying radiographs for the presence of pneumoconioses.

Methods

Surveillance Population Identification

The BHSP is a voluntary participation program implemented in June 1991 and is offered to current and former employees of prime contractors, subcontractors, DOE, and various temporary Crafts and Trades Union employees of Rocky Flats.

Prior to the implementation of the BHSP, 23 cases of CBD had been identified in current and former Rocky Flats employees. Three cases of CBD had been identified by periodic chest X-ray and symptom surveillance. Using the BeLPT as a screening tool investigators had identified four CBD cases in a pilot study of beryllium-exposed workers (*2*). The BeLPT and chest X-ray were used to identify 16 cases of CBD in a stratified population of employees (*4*). Since one of these cases was in an employee who had no identifiable contact with beryllium, any individual who self-identified with the potential for exposure to beryllium was allowed to participate in the BHSP.

The Beryllium Lymphocyte Proliferation Test

The peripheral blood BeLPT, which measures lymphocyte proliferation in response to beryllium salts (beryllium sulfate, beryllium fluoride) *in vitro*, is elevated in individuals with beryllium disease and in those sensitized to beryllium (*1–3,5,6*). The use of bronchoalveolar lavage (BAL) lymphocytes in the BeLPT has aided the diagnosis of beryllium sensitization and the diagnosis of CBD (*1*).

The BeLPT was used to identify beryllium-sensitized individuals in the BHSP. Three laboratories with recognized expertise in performing BeLPTs analyzed submitted peripheral blood specimens. An individual was considered beryllium sensitized when two consecutive or concurrent peripheral blood BeLPTs were found to be positive. An individual was also listed as sensitized to beryllium if the BAL BeLPT was positive but the peripheral blood BeLPT was negative. The use of two positive BeLPTs for the identification of sensitivity was done to reduce the number of false positives and to minimize unnecessary medical evaluations for CBD.

Beryllium Health Surveillance Program Testing

Current and former employees of Rocky Flats participated in the BHSP if they indicated a potential for exposure to beryllium during their employment at the site. Each participant signed an informed consent document and completed a self-administered questionnaire containing medical and occupational history questions. Participants received a venipuncture with 30 ml of blood collected for the peripheral blood BeLPT (60–90 ml collected for quality control specimens), and a posterior/anterior chest X-ray for B-reader review.

A quality-control program was implemented to monitor the results from the three BeLPT laboratories, and to monitor the occurrence of false-positive BeLPT results. Individuals participating in the BHSP were selected at random to serve as quality controls. When blood samples were redrawn for confirmational BeLPT from individuals who received a positive result on their initial BeLPT, specimens of the second blood test were sent to either one or two additional BeLPT laboratories. Analysis of quality-control BeLPT results included all specimens submitted from January 1992 through October 1994.

To examine the occurrence of false-positive BeLPT results, data were compared for all individuals who received an initial positive test and received a confirmational BeLPT. Only confirmational results from BeLPTs performed within 1 year of the date of the original positive finding were included in the comparison. A comparison was done to determine if the value of the initial positive BeLPT had any relationship to the percentage of confirmational BeLPT results that were positive or negative.

Posterior/anterior chest X-rays were evaluated according to the International Labor Office (ILO) classification system for radiographs of pneumoconioses by board-certified radiologists who were certified B-readers (*7*). Abnormal profusion of small opacities was defined as profusion greater than or equal to 1/0. Participants with a chest X-ray abnormality possibly associated with CBD, profusion 1/0 or greater, were contacted and informed of the availability of additional diagnostic procedures for a determination of CBD. Participants with a profusion of 0/1 were offered a 1-year BeLPT retest and a chest X-ray to determine if changes occurred in their BeLPT results or in their profusion rating.

As part of an X-ray quality assurance program, chest X-rays found to have an abnormality not associated with CBD, chest X-rays with an abnormality possibly associated with CBD, and a 5% random sample of all normal chest X-rays were sent to another board-certified B-reader radiology group for a second review.

Medical Evaluations for Chronic Beryllium Disease

Beryllium-sensitized individuals and individuals with a small-opacity profusion of 1/0 or greater on chest X-ray were offered a detailed medical evaluation for CBD including but not limited to exercise pulmonary physiology testing; computerized axial tomography; bronchoscope for BAL (for the collection of lung lymphocytes for the BeLPT), and transbronchial lung biopsy to assess the presence of granulomatous disease.

