information about particular lead sources that may be of concern in a given neighborhood. Often these officials can assist in the management of the lead-poisoned child, doing followup screening, conducting environmental investigations, and ensuring lead hazards are abated. They should keep the provider informed of actions they take on the child's behalf. The pediatric health-care provider is responsible for informing public health officials about lead-poisoned children, reporting any unusual sources or pathways of exposure, and reporting elevated blood lead levels, if this is required.

APPROPRIATE FOLLOWUP

APPROPRIATE FOLLOWUP INCLUDES:

Education.
Followup blood lead testing.
Medical evaluation, if appropriate.
Pharmacologic treatment, if appropriate.
Environmental investigation, if appropriate.
Referral to infant stimulation or child development programs, if appropriate.
Referral for social services.

Not all aspects of a poisoned child's followup will be managed by the pediatric health-care provider, although the provider is an important part of the team. Through his or her interactions with the child and family and the responsible public health agency, the provider should make sure that any appropriate interventions are occurring. The provider should make sure that the family receives education about childhood lead poisoning and ways of preventing it, and he or she should make sure that the child receives the appropriate followup blood lead testing. If the child needs a medical evaluation (for a blood lead level greater than or equal to 20 ug/dL) or pharmacologic treatment (Chapter 7), either the provider should do it or should refer the child to a place that treats large numbers of poisoned children. The provider should make sure that the child receives an appropriate environmental investigation and remediation with the help of the public health agencies. Particularly if the child is developmentally delayed, the provider should refer the child to an appropriate infant stimulation or child development program. In many cases, lead-poisoned children and their families will also benefit from social services followup.

CHAPTER 5. THE ROLE OF STATE AND LOCAL PUBLIC AGENCIES

A variety of local, state and federal agencies play a role in preventing childhood lead poisoning. Pediatric health-care providers and parents should know about what these agencies do so that they can use these resources effectively. In turn, these agencies must coordinate their activities to ensure that all aspects of childhood lead poisoning prevention—health, housing, and environment being addressed, and to provide the most comprehensive and cost effective services to at-risk children, their parents, and their health-care providers.

Government operations vary widely from state to state. In some states, city or local government takes the leading role in providing public health services such as lead poisoning prevention. In other states, county or state agencies take the lead role. Similarly, housing and environmental agencies with responsibility for addressing lead hazards may exist at the local, county, or state level.

PUBLIC HEALTH AGENCIES

THE PUBLIC HEALTH AGENCY SHOULD:

Ensure that necessary screening services are provided.
Analyze surveillance and other data to identify exposure patterns and high-risk populations.
Develop and implement a primary prevention plan that focuses on the highest risk sources and populations.
Coordinate prevention activities with other pertinent health, housing, and environmental agencies.
Ensure that medical and environmental followup services for poisoned children are provided.

In most cities and some towns, counties, and states, lead poisoning prevention programs are included within the public health department or agency. Traditionally, these programs have focused on screening for lead poisoning and ensuring medical or environmental followup for children identified as being poisoned. Many also undertake public education activities, but, historically, lack of resources has limited these agencies' ability to focus on primary prevention.

A comprehensive, multifaceted approach to preventing childhood lead poisoning would include screening and surveillance, risk identification, primary prevention activities, interagency coordination, and services for poisoned children.
SCREENING

As explained in Chapter 6, screening children for lead poisoning is important both to identify poisoned children and to provide data that can be used to target community-wide interventions. Public health agencies should have the primary responsibility for ensuring that children receive necessary blood lead screening. While it is not realistic for public agencies to actually perform most of the required screening, these agencies must work with individual and institutional pediatric health care providers to ensure that the private sector provides as much screening as possible. Screening by public agencies should focus on children who would not otherwise receive it in the private sector.

SURVEILLANCE AND RISK ASSESSMENT

Before a public health agency can design and implement a primary prevention plan, the agency must assess the sources of lead in the community, exposure patterns, and high-risk populations. The lead public health agency should generally take responsibility for the types of risk assessment activities described in Chapter 9, soliciting cooperation and assistance from housing and environmental agencies when appropriate. As explained in Chapter 9, blood lead screening provides data for assessing the extent and nature of a given community’s lead problem. Public health agencies should also take the lead in conducting or coordinating the collection of the environmental, housing, and demographic data needed to undertake a community-based risk assessment.

PRIMARY PREVENTION

One of the most important themes of this document is the need to identify and remove sources of exposure to lead before children are harmed, that is, the need for primary prevention. Public health agencies must take a leading role in designing and implementing primary prevention programs. One important activity for public health agencies is to use the data collected from screening and surveillance to develop a primary prevention plan designed to target resources to the most pervasive sources and the highest risk populations.

INTERAGENCY COORDINATION

Public health agencies cannot be expected to implement primary prevention activities by themselves. Many steps that must be taken lie within the expertise or jurisdiction of other government agencies, especially those dealing with housing or the environment. To prevent lead poisoning, all public agencies with a connection to this problem need to be enlisted in the effort. The activities of different types of agencies at different levels of government must be coordinated, preferably through formal arrangements under which the different agencies meet and consult. Public health agencies should take the lead in organizing interagency task forces or committees and in ensuring that all involved agencies communicate regularly.

PROVIDING SERVICES TO POISONED CHILDREN

Public health agencies have traditionally been responsible for ensuring that lead-poisoned children receive appropriate medical and environmental followup, often through a formal case-management system. Until lead poisoning has successfully been eradicated, public health agencies will have to devote much of their lead-poisoning prevention resources to case management services for poisoned children.

HOUSING AGENCIES

HOUSING AGENCIES SHOULD:

Work with public health agencies to provide needed housing and environmental services to poisoned children.

Enforce code requirements regarding lead hazards.

Assist public health agencies in educating property owners, tenants, real estate professionals, and building contractors about lead hazards in housing.

Use regulations and policies to increase the amount of safe and effective abatement performed.

Most states, and some cities and counties, have agencies with the responsibility for regulating housing quality or developing policies to ensure that people are provided with safe and affordable housing. As the focus shifts from severely poisoned children to lead hazards in children’s environments, the role of housing agencies will expand. A comprehensive, multifaceted role for housing agencies would include providing services to poisoned children; enforcing housing codes; educating the public; and making regulations and policies to increase the number of safe and effective abatements.

ENVIRONMENTAL AGENCIES

ENVIRONMENTAL AGENCIES SHOULD:

Participate in interagency efforts to prevent lead poisoning.

Adopt a multimedia approach to addressing environmental lead hazards.
Undertake monitoring, regulatory, licensing, and enforcement activities to reduce environmental exposure to lead. Most states, and some cities and counties, have agencies responsible for regulating exposures to toxic substances in the environment. Traditionally, such agencies have dealt with exposure to lead in the air, in drinking water, and in hazardous and solid waste, but have had little or no role in addressing the hazards associated with lead in paint. Some environmental agencies have begun to address the problems of toxic substances in housing, such as asbestos and radon, and they may also be willing to join an interagency effort to reduce exposure to lead hazards in housing. A comprehensive, multifaceted role for environmental agencies would include participation in interagency efforts, multimedia lead hazard reduction programs, monitoring, and regulation.

CHAPTER 6. SCREENING

SUMMARY

SCREENING IS IMPORTANT BOTH TO ENSURE THAT POISONED CHILDREN ARE IDENTIFIED AND TO GENERATE DATA TO TARGET PRIMARY PREVENTION ACTIVITIES.

VIRTUALLY ALL CHILDREN SHOULD BE SCREENED FOR LEAD POISONING. SCREENING CHILDREN WITH HIGH PROBABILITY OF EXPOSURE TO HIGH-DOSE SOURCES IS THE HIGHEST PRIORITY.

SCREENING SHOULD BE DONE USING A BLOOD LEAD TEST.

CHILDREN AT GREATEST RISK FOR HIGH-DOSE LEAD EXPOSURE SHOULD BE SCREENED MORE FREQUENTLY.

ANALYTICAL CONSIDERATIONS AFFECT INTERPRETATION OF BLOOD LEAD TEST RESULTS, PARTICULARLY AT LOW LEVELS.

Traditionally, the main purpose of a childhood lead poisoning screening program has been to identify asymptomatic lead-poisoned children and to intervene as quickly as possible to reduce their blood lead levels. An additional benefit of screening programs is that abatement of lead sources for poisoned children results in prevention of lead poisoning for children who would have been exposed to those sources in the future. As the focus in lead poisoning prevention turns more to primary prevention, an additional benefit of screening is that data generated can be used in targeting interventions to places with children at high risk for lead poisoning.

SUGGESTED PRIORITIES FOR SCREENING

VIRTUALLY ALL U.S. CHILDREN ARE AT RISK FOR LEAD POISONING.

CHILDREN AT HIGHEST RISK SHOULD BE GIVEN THE HIGHEST PRIORITY FOR SCREENING.

In 1984, the last year for which estimates are available, it is believed that between 3 and 4 million children younger than age 6 years (17% of all U.S. children in this age group) had blood lead levels above 15 ug/dL (ATSDR, 1988). Furthermore, about 74% of occupied, privately owned housing built before 1980 contains lead-based paint (defined as greater than or equal to 1 milligram per square centimeter (mg/cm²)) (HUD, 1990). BECAUSE ALMOST ALL U.S. CHILDREN ARE AT RISK FOR LEAD POISONING (ALTHOUGH SOME CHILDREN ARE AT HIGHER RISK THAN OTHERS), OUR GOAL IS THAT ALL CHILDREN SHOULD BE Screened, UNLESS IT CAN BE SHOWN THAT THE COMMUNITY IN WHICH THESE CHILDREN LIVE DOES NOT HAVE A CHILDHOOD LEAD POISONING PROBLEM. (Deciding that no problem exists requires that a large number or percentage of children be tested. *) The full implementation of this will require the ability to measure blood lead levels on capillary samples and the availability of cheaper and easier-to-use methods of blood lead measurement. Children at highest risk for lead poisoning are the highest priority for screening. Table 6.1 provides guidance on the groups for which repeated screening is most strongly indicated.

Children ages 6 to 72 months who live in or are frequent visitors to deteriorated old buildings, including day care centers, make up the highest priority group. Because the highest concentrations of lead in paint were used in the early 1900s, homes built before about 1960 are of greatest concern. Children whose homes are being renovated are also at extremely high risk. Since siblings, house mates, visitors, and playmates of children with confirmed lead poisoning may have similar exposures to lead, they also should be promptly screened. In communities with a high prevalence of lead poisoning, health departments should consider door-to-door screening, since many children with lead poisoning may be missed by fixed-site screening.

Children with parents whose work or hobbies involve lead may also risk lead exposure (Chapter 3). Also, children living near lead smelters or other industries where lead is processed may be at increased risk for lead poisoning.

In general, screening and assessment for lead poisoning should focus on children younger than 72 months of age, particularly on children younger than 36 months of age. Young children engage in the most hand-to-mouth activity (and therefore are at highest risk for lead exposure) and have the most rapidly developing nervous systems, making them more vulnerable to the effects of lead. Children with developmental delays, who may exhibit pica or have more extensive hand-to-mouth activity than other children, would be expected to be at increased risk for lead poisoning even if they are 72 months of age and older. These children may have to be screened more often during early infancy, and may require screening into their school years.
Children who have unexplained seizures, neurological symptoms, abdominal pain, or other symptoms that are consistent with lead poisoning should also have their blood lead levels measured. In addition, the possibility of lead poisoning should be considered in any child with growth failure, developmental delay, hyperactivity, behavior disorders, hearing loss, anemia, etc.

* The health departments need to take lead role in assessing whether or not a community has a childhood lead poisoning problem.

**SCREENING METHOD**

SCREENING SHOULD BE DONE USING A BLOOD LEAD TEST.

Since erythrocyte protoporphyrin (EP) is not sensitive enough to identify more than a small percentage of children with blood lead levels between 10 and 25 ug/dL and misses many children with blood lead levels greater than or equal to 25 ug/dL (McElvaine et al., 1991), measurement of blood lead levels should replace the EP test as the primary screening method. Unless contamination of capillary blood samples can be prevented, lead levels should be measured on venous samples. Obtaining capillary specimens is more feasible at many screening sites. Contamination of capillary specimens obtained by finger prick can be minimized if trained personnel follow proper technique (see Appendix I for a capillary sampling protocol). Elevated blood lead results obtained on capillary specimens should be considered presumptive and must be confirmed using venous blood. At the present time, not all laboratories will measure lead levels on capillary specimens.

Programs will need to increase their capacity to perform blood lead testing. During the transition to the use of the blood lead test as the primary screening method, some programs will temporarily continue to use EP as a screening test. In addition, some nutrition programs (for example, the Supplemental Food Program for Women, Infants, and Children (WIC)) use the EP test to identify children with iron deficiency.

For a discussion of the units used to report EP results (Page 48). All EP test results of greater than or equal to 35 ug/dL if standardized using 241 L cm-1 mmol-1, greater than or equal to 28 ug/dL if standardized using 297 L cm-1 mmol-1, or greater than or equal to 70 umol ZnPP/mol heme, if the hematofluorometer reports in these units, must be followed by a blood lead test (preferably venous) and an evaluation for iron deficiency. Work on developing easy-to-use, cheap, portable instruments for blood lead testing is ongoing.

**ANTICIPATORY GUIDANCE AND ASSESSING RISK**

ANTICIPATORY GUIDANCE HELPS PREVENT LEAD POISONING BY EDUCATING PARENTS ON WAYS TO REDUCE LEAD EXPOSURE.

QUESTIONS ABOUT HOUSING AND OTHER FACTORS ARE USED TO IDENTIFY WHICH CHILDREN ARE AT GREATEST RISK FOR HIGH-DOSE LEAD EXPOSURE.

ANTICIPATORY GUIDANCE AND ASSESSMENT OF RISK SHOULD BE TAILORED TO IMPORTANT SOURCES AND PATHWAYS OF LEAD EXPOSURE IN THE CHILD'S COMMUNITY.

Guidance on childhood lead poisoning prevention and assessment of the risk of lead poisoning should be part of routine pediatric care. Anticipatory guidance is discussed in more detail in Chapter 4. The guidance and risk assessment should emphasize the sources and exposures that are of greatest concern in the child's community (Chapter 3). Because lead-based paint has been used in housing throughout the United States, in most communities it will be necessary to focus on this source.

**SCREENING SCHEDULE**

THE SCREENING SCHEDULE IS BASED ON THE FACT THAT CHILDREN'S BLOOD LEAD LEVELS INCREASE MOST RAPIDLY AT 6-12 MONTHS AND PEAK AT 18-24 MONTHS.

ANTICIPATORY GUIDANCE ON PREVENTING LEAD POISONING AND ASSESSING THE RISK FOR HIGH-DOSE LEAD EXPOSURE SHOULD BE PART OF ROUTINE PEDIATRIC CARE.

THE URGENCY AND TYPE OF FOLLOW-UP DEPENDS ON THE SCREENING BLOOD LEAD TEST RESULT.

**BACKGROUND**

The rationale for the screening schedule is based on data such as those shown in Figure 6.1. Those data were collected in a prospective study in Cincinnati (Clark et al., 1985). Blood lead levels were measured every 3 months from birth onward, and illustrate the trends in blood lead concentration in relation to the child's age and housing age and condition. Blood lead concentrations increase steadily up to at least 18 months of age. The most rapid rate of increase occurs between 6 and 12 months of age. The highest blood lead levels occur in children living in deteriorated older housing.

**ASSESSMENT OF RISK**

Table 6.2 has sample questions. Starting at 6 months of age and at each regular office visit thereafter, pediatric health-care providers should discuss
Preventing Lead Poisoning in Young Children

An individual child should be tested. It is a guide for pediatric health-care providers and screening programs to use in conjunction with other pertinent information in determining when.

The following sections provide a minimum screening schedule for children aged 6 up to 36 and 36 to 72 months. The schedule is not rigid. Rather, the community she serves.

\[ \text{pottery. In her anticipatory guidance and assessment of her patients' risks of lead poisoning, she emphasizes sources of exposure that are common in} \]

improperly fired pottery. At every routine visit, she asks parents about the use of this pottery and screens any children whose parents use this.

patients' families store juice and punch in pottery imported from Mexico. In her guidance to parents, she warns them that lead can leach from.

EXAMPLE: A pediatrician in southern California almost exclusively serves communities built after 1988. She is aware, however, that some of her.

patients' families store juice and punch in pottery imported from Mexico. In her guidance to parents, she warns them that lead can leach from.

on the basis of responses to questions such as those in Table 6.2, children can be categorized as low or high risk for high-dose lead exposure. If the.

answers to all questions are negative, the child is at low risk for high-dose lead exposure and should be screened by a blood lead test at 12 months.

and again, if possible, at 24 months (since blood lead levels often peak at ages greater than 12 months). If the answer to any question is positive, the.

child is potentially at high risk for high-dose lead exposure, and a blood lead test should be obtained. FOR CHILDREN PREVIOUSLY AT LOW.

RISK, ANY HISTORY SUGGESTING THAT EXPOSURE TO LEAD HAS INCREASED SHOULD BE FOLLOWED UP WITH A BLOOD LEAD TEST.

On the basis of responses to questions such as those in Table 6.2, children can be categorized as low or high risk for high-dose lead exposure. If the.

answers to all questions are negative, the child is at low risk for high-dose lead exposure and should be screened by a blood lead test at 12 months.

and again, if possible, at 24 months (since blood lead levels often peak at ages greater than 12 months). If the answer to any question is positive, the.

child is potentially at high risk for high-dose lead exposure, and a blood lead test should be obtained. FOR CHILDREN PREVIOUSLY AT LOW.

RISK, ANY HISTORY SUGGESTING THAT EXPOSURE TO LEAD HAS INCREASED SHOULD BE FOLLOWED UP WITH A BLOOD LEAD TEST.

EXAMPLE: A pediatrician in southern California almost exclusively serves communities built after 1988. She is aware, however, that some of her.

patients' families store juice and punch in pottery imported from Mexico. In her guidance to parents, she warns them that lead can leach from.

in the community. THE QUESTIONS ARE NOT A SUBSTITUTE FOR A BLOOD LEAD TEST.

USING QUESTIONNAIRE RESULTS

IF ANSWERS TO THE QUESTIONNAIRE INDICATE THAT THE CHILD IS NOT AT HIGH RISK FOR HIGH-DOSE LEAD EXPOSURE, THE CHILD SHOULD BE SCREENED AT 12 MONTHS OF AGE, AND, IF RESOURCES ALLOW, AT 24 MONTHS OF AGE.

IF ANSWERS TO THE QUESTIONNAIRE INDICATE THAT THE CHILD IS AT RISK FOR HIGH-DOSE LEAD EXPOSURE, THE CHILD SHOULD BE SCREENED STARTING AT 6 MONTHS OF AGE.

FOR CHILDREN PREVIOUSLY AT LOW RISK, ANY HISTORY SUGGESTING THAT EXPOSURE TO LEAD HAS INCREASED SHOULD BE FOLLOWED UP WITH A BLOOD LEAD TEST.

SCREENING SCHEDULE

The following sections provide a minimum screening schedule for children aged 6 up to 36 and 36 to 72 months. The schedule is not rigid. Rather, it is a guide for pediatric health-care providers and screening programs to use in conjunction with other pertinent information in determining when an individual child should be tested.

CHILDREN 6 UP TO 36 MONTHS OF AGE:

A questionnaire should be used at each routine office visit to assess the potential for high-dose lead exposure and, therefore, the appropriate frequency of screening.

- **SCHEDULE IF THE CHILD IS AT LOW RISK FOR HIGH DOSE LEAD EXPOSURE BY QUESTIONNAIRE:** A child at low risk for exposure to high-dose lead sources by questionnaire should have an initial blood lead test at 12 months of age. If the 12-month blood lead result is less than 10 UG/DL, the child should be retested at 24 months if possible, since that is when blood lead levels peak. If a blood lead test result is 10-14 UG/DL, the child should be retested every 3 to 4 months. After 2 consecutive measurements are less than 10 ug/dL or three are less than 15 ug/dL, the child should be retested in a year. If any blood lead test result is greater than or equal to 15 UG/DL, the child needs individual case management, which includes retesting the child at least every 3 to 4 months.

- **SCHEDULE IF THE CHILD IS AT HIGH RISK FOR HIGH DOSE LEAD EXPOSURE BY QUESTIONNAIRE:** A child at high risk for exposure to high-dose lead sources by questionnaire should have an initial blood lead test at 6 months of age. If the initial blood lead result is less than 10 UG/DL, the child should be rescreened every 6 months. After 2 subsequent consecutive measurements are less than 10 ug/dL or three are less than 15 ug/dL, testing frequency can be decreased to once a year. If a blood lead test result is 10-14 UG/DL, the child should be screened every 3 to 4 months. Once 2 subsequent consecutive measurements are less than 10 ug/dL or three are less than 15 ug/dL, testing frequency can be decreased to once a year. If any blood lead test result is greater than or equal to 15 UG/DL, the child needs individual case management, which includes retesting the child at least every 3 to 4 months.

CHILDREN GREATER THAN OR EQUAL TO 36 MONTHS AND LESS THAN 72 MONTHS AGE:

As for younger children, a questionnaire should be used at each routine office visit of children from 36 to 72 months of age. Any child at high risk by questionnaire who has not previously had a blood lead test should be tested. All children who have had venous blood lead tests greater than or equal to 15 ug/dL or who are at high risk by questionnaire should be screened at least once a year until their sixth birthday (age 72 months) or later, if indicated (for example, a developmentally delayed child with pica). Children should also be rescreened any time history suggests exposure has increased. Children with blood lead levels greater than or equal to 15 ug/dL should receive followup as described below.