In the BHSP, a definitive diagnosis of CBD requires a history of exposure to beryllium, a positive peripheral blood BeLPT, a positive lung lavage BeLPT result, and histologic evidence of pulmonary granulomatous disease. A probable diagnosis of CBD generally includes evidence of granulomatous disease by chest X-ray or CT scan, a positive peripheral blood BeLPT, and a history of exposure to beryllium or relevant documentation of beryllium exposure.

Three-Year Beryllium Health Surveillance Program Retesting

In August 1993, the DOE approved BeLPT retesting for current Rocky Flats employees who had not been tested for 3 years or more and who previously had tested BeLPT negative. Current and former employees were also offered a 1-year BeLPT retest and chest X-ray if they had an unconfirmed positive BeLPT result or a chest X-ray with a small opacity profusion rating of 0/1. Individuals with a profusion of small opacities of 1/0 or greater who completed a clinical evaluation for CBD, but for whom no definitive diagnosis was reached, were offered a 1-year BeLPT retest and chest X-ray.

Periodic BeLPT retesting allows for the identification of BeLPT-negative-to-positive conversions, and also identifies false-negative BeLPT results. Determining which BeLPT retest results are BeLPT-negative-to-positive conversions and which are the identification of previous false-negative BeLPT results is not possible by use of the blood test alone. CBD medical evaluations would be required to definitively identify false-negative BeLPT results.

Table 1. Beryllium health surveillance population.

Status	No.
Current Rocky Flats employees contacted	8772
Participation forms returned	3902 (44.5%)
Requested participation	1932 (49.5%)
Initial BeLPT completed	1805
CBD	6
BeLPT positive (sensitized)	21
Employees contacted 3-year BeLPT retest	395
Requested participation	347
3-year BeLPT completed	347
CBD	1
BeLPT positive (sensitized)	7
Former Rocky Flats employees contacted	9865
Participation forms returned	3602 (36.5%)
Requested participation	2826 (78.5%)
Initial BeLPT completed	2463
CBD	20
BeLPT positive (sensitized)	44
Employees contacted 1-year BeLPT retest	25
Requested participation	25
1-year BeLPT completed	25
CBD	0
BeLPT positive (sensitized)	2

Results

Demographics

The BHSP surveillance population is characterized in Table 1. From June 1991 through October 1994, 8772 current Rocky Flats employees were sent BHSP participation forms; 44% (n=3902) returned the form. Of those returned, 49.5% (n=1932) indicated a desire to participate. From August 1993 through October 1994, 395 current Rocky Flats employees were contacted regarding 1-year/3-year BeLPT retesting. Of those eligible for retesting 88% (n=347) requested participation.

From June 1991 through October 1994, 9865 former employees of Rocky Flats were sent BHSP participation forms; 37% (n=3602) returned the form, and of those 78.5% (n=2826) indicated a desire to participate. From August 1993 through October 1994, 25 former Rocky Flats employees were contacted regarding 1-year/3-year BeLPT retesting. All of those eligible for retesting requested participation.

Chronic Beryllium Disease and Beryllium Sensitization Cases

Beryllium sensitization and CBD cases were diagnosed in people who held a wide variety of jobs at Rocky Flats (Table 2). Some of these workers had been identified as susceptible in an earlier beryllium health

study at Rocky Flats (*4*). New cases of CBD and beryllium sensitization were identified in workers with minimal opportunity for exposure to beryllium.

Between June 1991 and October 1994, 1805 current Rocky Flats employees received their initial BeLPT as participants in the BHSP. Seven cases of CBD were diagnosed in current employees, and 28 current employees were identified as beryllium sensitized (Table 1). During the same period, 2463 former employees received BeLPT as participants in the BHSP. Of this group, 20 individuals were diagnosed with CBD and 46 former employees were identified as beryllium sensitized (Table 1). Individuals identified as sensitized have diagnostic evaluations for CBD in progress.

A statistically significant difference ($p<0.001$) was found in the mean time from first identified beryllium exposure to the diagnosis of CBD in current employees (mean 22.1 years) versus former employees (mean 28.7 years), and a statistically significant difference ($p<0.001$) was found in the mean time from first identified beryllium exposure to the identification of beryllium sensitization in current employees (mean 16.7 years) versus former employees (mean 27.7 years). The relative distribution of these cases is shown in Table 3.