FOLLOWUP OF CHILDREN WITH BLOOD LEAD LEVELS GREATER THAN OR EQUAL TO 15 UG/DL

Followup of children with blood lead levels greater than or equal to 15 ug/dL is discussed in more detail in later chapters and is briefly summarized below. In general, such children should receive blood lead tests at least every 3 to 4 months.

IF THE BLOOD LEAD LEVEL IS 15 -19 UG/DL, the child should be screened every 3-4 months, the family should be given education and nutritional counseling as described in Chapter 4, and a detailed environmental history should be taken to identify any obvious sources or pathways of lead exposure. When the venous blood lead level is in this range in two consecutive tests 3-4 months apart, environmental investigation and
abatement should be conducted, if resources permit.

IF THE BLOOD LEAD LEVEL IS GREATER THAN OR EQUAL TO 20 UG/DL, the child should be given a repeat test for confirmation. If the venous blood lead level is confirmed to be greater than or equal to 20 ug/dL, the child should be referred for medical evaluation and followup as described in Chapter 7. Such children should continue to receive blood lead tests every 3-4 months or more often if indicated. Children with blood lead levels greater than or equal to 45 ug/dL must receive urgent medical and environmental followup, preferably at a clinic with a staff experienced in dealing with this disease. Symptomatic lead poisoning or a venous blood lead concentration greater than or equal to 70 ug/dL is a medical emergency, requiring immediate inpatient chelation therapy, as described in Chapter 7.

CLASSIFICATION ON THE BASIS OF SCREENING TEST RESULTS

On the basis of screening test results, children can be classified into categories according to their risk for adverse effects of lead. The urgency and type of followup are based on these risk classes. These classes are shown in Table 6.3.

MEASUREMENT OF BLOOD LEAD LEVELS

VENOUS BLOOD IS PREFERRED FOR BLOOD LEAD MEASUREMENT.

ANALYTICAL VARIATION IN THE LABORATORY CAN AFFECT BLOOD LEAD RESULTS.

LABORATORIES MEASURING BLOOD LEAD LEVELS SHOULD PARTICIPATE SUCCESSFULLY IN A BLOOD LEAD PROFICIENCY TESTING PROGRAM.

Several factors can influence the quality of blood lead measurements. The ubiquity of lead in the environment makes contamination of specimens during collection a major source of error. Analytical variation in the laboratory can affect results. Accuracy and precision of blood lead measurements, particularly at low concentrations, can be assured by the use of appropriate analytical standards, maintenance of equipment, training of personnel, and participation in external proficiency testing programs.

Since blood collected by venipuncture has a low likelihood of contamination compared to blood collected by finger stick, venous blood is the preferred specimen for analysis and should be used for lead measurement whenever practicable. In addition, venous specimens provide a larger volume for analysis and are less prone to clotting and other problems that can be encountered with capillary specimens (DeSilva and Donnan, 1977; Mitchell et al., 1974).

Fingerstick specimens are acceptable for blood lead screening, provided that special collection procedures are followed to minimize the risk of contamination. Personnel must be thoroughly trained in collection procedures. A procedure for collecting finger stick specimens is described in Appendix I. At the present time, not all laboratories will accept capillary samples for blood lead analysis.

Elevated blood lead results obtained on capillary specimens are presumptive and must be confirmed using venous blood. In general, children who have blood lead levels greater than or equal to 15 ug/dL on capillary samples should have these levels confirmed on venous samples, according to the timetable in Table 6.4. A child with a blood lead level greater than or equal to 70 ug/dL or with symptoms of lead poisoning should be treated immediately while the results of an immediate confirmatory test are awaited.

ADDITIONAL ANALYTICAL CONSIDERATIONS

Blood lead levels can be determined by several analytic methods. The method used can affect the specimen volume required, the choice of anticoagulant (usually heparin or ethylenediaimedinitetraacetic acid (EDTA)), and other aspects related to specimen suitability. Specimen collection procedures and equipment must be checked for compatibility with laboratory requirements. Special lead-free evacuated tubes are available for blood collection, but standard tubes containing EDTA or heparin (lavender or green caps) can be acceptable after screening each lot to determine the lead content of the containers, needles, etc. Though reports of unsuitable levels of background lead in other collection materials are infrequent, all materials used should be determined to be lead-free before use.

Several analytical techniques available can be used to make accurate blood lead measurements at levels <25 ug/dL. These techniques are electrochemical techniques, usually anodic stripping voltammetry (ASV), and atomic absorption spectroscopy (AAS). Either of these techniques is capable of achieving detection limits <2 to 5 ug/dL. Success by these methods, however, requires careful and meticulous attention to the details of the analysis.

The reliability of a set of blood lead measurements is greatly enhanced by the use of high quality lead standard solution for instrument calibration. In the United States, the National Institute of Science and Technology has made such a material (SRM 3121) available. In addition, a set of whole blood reference materials (SRM 955A, Lead in Blood) provides a useful set of control materials over a wide range of concentrations -- about 6 to 70 ug/dL.

Laboratories where blood is tested for lead levels should be successful participants in a blood lead proficiency testing program, such as the program conducted jointly by CDC, the Health Resources and Services Administration, and the University of Wisconsin. In interpreting laboratory results, it should be recognized that a proficient laboratory should measure blood lead levels to within several ug/dL of the true value (for example, within 4 or 6 ug/dL of a target value). The blood lead level reported by a laboratory, therefore, may be several ug/dL higher or lower than the actual blood lead level.
Analytical variability must be considered when interpreting blood lead results. Changes in successive blood lead measurements on an individual can be considered significant only if the net difference of results exceeds the limit of analytic variance that the laboratory allows. As a general rule, trends should not be considered significant unless the magnitude of the change is greater than or equal to 5 ug/dL.

The degree of analytical variability between laboratories that employ different analytic methods usually exceeds that within a single laboratory. Therefore, a single laboratory using one analytical method should be used to best compare multiple blood lead results from an individual or a population.

**ERYTHROCYTE PROTOPORPHYRIN (EP)**

EP IS NOT A SENSITIVE TEST FOR IDENTIFYING CHILDREN WITH BLOOD LEAD LEVELS BELOW ABOUT 25 UG/DL.

An EP level is elevated if it is greater than or equal to 35 ug/dL when standardized using 241 L cm-1 mmol-1, greater than or equal to 28 ug/dL when standardized using 297 L cm-1 mmol-1, or greater than or equal to 70 umol/mol when measured in umol/mol units. All elevated EP results should be followed by a venous blood lead test.

Laboratories measuring EP levels should be successful participants in an EP proficiency testing program.

**INTERPRETING EP RESULTS AND FOLLOWING UP ON CHILDREN WITH HIGH EP LEVELS.**

EP is not a sensitive test to identify children with blood lead levels below about 25 ug/dL, and therefore it is no longer the screening test of choice. Generally, EP is measured using a two-step extraction process followed by direct fluorometric measurement or by front-surface fluorometry (hematofluorometry). Most protoporphyrin in erythrocytes (about 90%) exists as zinc protoporphyrin (ZnPP) (Smith et al., 1980; Gotelli et al., 1980). This fraction is preferentially measured by hematofluorometers. Extraction methods measure all the protoporphyrin present, but strip the zinc from the ZnPP during the extraction process. For this reason, extraction results are sometimes referred to as {zinc} free erythrocyte protoporphyrin (FEP). Although the chemical forms measured by the two methods differ slightly, on a weight basis they are roughly equivalent, so results reported as EP, ZnPP, or FEP all reflect essentially the same analyte (Stanton et al., 1989).

In the past, an absorptivity of 241 L cm-1 mmol-1 has been used to determine EP levels. Recently, however, the correct absorptivity has been determined to be 297 L cm-1 mmol-1 (Gunter et al., 1989). Use of the correct absorptivity will result in EP values about 19% lower than those standardized using 241 L cm-1 mmol-1. Standardization of EP levels that are based on the correct absorptivity is expected to be widely adopted in 1992. Use of the correct standardization requires a change in calibration and is not simply a reduction of the screening cutoff value. Standardization criteria should also be considered when reviewing data in the literature.

An EP result of greater than or equal to 35 ug/dL standardized using 241 L cm-1 mmol-1 or greater than or equal to 28 ug/dL standardized using 297 L cm-1 mmol-1 is considered elevated. All elevated EP results should be followed with a venous blood lead test to determine if lead poisoning is responsible for the elevation. Elevated concentrations of EP also result from several health conditions other than lead intoxication, particularly iron deficiency (Reeves et al., 1984; Yip et al., 1983; Thomas et al., 1977). The iron status of children with elevated EP levels should always be determined, especially since iron deficiency and lead poisoning often coexist. In such cases, the EP may be disproportionately elevated in comparison to the blood lead level.

Some hematofluorometers report EP levels as umol ZnPP/mol heme. For instruments that give results in these units, EP values greater than or equal to 70 umol/mol should be considered elevated and should be promptly investigated (Stanton et al., 1989).

**ANALYTIC CONSIDERATIONS**

Only fresh blood is suitable for analysis by hematofluorometer (Blumberg et al., 1977). Complete oxygenation of sample hemoglobin is necessary to prevent low results in some instruments. The hemoglobin concentration in the sample can also affect hematofluorometer EP readings. Results obtained by extraction methods are not affected by these factors and can be used to confirm hematofluorometer EP results.

As with lead data, analytical variance must be considered when EP data are being interpreted. If trends in EP data are to be assessed correctly, analyses should preferably be performed by a single laboratory, and the variance of the method should be known when interpreting data. As with blood lead levels, interlaboratory variance usually exceeds intralaboratory variance. The observed variance for EP is wider than that for blood lead, underscoring the importance of analytical variance in the evaluation of EP data. In addition, because of substantial intermethod differences, extraction and hematofluorometer results should not be compared when assessing trends (Mitchell and Doran, 1985; Kaul et al., 1983; Peter et al., 1978). Laboratories that test patient specimens for EP levels should be participants in one or more external proficiency testing programs.

**REFERENCES**


CHAPTER 7. DIAGNOSTIC EVALUATION AND MEDICAL MANAGEMENT OF CHILDREN BLOOD LEAD LEVELS > OR = 20 UG/DL

SUMMARY

CHILDREN WITH BLOOD LEAD LEVELS > OR = 20 UG/DL NEED COMPLETE MEDICAL EVALUATIONS.

SEVERAL PHARMACOLOGIC AGENTS CAN REDUCE BLOOD LEAD LEVELS; HOWEVER, THE MOST IMPORTANT FACTOR IS REDUCING THE CHILD'S EXPOSURE TO LEAD.

RESEARCH AND NEW DEVELOPMENTS MAY CHANGE MANY ASPECTS OF THE MEDICAL MANAGEMENT OF POISONED CHILDREN.