Table 2. Current and former workers with CBD and CBD sensitization.

Job title	Status of workers: CBD diagnosed	Status of workers: Sensitization identified
Machinist	4	8
Electrician	3	4
Chemical operator[a]	*3*	*2*
Radiological protection technician	3	2
Janitor/laborer	2	8
Engineer	*2*	*7*
Clerical/secretarial	*2*	*5*
Sheet metal worker	2	4
Laboratory technician	*1*	*4*
Tool maker/tool grinder	1	3
Chemist/chemical engineer	*1*	*2*
Air filter technician	1	1
Guard/safety inspector	*1*	*1*
Metallurgical operator	1	1
Administrative/managerial		*4*
Pipefitter		4
Clerk packer		*3*
Parts inspector		2
Metallurgist/metallurgical analyst		2
Quality assurance inspector/engineer		2
Carpenter		*1*
Equipment operator		1
Stationary operating engineer		1
Technical support		*1*
Total	27	74

[a]Jobs in italics indicate those with minimal opportunity for exposure to beryllium.

Table 3. Current and former CBD and sensitized cases.

Years between first identified exposure to beryllium and diagnosis	CBD diagnosed Employee status: Current	CBD diagnosed Employee status: Former	Sensitization identified Employee status: Current	Sensitization identified Employee status: Former
0–10	0	0	6	3
11–20	3	2	15	5
21–30	3	13	6	18
31–40	1	5	1	19
41+	0	0	0	1
Total cases	7	20	28	46
Mean years between first identified exposure to beryllium and diagnosis	22.1	28.7	16.7	27.7

The total sensitization rate (CBD and sensitized cases) for the tested cohort (n=4268) was 2.3%. The CBD rate was 0.6% and the beryllium sensitization rate was 1.7%. These rates are comparable to rates previously reported in studies of beryllium-exposed workers.

Three-year BeLPT retesting has resulted in the identification of one case of CBD and nine cases of beryllium sensitization out of the 372 current and former employees retested (Table 4). The total sensitization rate (CBD and sensitized cases) for the 3-year retest cohort of 2.7% is not statistically different from the rate observed from initial BeLPT findings. After completing CBD medical evaluations, one of these individuals was diagnosed with CBD, and the nine remaining sensitized individuals will be offered an annual CBD medical evaluation.

Current employees of Rocky Flats who were identified as sensitized to beryllium or who were diagnosed with CBD were notified of the potential hazards related to further exposure to beryllium. These employees were removed from work areas where there was the potential for exposure to beryllium. Sensitized individuals are offered annual medical evaluations to monitor for the development of CBD. Individuals diagnosed with CBD are offered annual medical evaluations to monitor the progression of the disease and to provide treatment where appropriate.

Table 4. Three-year BeLPT retesting, August 1993 to October 1994.

	Current employees	Former employees	Total
No. tested	347	25	372
Outcome			
CBD diagnosed	1	0	1
Sensitized	7	2	9
% CBD/sensitization conversion	2.3%	8.0%	2.7%

Beryllium Lymphocyte Proliferation Test Quality Control Program

The BHSP BeLPT Quality Control Program was designed to monitor the results of the BeLPTs performed at the three BeLPT laboratories. Tables 5 and 6 show the results of split-sampling testing between laboratories. For all BeLPT results examined, on average there has been a 93% (range 85%–96%) agreement between the BeLPT laboratories. Examining only positive BeLPT results shows a 30% (range 21%–38%) agreement among the laboratories on split-specimen testing. Table 6 also shows data collected concerning the

Table 5. Quality control BeLPT findings, June 1991 to October 1994.

Quality control laboratories	BeLPT outcome[a]	Concordance/tested	% Concordance
A and B	Positive BeLPTs	29/88	33
	All BeLPTs	1076/1125	96
B and C	Positive BeLPTs	11/29	38
	All BeLPTs	268/299	90
A and C	Positive BeLPTs	11/53	21
	All BeLPTs	212/250	85

[a]Uninterpretable/indeterminate results, laboratory errors, insufficient cells, and single positive BeLPT results were removed; therefore, the sum of BeLPTs with reportable results may not equal the total number of results received.

Table 6. Positive BeLPT retest consistency, June 1991 to October 1994.