Children with blood lead levels between 10 ug/dL and 19 ug/dL and their siblings need followup and repeat screening as described in previous chapters. They do not, however, need medical evaluation as described in this chapter.

The cornerstones of clinical management are careful clinical and laboratory surveillance of the child, medical treatment when indicated, and eradication of controllable sources of environmental lead. THE MOST IMPORTANT FACTOR IN CASE MANAGEMENT IS TO REDUCE THE CHILD’S EXPOSURE TO LEAD.

All children with confirmed venous blood lead levels > or = 20 ug/dL require medical evaluation. The urgency of further medical evaluation depends on the blood lead level and whether symptoms are present.

The decision to institute medical management should virtually always be made on the basis of a venous blood lead measurement. No other screening test can be considered diagnostic. If the first evaluation was made on capillary blood, a confirmatory venous blood lead level must be done. Even if the first diagnostic measurement was on venous blood, it is preferable to retest before starting chelation therapy. For children with blood lead levels > or = 70 ug/dL or clinical symptoms of lead poisoning, chelation should not be postponed while awaiting results of the repeat test.
SYMPTOMS OF LEAD POISONING

SYMPTOMATIC LEAD POISONING IS A MEDICAL EMERGENCY.

SYMPTOMS OF LEAD POISONING IN A CHILD WITH AN ELEVATED BLOOD LEAD LEVEL CONSTITUTE A MEDICAL EMERGENCY, AND THE CHILD SHOULD BE HOSPITALIZED. Symptoms, which can mimic several other pediatric disorders, must be looked for so they are not missed (Piomelli et al., 1984).

Acute lead encephalopathy is characterized by some or all of these symptoms: coma, seizures, bizarre behavior, ataxia, apathy, incoordination, vomiting, alteration in the state of consciousness, and subtle loss of recently acquired skills. Any one or a mixture of these symptoms, associated with an elevated blood lead level, is an acute medical emergency. Lead encephalopathy is almost always associated with a blood lead level exceeding 100 ug/dL, although, occasionally, it has been reported at blood lead levels as low as 70 Ug/dL. Even when identified and promptly treated, severe and permanent brain damage may result in 70% - 80% of children with lead encephalopathy (Perlstein and Attala, 1966). Children with symptomatic lead poisoning with or without encephalopathy represent an acute medical emergency. THE POSSIBILITY OF LEAD ENCEPHALOPATHY SHOULD BE CONSIDERED IN THE DIFFERENTIAL DIAGNOSIS OF CHILDREN PRESENTING WITH COMA AND CONVULSIONS OF UNKNOWN ETIOLOGY.

Except for coma and seizures, symptomatic lead poisoning without encephalopathy is characterized by symptoms similar to those of lead encephalopathy. Symptomatic lead poisoning without encephalopathy is characterized by one or a combination of these symptoms: decrease in play activity, lethargy, anorexia, sporadic vomiting, intermittent abdominal pain, and constipation. These symptoms are usually associated with a blood lead levels of at least 70 ug/dL, although occasionally cases have been associated with levels as low as 50 ug/dL. If the blood lead level is below 50 ug/dL, other causes of the symptoms should be sought. SINCE ACUTE LEAD ENCEPHALOPATHY MAY DEVELOP IN ANY SYMPTOMATIC CHILD, TREATMENT AND SUPPORTIVE MEASURES MUST BE STARTED IMMEDIATELY ON AN EMERGENCY BASIS.

EVALUATION OF THE CHILD WITH A BLOOD LEAD LEVEL > OR = 20 UG/DL

TAKE A CAREFUL HISTORY AND DO A PHYSICAL EXAMINATION.

INCLUDE EVALUATION OF THE CHILD'S IRON STATUS AND OTHER SPECIAL DIAGNOSTIC TESTS.

HISTORY AND PHYSICAL EXAMINATION

A child with a blood lead level > or = 20 ug/dL should have a pediatric evaluation, whether or not symptoms are present.

Special attention should be given to:

1. A detailed history, including the presence or absence of clinical symptoms, child's mouthing activities, the existence of pica, nutritional status (especially iron and calcium intake), dietary habits, family history of lead poisoning, potential sources of lead exposure (including exposure due to home renovation), and previous blood lead measurements.
2. Detailed environmental and occupational histories of adults in the household or other places the child spends a lot of time.
3. The physical examination, with particular attention to the neurologic examination and psychosocial and language development. A neurobehavioral assessment may be useful in children receiving chelation therapy both at the time of diagnosis and as the child approaches school age. Findings of language delay or other problems can prompt referral to appropriate programs.
4. Evaluation of iron status using measurement of iron and total iron binding capacity or of ferritin.

IRON STATUS AND SPECIAL TESTS

1. TESTS FOR IRON DEFICIENCY
   BECAUSE IRON DEFICIENCY CAN ENHANCE LEAD ABSORPTION AND TOXICITY AND OFTEN COEXISTS WITH IT, ALL CHILDREN WITH BLOOD LEAD LEVELS > OR = 20 UG/DL SHOULD BE TESTED FOR IRON DEFICIENCY. Measurements of hemoglobin, hematocrit, and reticulocyte are not adequately sensitive, and erythrocyte protoporphyrin (EP) is not specific enough to diagnose iron deficiency (although EP can be used to screen for iron deficiency).

   SERUM IRON AND IRON BINDING CAPACITY (TRANSFERRIN SATURATION) AND FERRITIN are the most sensitive indicators of iron status. An abnormally low ratio of serum iron to iron binding capacity (transferrin saturation) of 0.2 is consistent with iron deficiency. The serum ferritin level, however, is the most definitive and accurate indication of overall iron status, although it is an acute phase reactant and may be falsely elevated in sick children; a value < or = 12 ug/dL indicates iron deficiency. Although all iron deficient children should receive treatment for this condition, the treatment should not be started until after chelation is completed in children receiving dimercaprol (BAL).

2. EP LEVEL
   An elevated EP level indicates impairment of the heme biosynthetic pathway. EP levels are sensitive screening tests for iron deficiency, and iron status should be assessed in any child with an elevated EP level (that is, > or = 35 ug/dL when standardized using 241 L cm-1 mmol-1, > or = 28 ug/dL when standardized using 297 L cm-1 mmol-1, or > or = 70 umol/mol when measured in umol/mol units).
Because EP levels take about 2 weeks to increase, EP levels may provide an indication of the duration of lead exposure (Chisolm, 1982; Chisolm, personal communication). Similarly, monitoring the EP level after medical and environmental interventions for poisoned children may be useful. If exposure to lead has ceased, EP values elevated because of lead poisoning decline slowly over several weeks or months (Piomelli et al., 1984). A progressive decline in EP concentrations indicates that combined medical and environmental case management is Proceeding efficaciously.

3. EDETATE DISODIUM CALCIUM (CANA2EDTA) PROVOCATIVE CHELATION TEST

The mobilization test is used to determine whether a child with an initial confirmatory blood lead level of 25 to 44 µg/dL will respond to chelation therapy with a brisk lead diuresis (Piomelli et al., 1984; Markowitz and Rosen, 1991). Because of the cost and staff time needed for quantitative urine collection, this test is used only in selected medical centers where large numbers of lead-poisoned children are treated. Children whose blood lead levels are \( > \sigma = 45 \) µg/dL should not receive a provocative chelation test; they should be referred for appropriate chelation therapy immediately.

The outcome of the provocative chelation test is determined not by a decrease in the blood lead level but by the amount of lead excreted per dose of CaNa2EDTA given. This ratio correlates well with blood lead levels. In one study, almost all children with blood lead levels 45 µg/dL had positive provocative tests, 76% of the children with blood lead levels 35 to 44 µg/dL had positive test results, and 35% of the children with blood lead levels 25 to 34 µg/dL had positive test results (Markowitz and Rosen, 1991). This test should not be done until the child is iron replete, since iron status may affect the outcome of the test (Markowitz et al., 1990).

CONDUCTING A CANA2EDTA PROVOCATIVE CHELATION TEST. First, a repeated baseline blood lead level must be obtained. The patient is asked to empty the bladder, and then CaNa2EDTA is administered at a dose of 500 mg/m² in 5% dextrose infused OVER 1 HOUR. (A somewhat painful but practical alternative is to administer intramuscularly the same dose mixed with procaine so that the final concentration of procaine is 0.5%.) All urine must be collected with lead-free equipment over the next 8 hours. (An 8 hour mobilization test has been shown to be as reliable as a 24-hour mobilization test (Markowitz and Rosen, 1984).) An 8-hour test can be accomplished on an out-patient basis, but the patient should not leave the clinic during this test. In the laboratory, the urine volume should be carefully measured and stored at 20 degrees Centigrade until the lead concentration is measured. Extreme care must be taken to ensure that lead-free equipment is used.

The use of lead-free apparatus for urine collection is mandatory. Special lead-free collection apparatus must be used if valid test results are to be obtained. The laboratory that will perform the analysis should supply the proper collection apparatus. Preferably, urine should be voided directly into polyethylene or polypropylene bottles that have been cleaned by the usual procedures, then washed in nitric acid, and thoroughly rinsed with deionized, distilled water. For children who are not toilet trained, plastic pediatric urine collectors can be used. Urine collected in this manner should be transferred directly to the urine collection bottles.

INTERPRETATION OF A CANA2EDTA PROVOCATIVE CHELATION TEST. To obtain the total lead excretion in micrograms, the concentration of lead in the urine (in micrograms per milliliter) is multiplied by the total urinary volume (in milliliters). The total urinary excretion of lead (micrograms) is divided by the amount of CaNa2EDTA given (milligrams) to obtain the lead excretion ratio:

\[
\text{Lead excreted (ug)} \div \text{CaNa2EDTA given (mg)}
\]

An 8-hour CaNa2EDTA chelation provocative test is considered positive if the lead excretion ratio is \( > 0.6 \) (Markowitz and Rosen, 1991). Some clinicians use a cutoff of 0.5 for the lead excretion ratio (Weinberger et al., 1987). Children with blood lead levels 25 to 44 µg/dL and positive chelation test results should undergo a 5-day course of chelation.

Regardless of age, all children with elevated blood lead values and negative provocative chelation results should have blood lead levels measured monthly. If the elevation in blood lead values persists, the CaNa2EDTA provocative test can be repeated every 1 to 3 months and interpreted according to the above guidelines.

4. RADIOLOGIC EXAMINATION OF THE ABDOMEN

Radiologic examination of the abdomen (flat plate) may show radiopaque foreign material if the material has been ingested during the preceding 24 to 36 hours. Neither negative nor positive x-ray results are diagnostic or definitive. A flat plate of the abdomen may, however, provide information about the source of lead if paint chips or other lead objects are found.

5. RADIOLOGIC EXAMINATION OF THE LONG BONES

X-rays of the long bones are unreliable for diagnosing acute lead poisoning, and they should not be obtained on a routine basis. They may provide some indication of whether lead poisoning has occurred in the past or has been ongoing for a length of time, and this may occasionally be important. Lines of increased density in the metaphyseal plate of the distal femur, proximal tibia, and fibula may be caused by lead which has disrupted the metabolism of bone matrix. Although these lines are sometimes called lead lines, they are areas of increased mineralization or calcification and not x-ray shadows of deposited lead.

The following tests are NOT indicated for the diagnosis or clinical management of lead poisoning:

6. MICROSCOPIC EXAMINATION OF RED CELLS FOR BASOPHILIC STIPPLING

Since basophilic stippling is not always found in severe lead poisoning and is insensitive to lesser degrees of lead poisoning, it is not useful in diagnosis.

7. TESTS OF HAIR AND FINGERNAILS FOR LEAD LEVELS

The levels of lead in hair or fingernails do not correlate well with blood lead levels, except in extreme cases of symptomatic lead poisoning; therefore, these tests are not useful in diagnosis. Children should never receive chelating agents on the basis of analyses of lead levels in hair or fingernails.
PHARMACOLOGY OF CHELATING AGENTS

Table 7 1 Several drugs are used in the treatment of lead poisoning. These drugs, capable of binding or chelating lead, deplete the soft and hard (skeletal) tissues of lead and thus reduce its acute toxicity (Chisolm, 1968; Markowitz and Rosen, 1984; Piomelli et al., 1984; Rosen et al., in press). All drugs have potential side effects and must be used with caution (Piomelli et al., 1984). The basic pharmacologic characteristics of the various drugs are described below.

BAL

MECHANISM OF ACTION. Two molecules of dimercaprol (BAL) combine with one atom of heavy metal to form a stable complex. BAL enhances fecal and urinary excretion of lead and diffuses well into erythrocytes. Because it is predominantly excreted in bile, BAL can be administered in the presence of renal impairment (Chisolm, 1968).

ROUTE OF ADMINISTRATION AND DOSAGE. BAL is available only in peanut oil for intramuscular administration. It is usually given every 4 hours, although it may be given every 8 hours; dosages are discussed under the heading Treatment Guidelines for Children with Blood Lead Levels ≥ 20 ug/dL.

PRECAUTIONS AND TOXICITY. For patients with glucose-6-phosphate dehydrogenase deficiency (G-6-PD), some clinicians recommend that BAL should be used only in life-threatening situations because it may induce hemolysis. Medicinal iron should never be administered during BAL therapy, because the combination of iron and BAL has been implicated in serious reactions. If iron deficiency coexists, it should not be treated until after BAL therapy has been completed. In cases of extreme anemia, blood transfusions are preferable.

Between 30% and 50% of patients who receive BAL will experience side effects. Mild febrile reactions and transient elevations of hepatic transaminase may be observed. Other minor adverse effects include, in order of frequency, nausea and occasional vomiting, headache, mild conjunctivitis, lacrimation, rhinorrhea, and salivation. Most side effects are transient and rapidly subside as the drug is metabolized and excreted. Intravenous hydration coupled with restricting oral intake can circumvent, in large part, gastrointestinal distress.

BAL SHOULD NOT BE USED FOR CHILDREN WHO ARE ALLERGIC TO PEANUTS OR PEANUT PRODUCTS.

CaNa2EDTA

Only CaNa2EDTA can be used for treating children with lead poisoning. Na2EDTA (disodium edetate) should never be used for treating children with lead poisoning because it will induce tetany and possibly fatal hypocalcemia.

MECHANISM OF ACTION. CaNa2EDTA increases urinary lead excretion twentyfold to fiftyfold. CaNa2EDTA removes lead from the extracellular compartment only, because it does not enter cells (Osterloh and Becker, 1986).

ROUTE OF ADMINISTRATION AND DOSAGE. The preferred route for administration of CaNa2EDTA is intravenous. CaNa2EDTA must be diluted to a concentration of <0.5% either in dextrose and water or in 0.9% saline solution. It can be given as a continuous infusion or it can be given in two divided doses a day through a heparin lock over 30 to 60 minutes. CaNa2EDTA causes extreme pain when administered intramuscularly; therefore, when given by this route, it should be mixed with procaine so that the final concentration of procaine is 0.5%. CaNa2EDTA should never be given orally because it enhances absorption of lead from the gastrointestinal tract.

Dosages vary by situation and are detailed under the heading Treatment Guidelines for Children with Blood Lead Levels ≥ 20 ug/dL. Individual courses should be limited to 5 days and repeated courses should be given at a minimum of 2- to 5-day intervals. Particularly when CaNa2EDTA is given on an outpatient basis, some clinicians use sequential 3-day courses of treatment.

PRECAUTIONS AND TOXICITY. During chelation therapy with CaNa2EDTA, urine output, urine sediment, blood urea nitrogen (BUN), serum creatinine, and hepatocellular enzyme levels must be carefully monitored. The appearance of protein and formed elements in urinary sediment, and rising BUN and serum creatinine values reflect impending renal failure, the serious toxicity associated with inappropriately excessive, or prolonged administration of CaNa2EDTA. Liver transaminases may increase by the fifth day of therapy, but return to pretreatment levels within a week after treatment has ended.

When CaNa2EDTA is used alone without concomitant BAL therapy, it may aggravate symptoms in patients with very high blood lead levels. Therefore, it should be used in conjunction with BAL when the blood lead level is ≥ 70 ug/dL or overt clinical symptoms of lead poisoning are present. In such cases, the first dose of BAL should always precede the first dose of CaNa2EDTA by at least 4 hours.

The kidney is the principal site of potential toxicity. Renal toxicity is dose related, reversible, and rarely (if ever) occurs at doses <1500 mg/m² when the patient is adequately hydrated. CaNa2EDTA must never be given in the absence of an adequate urine flow (Piomelli et al., 1984).

D-Penicillamine

The Food and Drug Administration (FDA) has approved D-penicillamine for the treatment of Wilson's disease, cystinuria, and severe, active rheumatoid arthritis. Although not approved for this use, it is used in some centers for treating lead poisoning. Until the recent approval of succimer, it was the only commercially available oral chelating agent. It can be given over a long period (weeks to months). D-penicillamine has been used mainly for children with blood lead levels <45 ug/dL.

MECHANISM OF ACTION. D-penicillamine enhances urinary excretion of lead, although not as effectively as CaNa2EDTA. Its specific mechanism and site of action are not well understood.
If succimer is used, the following precautions must be taken:

PRECAUTIONS AND TOXICITY. Toxic side effects (albeit minor in most cases) occur in as many as 33% of patients given the drug (Shannon et al., 1988). The main side effects of D-penicillamine are reactions resembling those of penicillin sensitivity, including rashes, leukopenia, thrombocytopenia, hematuria, proteinuria, hepatocellular enzyme elevations, and eosinophilia. Anorexia, nausea, and vomiting are infrequent. Of most concern, however, are isolated reports of nephrotoxicity, possibly from hypersensitivity reactions. For these reasons, patients should be carefully and frequently monitored for clinically obvious side effects, and frequent blood counts, urinalyses, and renal function tests should be performed. In particular, blood counts and urinalyses should be done on day 1, day 14, day 28, and monthly thereafter. If the absolute neutrophil count falls to < 1500/ug/dL, the count should be rechecked immediately, and treatment should be stopped if it falls to < 1200/ug/dL.

D-penicillamine should not be given on an outpatient basis if exposure to lead is continuing or the physician has doubts about compliance with the therapeutic regimen.

ROUTE OF ADMINISTRATION AND DOSAGE. D-penicillamine is administered orally. It is available in capsules or tablets (125 mg and 250 mg). These capsules can be opened and suspended in liquid, if necessary. The usual dose is 25 to 35 mg/kg/day in divided doses. Side effects can be minimized, to an extent, by starting with a small dose and increasing it gradually, monitoring all the time for side effects. For example, 25% of the desired final dose could be given in week 1, 50% in week 2, and the full dose by week 3.

PRECAUTIONS AND TOXICITY. To date, toxicity due to succimer (transient elevations in hepatic enzyme activities) appears to be minimal. Consequently, the full spectrum and incidence of adverse reactions, including the possibility of hypersensitivity or idiosyncratic reactions, have not been determined.

MECHANISM OF ACTION. Succimer appears to be more specific for lead than the most commonly used chelating agent, CaNa2EDTA; the urinary loss of essential trace elements (for example, zinc) appears to be considerably less with succimer than with CaNa2EDTA (Aposhian and Aposhian, 1990). The site of lead chelation by succimer is not known.

ROUTE OF ADMINISTRATION AND DOSAGE. Succimer is administered orally. It is available in 100 mg capsules. The recommended initial dose is 350 mg/m square (10 mg/kg) every 8 hours for 5 days, followed by 350 mg/m square (10 mg/kg) every 12 hours for 14 days. A course of treatment, therefore, lasts 19 days. If more courses are needed, a minimum of 2 weeks between courses is preferred, unless blood lead levels fall below 45 ug/dL and the lead hazards in their homes are abated or alternative lead hazard-free housing has been identified.

In rats, gastrointestinal absorption of lead and whole body lead retention were reduced by a single oral dose of succimer (Kapoor et al., 1989). The potential for enhancing human lead absorption from the gastrointestinal tract during the use of succimer is under study.

1. Children with blood lead levels >45 ug/dL who are being treated with succimer, should, if possible, be hospitalized until their blood lead levels fall below 45 ug/dL and the lead hazards in their homes are abated or alternative lead hazard-free housing has been identified.

D-PENICILLAMINE SHOULD NOT BE ADMINISTERED TO PATIENTS WITH KNOWN PENICILLIN ALLERGY.
TREATMENT GUIDELINES FOR CHILDREN WITH BLOOD LEAD LEVELS > OR = 20 UG/DL

THE MOST IMPORTANT FACTOR IN MANAGING CHILDHOOD LEAD POISONING IS REDUCING THE CHILD'S EXPOSURE TO LEAD.

CHILDREN WITH SYMPTOMATIC LEAD POISONING, WITH AND WITHOUT ENCEPHALOPATHY, SHOULD BE MANAGED BY A MULTIDISCIPLINARY TEAM.

ASYMPTOMATIC CHILDREN WITH BLOOD LEAD LEVELS > OR = 45 UG/DL SHOULD RECEIVE CHELATION THERAPY.

DIFFERENT CLINICAL CENTERS AND PROGRAMS USE DIFFERENT PROTOCOLS TO MEDICALLY MANAGE CHILDREN WITH BLOOD LEAD LEVELS OF 25 TO 44 UG/DL.

THE SINGLE MOST IMPORTANT FACTOR IN MANAGING OF CHILDHOOD LEAD POISONING IS REDUCING THE CHILD'S EXPOSURE TO LEAD; SOME CHILDREN, HOWEVER, WILL BENEFIT FROM CHELATION THERAPY. One approach for pharmacologic treatment of children with lead poisoning follows. It is a general guide and is not the only pharmacologic regimen that can be used to treat poisoned children.