Positive BeLPT value range	No. positive on first BeLPT (*n*=222)	No. negative on first BeLPT retest (*n*=141)	% Reversion
1.6–2.9	61	54	88.5
3.0–4.9	62	52	83.9
5.0–9.9	40	21	52.5
10.0–19.9	26	9	34.6
20.0–49.9	17	5	29.4
≥50.0	16	0	0.0

issue of false-positive BeLPT results. To examine the potential for false positives occurring, BeLPT-positive results were compared with the outcome of confirmational BeLPT testing. Positive BeLPT values were divided into six categories to determine if the value of a positive BeLPT result had any relationship to the rate with which confirmational BeLPT results were found to be positive or negative. A false-positive rate of 88.5% was found between initial BeLPT-positive values and confirmational BeLPT values when the initial BeLPT value was less than 3.0. Rates decreased until no false positives were detected for initial BeLPT values greater than 50.0.

Chest X-rays

A total of 4255 posterior/anterior chest X-rays were evaluated according to the ILO classification system for radiographs of pneumoconioses by board certified radiologists who were certified B-readers. Findings for the initial evaluation are shown in Table 7. A total of 119 individuals had abnormalities possibly associated with CBD, profusion 1/0 or greater; and 869 had abnormalities not associated with CBD, profusion 0/1 or less.

Table 7. Posterior/anterior chest X-rays.

Findings	No.
Total submitted for initial B-reader review	4255
Results of initial review	
Normal	3267
Abnormal, not associated with CBD	869
Abnormal, possibly associated with CBD	119
Medical evaluation of abnormal chest X-rays possibly associated with CBD[a]	
CBD	
Borderline BeLPT	1
Negative BeLPT	1
Sensitized (lavage BeLPT positive, blood BeLPT negative)	1
Miscellaneous (normal, COPD, emphysema, asbestosis, etc.)	97

COPD, chronic obstructive disease. [a] *n*=100; 19 declined medical evaluation.

Abnormal findings included densities/nodules/masses, pleural changes that may have resulted from asbestos exposure, previous infections or trauma, pulmonary hypertension, obstructive pulmonary disease, cardiac abnormalities, spinal abnormalities, and abnormalities of the major blood vessels and diaphragm. The Rocky Flats Medical Director sent letters to former employees recommending that they contact their private physicians regarding abnormal chest X-rays. Rocky Flats Occupational Health physicians reviewed abnormal findings with current employees. Many of the abnormalities were resolved upon review of previous chest X-rays in conjunction with a repeat chest X-ray.

Of the chest X-rays for the 27 individuals diagnosed with CBD, only one had a small opacity profusion of 1/0 or greater, one had a small opacity profusion of 0/1, and the remaining 25 were rated as 0/0. For the 74 beryllium-sensitized cases, chest X-ray results revealed three people with small opacity profusion of 1/0 and one with a small opacity profusion of 0/1; the remaining 69 were rated as 0/0.

To date, only one case of CBD has been identified in which chest X-ray findings indicated CBD not already suggested by the peripheral blood BeLPT. In addition, one individual with a small opacity profusion of 1/0 referred for evaluation was found to be BAL BeLPT positive. No indication of granulomatous disease was found on biopsy. The peripheral blood BeLPT results for this individual were positive on the initial draw. Since individuals whose chest X-rays showed a small opacity profusion of 1/0 or greater were referred for CBD medical evaluations, the second confirming BeLPT blood draw for this individual was performed as part of the CBD medical evaluation process. The result of this confirming BeLPT was positive. This individual is listed as a presumed case of CBD. Another individual who was referred for medical evaluation as the result of a chest X-ray with a opacity profusion of 1/0 was peripheral blood BeLPT-negative, but was found to be BAL-positive. This individual was classified as beryllium sensitized, and will be reevaluated annually for CBD, since no evidence of granulomatous disease was found on lung biopsy.

Table 8 lists the differences in radiographic findings between the initial and second B-reader review for 869 abnormal chest X-rays not associated with CBD, 119 chest X-rays possibly associated with CBD as determined by the initial B-reader review, and 154 normal chest x-rays as determined by the initial B-reader review.

Discussion

Demographics of the Beryllium Health Surveillance Program Study Population

The number of program participants tested (*n*=4268) from June 1991 through October 1994 was comprised of 42% current employees and 58% former employees of Rocky Flats. Nearly 50% (49.5%) of current employees requested participation in the BHSP, as did 78.5% of former employees. Former employees apparently had an increased level of concern regarding exposure to beryllium and related health effects. However, this increased participation rate might also have been because former employees had not previously had the same opportunity to receive testing for beryllium sensitivity as current employees.