MEDICAL MANAGEMENT OF SYMPTOMATIC LEAD POISONING (WITH OR WITHOUT ENCEPHALOPATHY)

GENERAL MANAGEMENT. Children with symptomatic lead poisoning (with or without encephalopathy) must be treated only at a pediatric center that has an intensive care unit. They should be managed by a multidisciplinary team that includes, as needed, critical care, toxicology, neurology, and neurosurgery. The child's neurological status and fluid balance must be carefully monitored.

The symptoms associated with lead poisoning (with or without lead encephalopathy) are described under the heading Symptoms of Lead Poisoning. One or more of those symptoms associated with an elevated blood lead level constitutes an acute medical emergency. Because chelation regimens are the same for cases of symptomatic lead poisoning (with and without encephalopathy), guidelines for clinical management have been included in a single section.

CHELATION THERAPY. Although succimer has been approved for chelation of children with blood lead levels >45 ug/dL, experience in treating symptomatic children is limited. Therefore, the treatment regimen discussed here uses CaNa2EDTA and BAL. Chelation with succimer is discussed under the heading Succimer.

Start treatment with a dose of 75 mg/m square BAL only, given by deep intramuscular injection; administer BAL at a dose of 450 mg/m square/day in divided doses of 75 mg/m square every 4 hours. Once this dose is given and an adequate urine flow is established, administer CaNa2EDTA at a dose of 1,500 mg/m square/day. Give CaNa2EDTA as a continuous intravenous infusion in dextrose and water or in a 0.9% saline solution. The concentration of CaNa2EDTA should not exceed 0.5% in the parenteral fluid. (When treating a child with encephalopathy, the physician may choose to give CaNa2EDTA intramuscularly to reduce the amount of fluid administered.) Treat with combined BAL-CaNa2EDTA therapy for a total of 5 days. During treatment, monitor renal and hepatic function and serum electrolyte levels daily (Piomelli et al., 1984).

A second course of chelation therapy with CaNa2EDTA alone (at blood lead levels 45 - 69 ug/dL) or combined with BAL (at blood lead levels 70 ug/dL), may be required once there is a rebound in the blood lead level after chelation. Wait at least 2 days before giving a second course of chelation. A third course is required only if the blood lead concentration rebounds to a value > or = 45 ug/dL within 5 to 7 days after the second course of treatment. Unless there are unusual and compelling clinical reasons, wait at least 5 to 7 days before beginning a third course of CaNa2EDTA (Piomelli et al., 1984).

MEDICAL MANAGEMENT OF ASYMPTOMATIC LEAD POISONING

Clinical management of asymptomatic lead-poisoned children with blood lead levels high enough to require chelation is similar to that of symptomatic children. Focus on reducing the child's exposure to lead and decreasing the child's body burden of lead.

Although succimer has been approved for chelation of children with blood lead levels > 45 ug/dL, experience with this drug is limited. Therefore, the treatment regimen discussed here uses CaNa2EDTA and BAL.

BLOOD LEAD LEVEL > OR = 70 UG/DL. Children with blood lead levels > or = 70 ug/dL (with or without symptoms) represent an acute medical emergency. If the blood lead level is > or = 70 ug/dL, give both BAL and CaNa2EDTA in the same doses and using the guidelines as for treatment of symptomatic lead poisoning (discussed under the heading Treatment Guidelines for Children with Blood Lead Levels > or = 20 ug/dL.). A second course of chelation therapy with CaNa2EDTA alone may be required if the blood lead concentration rebounds to a value > or = 45 ug/dL within 5 to 7 days after treatment. In general allow at least 5 to 7 days before beginning a second course of CaNa2EDTA. Some practitioners give a second course of chelation after a 3-day rest period if the immediate post-treatment blood lead level is >35 ug/dL (J. Chisolm, personal communication).

BLOOD LEAD LEVEL 45 TO 69 UG/DL. If the blood lead value is between 45 and 69 ug/dL, chelation treatment should be limited to CaNaEDTA only. CaNa2EDTA is given for 5 days at a dose of 1,000 mg/m square/ day intravenously by continuous infusion or in divided doses, as described under the heading CaNa2EDTA. During treatment, evaluate renal and hepatic function and serum electrolyte levels regularly. Do not continue CaNa2EDTA treatment for more than 5 days (Piomelli et al., 1984).
A second course of chelation therapy with CaNa2EDTA alone may be required if the blood lead level rebounds to 45 ug/dL within 7 to 14 days after treatment. Allow 5 to 7 days before beginning a second course of CaNa2EDTA.

BLOOD LEAD LEVEL 25 TO 44 UG/DL. For this blood lead range, the effectiveness of chelation therapy in decreasing the adverse effects of lead on children's intelligence has not been shown. Treatment regimens vary from clinic to clinic. Some practitioners treat children with lead levels in this range pharmacologically. (Although it is not approved for this use, some use D-penicillamine for children in this blood lead range.) The minimum medical management for children with these blood lead levels is to decrease the children's exposure to all sources of lead, to correct any iron deficiency and maintain an adequate calcium intake, and to test frequently to ensure that the child's blood lead levels are decreasing. Many experienced practitioners decide whether to use chelation therapy on the basis of the results of carefully performed CaNa2EDTA mobilization tests (See Edetate Disodium Calcium (CaNa2EDTA) Provactive Chelation Test).

BLOOD LEAD LEVEL 20 TO 24 UG/DL. ONLY VERY MINIMAL DATA EXISTS ABOUT CHELATING CHILDREN WITH BLOOD LEAD LEVELS BELOW 25 UG/DL, AND SUCH CHILDREN SHOULD NOT BE CHELATED EXCEPT IN THE CONTEXT OF APPROVED CLINICAL TRIALS. A child with a confirmed blood lead level of 20 to 24 ug/dL will require individual case management by a pediatric health-care provider. The child should have an evaluation with special attention to nutritional and iron status. The parents should be taught about: 1) the causes and effects of lead poisoning, 2) the need for more routine blood lead testing, 3) possible sources of lead intake and how to reduce them, 4) the importance of adequate nutrition and of foods high in iron and calcium, and 5) resources for further information. (This is described in more detail in Chapter 4.) Sequential measurements of blood lead levels along with review of the child's clinical status should be done at least every 3 months. Iron deficiency should be treated promptly. Children with blood lead levels in this range should be referred for environmental investigation and management. IDENTIFYING AND ERADICATING ALL SOURCES OF EXCESSIVE LEAD EXPOSURE IS THE MOST IMPORTANT INTERVENTION FOR DECREASING BLOOD LEAD LEVELS (CHAPTER 8).

POST-CHELATION FOLLOWUP

RECHECK BLOOD LEAD LEVELS 7 TO 21 DAYS AFTER TREATMENT. DETERMINE IF RETREATMENT IS NECESSARY. DO NOT DISCHARGE A CHILD FROM THE HOSPITAL UNTIL A LEAD FREE ENVIRONMENT CAN BE ASSURED.

At the end of each treatment cycle, the blood lead concentration usually declines to <25 ug/dL. Within a few days, however, reequilibration among body lead compartments takes place and may result in a rebound; thus, THE BLOOD LEAD LEVEL MUST BE RECHECKED 7 TO 21 DAYS AFTER TREATMENT TO DETERMINE WHETHER RETREATMENT IS NECESSARY (Piomelli et al., 1984; Chisolm et al., 1985).

Children who undergo chelation treatment require long-term followup preferably from pediatric health-care providers, nutritionists, environmental specialists, and community out-reach workers. Community outreach workers provide a critical bridge between hospital-based or clinic-based (outpatient) medical care, health advocacy education, and environmental remediation outside the hospital. Children should NEVER be discharged from the hospital UNTIL THEY CAN GO TO A LEAD-FREE ENVIRONMENT (CDC, 1985; Piomelli et al., 1984). Lead-free safe housing (with friends, relatives, or in designated transitional housing), in which a treated child can live during the entire abatement process through the post-abatement clean-up, must be arranged. With appropriately carried-out public health measures, complete and safe abatement should be achieved during the treatment period (CDC, 1985).

Once a child is discharged to a safe environment, frequent followup is mandatory. In general, depending on the initial blood lead value, most children who require chelation therapy must be followed closely for at least one year or more. All children undergoing chelation treatment should be seen every other week for 6-8 weeks, then once a month for 4-6 months. A child treated with BAL and CaNa2EDTA should be followed more closely: weekly for 4 to 6 weeks, then monthly for 12 months.

At each clinic visit, housing information should be updated. If history suggests that exposure is increasing or if blood lead levels are rising, the dwelling must be reinspected to evaluate the possibility of new sources of environmental lead, inadequate abatement, or unsound structures in buildings (for example, poor plumbing with leaks) that cause further chipping or breakdown of a previously repaired dwelling (Piomelli et al., 1984).

RESEARCH AREAS AND FUTURE TRENDS IN THE MANAGEMENT OF CHILDHOOD LEAD POISONING

FURTHER EVALUATION IS NEEDED ON:
XRAY FLUORESCENCE (XRF) MEASUREMENTS OF LEAD IN BONE.
EFFICACY OF CHELATING AGENTS IN REDUCING THE ADVERSE NEUROBEHAVIORAL EFFECTS OF LEAD.
USES OF SUCCIMER.
TOXICITY OF CANA2EDTA AND OTHER CHELATING AGENTS.
BONE LEAD MEASUREMENTS USING XRAY FLUORESCENCE (XRF)
According to published data, L-line and the K-line XRF techniques permit non-invasive assessment of skeletal lead stores. These bone stores reflect the lead burden accumulated over an individual's life. In contrast, blood lead values reflect recent lead exposure and absorption during the past 1 to 3 months and provide limited information about lead toxicokinetics over time (Rabinowitz et al., 1977). Evaluations using the L-line methodology in children have shown that blood lead levels underestimate the body burden of lead in lead-poisoned children (Rosen et al., in press); and sequential measurements of lead in lead-poisoned children by the L-line technique have shown decreases in bone lead after CaNa2EDTA treatment or environmental intervention (Rosen et al., in press). K-line techniques have been used mainly to measure bone lead levels in workers. Quantitation of bone lead content of children takes about 16 minutes.

At present, XRF equipment is available only in a few centers in the United States and Europe.

EFFICACY OF CHELATING AGENTS

The benefits of chelation therapy in symptomatic lead-poisoned children are well known (Chisolm, 1968). Prompt intervention with chelating agents prevents progression to symptomatic disease and normalizes biochemical indices of lead toxicity. However, the efficacy of chelating agents in reversing or modifying the adverse neurobehavioral effects at all blood lead levels in apparently asymptomatic children needs to be carefully assessed. Better understanding of this issue is critical in deciding the end-point of medical treatment. It is also essential in defining when chelation should be used.