The sensitization rate (CBD and sensitized cases) for the population studied (*n*=4268) was 2.3%. This rate is comparable to the sensitization rate (CBD and sensitized cases) for previously studied beryllium-exposed populations (*n*=946) at Rocky Flats, which was 2.5%. Previously

Table 8. Differences in findings between first and second B-reader review.

First review findings	No.	Second review findings	No. different	% Different
Normal	154	Abnormal, not associated with CBD	20	13.0
Normal	154	Abnormal, possibly associated with CBD	1	0.6
Abnormal, not associated with CBD	869	Normal	116	13.3
Abnormal, not associated with CBD	869	Abnormal, possibly associated with CBD	12	0.2
Abnormal, possibly associated with CBD	119	Normal	7	5.9
Abnormal, possibly associated with CBD	119	Abnormal, not associated with CBD	33	27.7

studied populations were selected from the current employee workforce based upon a significant opportunity for exposure to beryllium. The BHSP study population is comprised of current and former employees with any level of exposure to beryllium.

The statistically significant difference found in the mean time from the first identified beryllium exposure to the diagnosis of CBD or the identification of sensitization between current and former employees might in part be an artifact of the order in which individuals were offered testing. Testing for former employees was delayed until the majority of testing for current employees had been completed. Other causes for these differences might be changes in testing methodology, changes in the sensitivity of the BeLPT, and changes in medical criteria for diagnosing CBD. We recognize that the mean times between the first identified beryllium exposure and the diagnosis of beryllium sensitization or CBD are only estimates, but nonetheless they provide an estimate of the minimum length of time that a beryllium-exposed employee may have to be followed subsequent to exposure.

Posterior/Anterior Chest X-rays

The use of posterior/anterior chest X-rays evaluated by B-reader radiologists, using the ILO classification system for radiographs of pneumoconioses, proved to be an ineffective method of identifying individuals for medical referral for CBD evaluation. Of the 101 cases of beryllium sensitization and CBD identified during this period, four individuals had a profusion of small opacities of 1/0 and three had a profusion of 0/1. Of these, one case of CBD was found with a profusion of small opacities of 1/0. This person was referred for a CBD medical evaluation because of the chest X-ray findings. This individual was found to be repeatedly peripheral blood BeLPT negative, and lung lavage BeLPT positive. However, biopsy revealed no evidence of pulmonary granulomas. This single case would most likely not have been discovered without the chest X-ray portion of the BHSP. The overall value of posterior/anterior chest X-rays evaluated by B-reader radiologists appears limited as a means of identifying candidates for CBD medical evaluations. The chest X-ray was nonspecific for the diagnosis of CBD in this population of workers. These observations are similar to those reported elsewhere (*4,8,9*). Based on these data, the posterior/anterior chest X-ray should not be the sole means of screening for CBD or beryllium sensitization in an occupational beryllium health surveillance program.

In general, the variability between the two B-reader radiology groups' evaluations of a random sample of normal chest X-rays and all chest X-rays with an identified abnormality was similar to that previously reported (*10*). No reason was identified for the variability (33.6%) between the first radiology group's findings of abnormalities possibly associated with CBD and the findings of the second radiology review. However, the first group's opacity profusion ratings were consistently higher than those of the second.

Beryllium Lymphocyte Proliferation Test Quality Control

The BHSP used a quality-control program to monitor and verify BeLPT results. A beryllium health surveillance program based on the BeLPT should have a quality-assurance program in place to monitor test results.

The results of split-specimen testing among the three laboratories showed 30% agreement on positive BeLPTs. These results were disappointing and clearly point to the necessity for split-specimen testing and repeat testing for positive and borderline-positive BeLPT results. We believe that differences in the technical procedures for performing the BeLPT among the laboratories are the principal reasons for the differences seen in BeLPT quality control results. Until standardized laboratory methodology is used by BeLPT laboratories, the ability to compare BeLPT results among laboratories is suspect (*11*).