SUCCIMER

Data are needed on the tissue sites of lead chelated by succimer, the adverse effects of succimer, the effect of succimer on absorption of lead from the gastrointestinal tract, and the effectiveness of different dose regimens of succimer. Assuming that no new significant adverse effects are noted after succimer is used more widely, the efficacy and appropriate use of succimer for treating lead-poisoned children with blood lead levels below 45 ug/dL needs to be established.

TOXICITY OF CaNa2EDTA

Results of one animal study suggest that CaNa2EDTA may transiently increase brain lead levels (Cory-Slechta et al., 1987). The redistribution of lead during chelation needs further study.

REFERENCES


CHAPTER 8. MANAGEMENT OF LEAD HAZARDS IN THE ENVIRONMENT OF THE INDIVIDUAL CHILD

SUMMARY

TO ERADICATE CHILDHOOD LEAD POISONING, LEAD HAZARDS MUST BE ABATED.

ENVIRONMENTAL CASE MANAGEMENT INCLUDES A NUMBER OF ACTIONS PRESCRIBED FOR A CHILD WITH LEAD POISONING.

PRECAUTIONS MUST BE TAKEN TO ENSURE THAT ABATEMENT IS CONDUCTED IN THE SAFEST AND MOST EFFECTIVE MANNER POSSIBLE.

Eradicating childhood lead poisoning requires a long-term active program of primary lead-poisoning prevention, including abatement of lead-based paint hazards in homes, day-care centers, and other places where young children play and live. For the child who is lead poisoned, however, efficient and effective interventions are needed as quickly as possible. Abatement means making the source of lead inaccessible to the child.

Lead-based paint is the most common source of high-dose lead poisoning. Complete abatement of lead-based paint means eliminating all lead-based paint in a housing unit as a source of lead for the child, either by removing the paint or by using permanent barriers. Complete abatement of the lead hazards in the child's environment is the most effective and only certain way to prevent further damage. Complete abatement is expensive, but once a dwelling is abated, many generations of children may live in that home and reap the benefits. Unfortunately, complete abatement may not always be possible, and shorter term, preventive maintenance procedures may have to be undertaken to minimize the potential for further damage.

Lead-based paint is rarely completely abated in many of the largest childhood lead poisoning prevention programs. Instead, various degrees of incomplete abatement -- designed to eliminate the worst hazards and prevent near-term exposures -- are conducted. Development of cost-effective, safe, simple, and widely applicable methods of complete paint abatement is a high priority.

Whether complete abatement or preventive maintenance is done, persons performing the work should be knowledgeable of the hazards of lead to themselves, to children, and to the environment. They should be trained in the proper procedures for abatement and preventive maintenance, since improperly performed work can actually increase the hazards to the child.

Each situation in which a child gets poisoned is unique and must be evaluated by a person or team of persons skilled and knowledgeable about lead poisoning, hazard identification, and interventions to reduce lead exposure, including abatement of lead-based paint in housing. Childhood lead poisoning prevention programs need to work closely with other relevant agencies (for example, housing and environmental agencies) to ensure that the quickest and most effective approach is taken to remediating the environments of poisoned children.

The 1985 CDC statement on Preventing Lead Poisoning in Young Children set the level for environmental intervention at 25 ug/dL. In this new statement CDC recommends environmental intervention for children with blood lead levels of > or = 20 ug/dL, or of > or = 15 ug/dL that persist. Where resources are limited, however, individual environmental intervention must first focus on those children with the highest blood lead levels. CDC also recommends that environmental interventions be directed at primary prevention of lead poisoning in communities with a large number or percentage of children with blood lead levels > or = 10 ug/dL. (Chapter 9).

WHEN RESOURCES ARE LIMITED, ENVIRONMENTAL INTERVENTION MUST FIRST FOCUS ON THOSE CHILDREN WITH THE HIGHEST BLOOD LEAD LEVELS. WHEN POSSIBLE, ABATEMENT SHOULD BE CONDUCTED FOR PRIMARY PREVENTION OF LEAD POISONING.

The Department of Housing and Urban Development has issued Lead-Based Paint Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing, hereafter called the HUD Guidelines (HUD, 1990, also published in the Federal Register 55FR14556). (The worker protection guidance was subsequently revised and published in the Federal Register, 55FR39873.) This document is referenced frequently in this chapter because it contains the most comprehensive information on identifying and abating lead-based paint hazards available. It is not expected that every childhood lead poisoning prevention program or every homeowner will follow the guidelines completely. These guidelines were written
for lead hazards in public and Indian housing, particularly for use during comprehensive modernization programs. Such programs, carried out when the property is vacant and in multiple units at one time, offer opportunities for very thorough and complete abatements. Most abatement of lead-based paint in the private sector does not occur in such a context. In the private sector, abatement is generally done in occupied housing scattered throughout an area, often with limited resources. In the context of this chapter, the HUD guidelines are an information source on identifying and abating hazards.

**ENVIRONMENTAL CASE MANAGEMENT**

ENVIRONMENTAL CASE MANAGEMENT INCLUDES

- **EDUCATING PARENTS ABOUT THE SOURCES, EFFECTS, AND PREVENTION OF LEAD POISONING.**
- **INVESTIGATING THE ENVIRONMENT TO IDENTIFY LEAD SOURCES AND EFFECTIVELY COMMUNICATING THE RESULTS OF THIS INVESTIGATION.**
- **TAKING EMERGENCY MEASURES TO REDUCE LEAD EXPOSURE.**
- **DOING LONG-TERM INTERVENTIONS TO REDUCE LEAD EXPOSURE.**
- **EVALUATING THE EFFICACY OF THE INTERVENTIONS.**

Environmental case management includes a number of actions prescribed for a child with lead poisoning. Ideally, environmental case management should be conducted by a team of professionals in public health, environmental activities, medical management, and social management. A team approach to intervention will help ensure that followup is timely and effective. The management team may need to solve many related problems, such as whether to investigate supplemental addresses, where to find temporary alternative housing, and how to use community resources to assist the family in dealing with the lead-poisoned child.

A team approach to case management is most effective when all team members:

1. Demonstrate professionalism.
2. Show genuine concern for the poisoned child and family.
3. Support other team members.
4. Use similar terms, descriptions, and reference points to communicate with the child's family.
5. Meet specific time frames for followup.
6. Reinforce education of the family at every encounter.

**TIME FRAMES FOR INVESTIGATIONS AND INTERVENTIONS**

The following guidelines describe the maximum time within which environmental interventions should be implemented. All children with blood lead levels \( \geq 20 \) ug/dL should have environmental interventions conducted as quickly as possible. Children with blood lead levels \( \geq 45 \) ug/dL require prompt chelation therapy. THE HOMES OF THESE CHILDREN MUST BE REMEDIATED BEFORE THEY ARE ALLOWED TO RETURN.

**BLOOD LEAD LEVELS > OR = 70 UG/DL.** Children with blood lead levels above 69 ug/dL constitute a medical emergency and must be hospitalized immediately. They are at highest risk for severe, permanent neurologic damage due to lead exposure and must be given highest priority for followup. Environmental investigation and intervention should be started within 24-48 hours and should include the child's home and potential sites of exposure, such as a relative's home or a day-care center. The homes of these children must be remediated before they are allowed to return.

**BLOOD LEAD LEVELS BETWEEN 45 AND 69 UG/DL.** These children can be given a slightly lower intervention priority than the children classified as medical emergencies. Environmental investigation and intervention should begin within 5 working days and should include the same components as for children with higher blood lead levels. The homes of these children must be remediated before they are allowed to return.

**BLOOD LEAD LEVELS BETWEEN 20 AND 44 UG/DL.** Environmental investigation and intervention should begin within 10 working days. Since many of these children will not be hospitalized and since allowing exposures to continue might lead to further increases in blood lead levels, environmental interventions for these children should be conducted as quickly as possible.

**BLOOD LEAD LEVELS BETWEEN 15 AND 19 UG/DL.** Environmental investigation and intervention for children at this level should be based upon program resources and the ability of program staff to respond. At a minimum, these children and their families should have education regarding lead poisoning. If blood lead levels \( \geq 15 \) ug/dL persist, environmental intervention should be made where possible -- including assisting the parents in locating potential sources of lead contamination in and around the home and instructing them about how to reduce the risk of lead contamination. If resources permit, a full environmental inspection for lead-based paint should be done for such children.

Although full environmental investigation and abatement is not recommended as part of the management of children with blood lead levels below 15 ug/dL, the identification and reduction of lead hazards in all high-risk housing is an important primary prevention measure (Chapter 9).

**EDUCATING PARENTS ABOUT LED POISONING**

Preventing Lead Poisoning in Young Children

The parents of all lead-poisoned children should be educated about lead poisoning. In communities with a high incidence of lead poisoning, communitywide educational efforts should be considered. These efforts should provide information similar to that in the anticipatory guidance provided by pediatric health care providers. Information provided should include:

1. Causes and effects of lead poisoning.
2. Relationship of the child's blood lead level to the potential for adverse health effects.
3. Need for followup blood lead testing of the child.
4. The child's possible sources of lead intake and practical means for reducing and eliminating these sources.
5. Role of nutrition in decreasing lead absorption.
6. Resources where parents can get further information (addresses and telephone numbers of local health-care providers or public health agencies).

Ideally, this information should be provided during a face-to-face meeting with the parents. When local resources are limited, however, written material (in an appropriate language) may be mailed to the child's family. Educating parents about lead poisoning is further discussed in Chapter 4.

INVESTIGATING THE ENVIRONMENT AND COMMUNICATING THE RESULTS

The technical aspects of inspecting a home for lead-based paint are discussed below. In general, an investigation of the environment of a lead poisoned child should include the following steps:

1. Determine the most likely sources of high-dose exposure to lead.
2. Investigate the child's home to identify possible sources of lead. Include both the interior and exterior environment and give special attention to painted surfaces, dust, soil, and water. (Details on how to test for lead-based paint are in the next section.)
3. Advise parents and caretakers about identified and potential sources of lead and ways to reduce exposure.
4. In cases in which the parent does not own the home, notify the property owner immediately that a child residing on the property has lead poisoning. Discuss the results of the environmental investigation and the abatement interventions required with the property owner. Emphasize the importance of prompt abatement. When a child with a medical emergency from lead poisoning is identified, an immediate, face-to-face meeting with the property owner may best demonstrate the need for emergency intervention.
5. Advise parents and property owners that no residents or personal belongings should remain in the home during abatement.
6. Monitor the effectiveness and timeliness of abatement procedures closely.
7. Coordinate environmental activities with those of other professionals, including the health-care providers and persons responsible for public health and social management. A team approach to intervention will help provide a timely and effective followup.