Possible reasons for the disagreement between BeLPT results from different laboratories are speculative, but can include differences in technical procedures, differences in instrumentation, differences in laboratory technician skill, handling procedures for blood specimens, and laboratory experience level. Clearly this is a difficult assay that requires considerable skill and experience to perform correctly. Temperature and time are factors that can affect BeLPT results. Maintaining blood specimens at room temperature from the time of the blood draw to receipt at the laboratory is an important factor in maintaining the viability of the blood cells (*2*). Similarly, the time from the blood draw until receipt by the laboratory is important. Previous investigations concerning cell viability showed that no significant decrease in cell reactivity was seen up to 24 hr after the blood draw (*2*).

The Beryllium Lymphocyte Proliferation Test

The usefulness of the peripheral blood BeLPT to monitor a beryllium exposed population for the development of beryllium sensitization and CBD was demonstrated in the BHSP study population. However, the BeLPT has limitations that include the following: *a*) Because of the potential for false-positive BeLPT results, beryllium sensitization requires two consecutive or concurrent positive BeLPTs. *b*) False-negative BeLPTs are known to occur. *c*) At present only five commercial or hospital laboratories are qualified to perform the BeLPT. *d*) The BeLPT must be performed within 24 hr of blood-specimen collection. *e*) The lack of agreement between laboratories on split-specimen BeLPTs is common.

The need for BeLPT retesting has been demonstrated through the identification of 10 cases of beryllium sensitization in individuals who previously tested normal. These individuals had previously had peripheral blood BeLPT negative results between 1989 and 1991. One of these individuals, following a medical evaluation, has been diagnosed with CBD. Although there is no standard for retesting, we have established a 3-year retest frequency for individuals who previously were negative on the peripheral blood BeLPT. More frequent retesting, for example annually, may be recommended if prior clinical findings or recent symptoms suggest CBD. These 10 sensitized retest cases represent either BeLPT negative to positive conversions or the identification of prior false-negative BeLPT results. Analysis of these data showed that the lower the value of the initial BeLPT positive, the greater the percentage of false positives identified as the result of confirmational testing.

Beryllium Exposure: Population at Risk

An evaluation of the job titles and work histories of the beryllium-sensitized and CBD cohorts suggests that exposure to beryllium at levels below the threshold limit value (TLV) of 2.0 $\mu g/m^3$ may result in beryllium sensitization. This may be particularly important for individuals who are more sensitive to beryllium exposures than the general population (*12*). The long latency period for development of beryllium sensitization or CBD and the potential for continued low-level exposures over time make the determination of a safe level for beryllium exposure difficult.

As the use of beryllium continues to increase in aerospace, electronics, and a variety of other industries, the health surveillance of beryllium-exposed populations becomes vitally important to occupational physicians and to epidemiologists in occupational settings. This investigation has shown that the BeLPT is the most effective method for detection of beryllium sensitization. It has also demonstrated that posterior/anterior chest X-rays previously used in beryllium health surveillance programs are not effective as a sole screening tool. Occupational physicians in industries that use beryllium or beryllium alloys should strongly consider the potential for employees to develop beryllium sensitization and CBD even though routine health monitoring is provided. It is important to recognize that, for some employees, exposure to beryllium at levels below the TLV might cause disease. We have reported on a population of employees in whom applicable safety exposure requirements for beryllium were maintained yet beryllium sensitization and CBD occurred. We have also reported cases of sensitization and CBD in employees with jobs that were thought not to be of concern because of their minimal opportunity for exposure to beryllium.

Lessons Learned

We have learned a number of lessons at Rocky Flats regarding establishing and maintaining a beryllium health surveillance program. Some of these may have application at other facilities where beryllium is used. Of paramount importance is the identification of workers exposed to beryllium. Without considerable coordination with supervisory and industrial hygiene personnel, groups of exposed workers can be missed or expensive medical monitoring can be performed unnecessarily. If beryllium operations are confined to specific areas and access to these areas is limited, the identification of workers needing monitoring can be simplified and the costs of surveillance reduced. Since chest X-rays have not been useful in identifying early disease, they need not be routinely done. The BeLPT can assist industry in demonstrating the adequacy of beryllium-exposure control procedures. Unfortunately, because of the typically low prevalence of CBD, several years of testing are necessary to document the control of exposure.

The BHSP has provided, and will continue to provide, important information for occupational physicians and private health-care professionals concerning the design, implementation, and ongoing management of a program for the detection of beryllium sensitization and CBD in populations at risk.

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