EMERGENCY MEASURES TO REDUCE LEAD EXPOSURE

The first phase of environmental intervention may be to use short-term emergency interventions to temporarily reduce lead hazards. As soon as a blood lead level \( \geq 20 \text{ ug/dL} \) (or, if resources permit, \( \geq 15 \text{ ug/dL} \)) is confirmed, parents should be advised of the hazards of lead-based paint and lead dust. They should be told not to attempt abatement themselves improper abatement will most likely increase lead dust levels in the home and create additional, more severe exposure for the child. The temporary nature of interventions other than abatement should be emphasized.

When the source of lead is paint and paint-contaminated dust, parents can be instructed to stabilize the paint, wet-mop all floors, and wet-clean window sills and window wells at least twice per week. Cleaners high in phosphates appear to work particularly well. Sponges and rags used in this cleaning should be used for no other purpose. In particular, they should not be used to wash dishes or clean eating- or food-preparation surfaces, since dangerous contamination could result. Children's hands should be washed regularly, particularly before eating. Toys and pacifiers that are mouthed should be washed at least daily. Cribs and playpens should be moved away from chipping or peeling paint; furniture can be placed in front of areas that are not intact to make them less accessible. Dry sweeping of dust should be avoided, because it will stir up and spread the dust. Other measures to reduce lead exposure are discussed in Chapter 4.

LONG-TERM MEASURES TO REDUCE LEAD EXPOSURE

The next phase of environmental intervention involves long-term hazard reduction. If the source of lead is paint and paint-contaminated dust, the lead hazards are permanently abated only when all lead-based paint is completely removed or otherwise made permanently inaccessible. Less extensive practices, which are commonly used by childhood lead poisoning prevention programs, may be called "long term abatement." Certain maintenance procedures (for example, frequent cleaning and keeping walls freshly painted) may be classified as "preventive maintenance," but in general these procedures offer no absolute assurance of safety. In cases other than "permanent abatement," how long the hazard will remain under control depends on such factors as the quality of the workmanship, the thoroughness of the procedure, the soundness of the underlying structure, and the condition of the plumbing and roof. Moisture from leaky pipes or roofs can quickly cause paint that was smooth and intact to blister and scale, generating hazardous levels of lead dust. Except in unusual situations (such as in the case of housing that is not likely to be viable for more than a couple of years or when no alternative housing is available), temporary measures to reduce exposure should not be a substitute for abatement or an excuse for delaying abatement.

Technical aspects of lead-based paint abatement are discussed below.

EVALUATING INTERVENTION ACTIVITIES
The effectiveness of any intervention for a lead-poisoned child should be evaluated by its impact on the child's blood lead level. Measurement of environmental lead levels may also be helpful.

**ASSESSING THE LEAD PROBLEM IN THE CHILD'S COMMUNITY**

If a number of children are identified as being lead-poisoned in a community, communitywide interventions as described in Chapter 9 should be considered.

**TESTING FOR AND ABATING LEAD-BASED PAINT**

Tests for measuring the lead content of paint on walls have limitations; new tests for evaluating lead in paint are being developed.

Proper abatement must be done by experts; untrained parents, property owners, workers or contractors should not attempt it.

Note: Remodeling or repainting homes with lead-based paint should be considered just as hazardous as abatement. Whenever lead-based paint must be disturbed by sanding, scraping, heating, or other forms of abrasion, the same precautions should be taken for remodeling or repainting as for abatement itself.

**INSPECTION AND TESTING**

Several methods are available for determining the lead content of paint. These include XRF, wet chemical methods, and chemical spot tests. Although XRF analyzers are convenient, instruments available at the present time have limitations. A study by the National Institute of Standards and Technology (NIST, 1989) indicated possible substrate errors in the direct-reading XRF’s of as much as + or -2 mg/square cm. These errors were caused by differences in base materials in walls and trim. (At very high readings, for example, above 3 mg/square cm, this error has no practical significance). The spectrum analyzer, while considerably more expensive than the direct reader, provided much more accurate results. Only fully trained and experienced personnel should use XRF analyzers.

Wet chemical methods of analysis must be used if an XRF machine is not available or if it produces ambiguous results. Wet chemical methods require that a paint chip sample with all layers of paint on the surface be sent to a laboratory for analysis. Wet chemical analysis has two major disadvantages - results are not available immediately, and it is expensive.

Like XRF, chemical spot tests are performed on-site. A scratch is made through all layers of paint, and a chemical is placed on the scratch. If the scratch turns certain colors, further evaluation is needed. Chemical spot tests are qualitative, not quantitative, and the interpretation of the results is subjective. These tests are being refined and evaluated as to their safety, accuracy, and reliability.

Further information on proper testing procedures for lead-based paint is in the NIST study report and the HUD Guidelines.

The 1985 CDC statement on lead recommended an XRF value of 0.7 mg/square cm as the maximum level of lead in paint in a residence. The HUD standard, mandated by Congress, is 1.0 mg/square cm. Several states have established their own XRF standards for lead in paint; these standards range from 0.7 mg/square cm to 1.2 mg/square cm. The HUD document and some state regulations use a standard of 0.5% lead by weight for laboratory analysis.

Lead in paint should always be considered a "potential" hazard. An immediate lead hazard exists when lead-based paint is: 1) chipping, peeling or flaking; 2) is chalking, thereby producing lead dust; 3) is on a part of a window which is abraded through the opening and closing of the window; 4) is on any surface which is walked on (like floors) or otherwise abraded; 5) can be mouthed by a child (for example, window sills); or 6) is disturbed by repainting or remodeling. A potential lead hazard can easily become an immediate hazard through natural aging, plumbing or roof leaks, or the paint being disturbed. All lead-based paint exceeding the action level should, therefore, be abated whenever possible. Otherwise, complicated records must be kept of unabated surfaces, and those surfaces must be inspected frequently to make certain that they have not become immediate hazards.

When inspecting for lead-based paint hazards, care must be taken to evaluate all types of surfaces, including walls, ceilings, doors and windows, trim and jambs, woodwork, stairway components, porch components, garages, sheds, fences, play equipment, and any other structures on the premises. Because of legal requirements in some areas, it may be necessary to test every surface that may be painted with lead paint (that is, every window, every door, every piece of trim, etc.). Often, however, abatement decisions can be made without this costly and time-consuming approach. Even with an XRF, a full inspection of all surfaces in an average home may take 4 hours or more. Sometimes, extrapolating XRF results to untested surfaces may make sense. Such extrapolation, however, should only be used for positive results. For example, if test results for one window are positive for lead, it is safe to assume that all similar windows are painted with lead-based paint; if test results for one window are negative, it is not safe to assume that no windows have lead-based paint.

Recent studies have indicated that many children are poisoned by lead-contaminated dust ingested through normal hand-to-mouth activity. This dust can come from lead contaminated soil that is tracked into the home on shoes or from the clothes of a parent who works with lead. However, the most common source of lead dust in the average old house is lead-based paint. Some believe that the level of lead dust in a house can be used as a measure of the severity of the immediate hazard.
ABATEMENT

Proper abatement includes the following steps:

1. Proper training of all workers involved in the abatement.
2. Protecting those workers whenever they are in the abatement area.
3. Containing lead-bearing dust and debris.
4. Replacing, encapsulating, or removing lead-based paint.
5. Cleaning the abatement area thoroughly.
6. Disposing of abatement debris properly.
7. Inspecting to make certain the property is ready for reoccupancy.

Abatement should never be attempted by untrained parents, property owners, or contractors. The property owner's responsibility is not met until all the above steps have been completed.

PREPARATION: Just prior to abatement, all personal belongings, movable furniture, and drapes should be removed from the abatement area. In homes with deteriorated lead-based paint, furniture may be highly contaminated with lead dust. It is recommended that badly soiled carpets and drapes be discarded because of the difficulty of removing lead from them. Furniture should be cleaned before it is returned to the abated dwelling or it should be replaced. Wood, metal, glass and plastic surfaces should be washed with a high phosphate detergent. If possible, all upholstered furniture, carpets, drapes, and bare surfaces should be vacuumed with a High Efficiency Particle Accumulator (HEPA).

PRECAUTIONS: Residents and their belongings should remain out of their homes during abatement. Under no circumstances should children and pregnant women be allowed to enter the dwelling unit during the abatement because abatement can generate large quantities of hazardous lead dust.

TRAINING: All workers involved in a lead abatement project should be properly trained in the following: health effects of lead; proper procedures for worker protection, including procedures for personal hygiene and for wearing and caring for respirators; containment of an abatement project; various methods for abating lead-based paint and the safety and environmental hazards involved with each; and procedures for transporting and disposing of abatement debris properly.

WORKER PROTECTION: All workers on a lead abatement project and their families must be protected from the hazardous lead dust that will be generated. The minimum acceptable protection would be coveralls (preferably disposable); shoe coverings; hair covering; gloves; goggles; and a properly fitted, negative-pressure, half-mask respirator with a HEPA filter. Other, more protective respirators may be needed to protect from hazards such as organic vapors. If the abatement methods used would generate significant quantities of lead dust or organic vapors, workers must wear more protective respirators, such as supplied air-respirators. The potential hazard to workers of lead dust INGESTION is as significant, if not more significant, than inhalation. Workers must not eat, drink, or smoke on the job; and hands and face must be washed before breaks and at the end of the day. On-site showers should, if possible, be provided. If on-site showers are not available, workers must shower and wash their hair immediately upon returning home. They must be careful not to carry hazardous levels of lead dust home on their bodies, shoes, or clothing. Therefore, work clothes should not be worn home; either workers should wear protective workclothes instead of street clothes at the worksite or they should wear protective garments over their street clothes. Work clothes should be disposed of or laundered by the employer to prevent the contamination of automobiles, homes, etc. with dust; lead-contaminated clothing should be handled with care and should not be laundered with other clothing of the worker or his family.

Note: The chapter in the HUD guidelines on worker protection was revised and published separately in the Federal Register on September 28, 1990 (55FR39873).

CONTAINMENT: The work area should be contained with plastic (6 mil) to protect other living areas, yards, heating and ventilation systems, etc. from contamination. All nonmovable furnishings, such as counters, cabinets, and radiators should be covered with plastic. All floors should also be covered with plastic to prevent lead dust from being deposited in cracks and crevices and from being ground into the surface during the abatement.

ABATEMENT: Abatement methods fall into three categories:

1. replacement,
2. encapsulation or enclosure, and
3. paint removal.

These categories are discussed in more detail as follows:

REPLACEMENT: Removing the building component (such as a window, door, or baseboard) and replacing it with a new one.

ENCAPSULATION: Covering a lead-painted surface with a material that will effectively prevent access to the lead-based paint and that will also prevent lead-bearing dust from that surface from entering the living environment.

PAINT REMOVAL: Stripping paint by heat, chemical, or mechanical means. This can be done either on-site or at the premises of a chemical stripping firm.

Certain methods of removing lead-based paint may be particularly hazardous to both the worker and the building occupants and may be banned in some areas. They are:

1. Removing paint with an open-flame torch or other heating device that operates at temperatures likely to volatilize lead (the melting point of