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On the Diagnosis and Treatment of Lead Poisoning

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The essential nature of lead poisoning, as well as that of the other heavy metal intoxications, remains a matter of speculation and hypothesis. Despite the large amount of valuable clinical and experimental information which is available, our knowledge is scanty at certain critical points, and much of the information which has been used to explain the entire picture is at best controversial. In this situation it is well to recognize the difference between facts and working hypotheses. When facts, even those of the most empirical type, are made the basis of procedure and practice, we cannot criticize, even when these facts are seen to be inadequate. But when hypotheses are converted into gospels to be passionately held or just as passionately condemned, we are in danger of using them to conjure up wish fulfilment knowledge on the one hand, and to obscure and hinder the development of new facts on the other.

It is with these ideas in mind that I present some new facts which are of importance in the diagnosis and the treatment of lead poisoning. If these facts are not discussed in relation to existing interpretations of the character of lead poisoning, it is because adequate interpretations must come more from the future than from the present or past, and because the facts by themselves are sufficiently important to occupy the time at our disposal.

The diagnosis of lead poisoning rests on a proper evaluation of the following matters: (1) Exposure to lead compounds; (2) susceptibility to lead; (3) symptomatology; (4) physical findings; and (5) laboratory findings specifically related to lead to a greater or lesser degree. Such experimental evidence as follows is presented with the purpose of clarifying somewhat the means and the limitations involved in such an evaluation.

*Read at a meeting of The Academy of Medicine of Cincinnati, December 9, 1929.

EXPOSURE.

Measurements of exposure have become a matter of necessity, not only in intelligent efforts to prevent lead poisoning but also in diagnosis. A considerable amount of information has been collected, notably by Legge in England, and Teleky in Germany, indicating the quantity of lead exposure which is capable of producing lead intoxication over a period of time. With the tremendous increase in industrial use of lead compounds, it becomes increasingly important to assess the significance of the exposure to lead associated with various industries. By far the commonest and most important exposures are due to the contamination of the air with finely divided lead compounds. It is a simple matter to measure the extent of such contamination of the air in the immediate vicinity of workers. Thus most of the occupations in a particular industry have their own hazards, qualitatively and quantitatively. The toxicity of the lead compounds varies with their physical and chemical characteristics, but it may be said that any type of lead dust, regardless of its solubility or particulate size is capable of producing lead poisoning if present in sufficient concentration in the air inhaled by animals or man. It has been established on a fairly sound basis, that the regular inhalation through the usual working day of air containing less than five miligrams of lead per ten cubic meters of air does not produce serious lead intoxication in individuals of a representative group.[1] A lower figure than this should be maintained in all industrial plants where lead compounds are used. One can only be sure that this is done by means of repeated examinations of the air breathed by workers.

In the non-industrial population poisoning is most frequently occasioned by the

[1]Legge, Thomas M., and Goadby, Kenneth W.: Lead Poisoning and Lead Absorption, London, 1912, page 207.

DUP050315120

TABLE I

COMPARISON OF MEAN VALUES OF GROUPS WITH VARIABLE EXPOSURE

Subjects	Lead in Faeces Mgs/Gm Ash	Lead in Urine Mgs/Liter	Number of Persons
Children	.087	.088	36
Medical Students	.080	.080	71
Workmen—No Known Exposure	.074	.096	84
Same Type Workmen—History of Previous Exp.	.100	.130	114
Garage Mechanics	.130	.120	70
Moderately Exposed Workmen	.192	.181	108
Severely Exposed Workmen	.730	.210	122

ingestion of lead with drinking water and wines and food, and in the case of children especially, by chewing or sucking toys, furniture, or other objects painted with lead paints. That cases of the latter type occur is sufficient reason for abolishing the use of lead paints on toys, beds, playpens, and furniture commonly used by children.

In the latter instances there is no simple way of determining the extent of exposure, and even under industrial conditions the ordinary methods of measuring exposure are inadequate in that they do not indicate the extent of absorption of lead which results from carelessness or the improper use or inadequacies of respirators and bathing and washing facilities. A better measure of the total picture may be obtained by a study of the excretion of lead occurring among persons who are experiencing lead exposure.

Table I illustrates the variation in the extent of lead excretion shown by representative groups selected because of observed variations in degree of lead exposure. It is clear that the exposure to lead on the part of most non-industrialized persons, is small. Nevertheless the conditions of life on an earth consisting partly of lead and in an environment in which lead is used for many purposes, presuppose some degree of lead absorption on the part of everyone. That such a small absorption produces a regular excretion of lead, militates against our ancient concept of an almost quantitative accumulation of lead in the tissues, and equally strongly against the notion that lead may exist in an immobile state in the body. It demonstrates also that the toxicity of lead has a quantitative aspect. The table shows that lead excretion increases with increased exposure. Thus we have a valuable method of determining the relative magnitude of exposure in a particular occupation, by making a study of the lead excretion of a representative group large enough to take into account the sampling error occasioned by individual variation. On the other hand, with these data, we are able to classify future subjects as to the significance of their exposure to lead, by merely studying their excreta.

In the individual case in which the diagnosis is at stake the examination of a single sample of faeces or urine or both does not yield adequate information. This is especially true if the exposure has been discontinued for some days or weeks prior to examination. In the latter situation we must study the individual's excretion long enough to determine the average rate of his excretion, and whether it is on the decrease.

Table II shows the continuous lead excretion in the faeces and urine of one subject, J. F., whose lead exposure has been moderate. The initial drop in excretion is most significant. It is a characteristic feature of the excretion of all lead workers in a dusty atmosphere if observed immediately after removal from exposure. The first figure in the curve of faecal excretion represents largely lead inhaled during the previous day while at work, and subsequently carried from the upper respiratory passages with mucus, etc., to the intestinal tract, where most of it is excreted without having been absorbed. With the clearing of the nose and throat and alimentary tract, the excretion falls to the level occasioned by the magnitude of lead which is actually absorbed into the

TABLE II

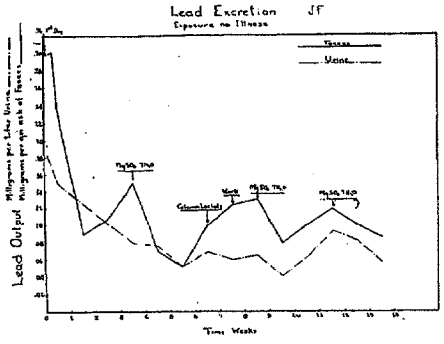

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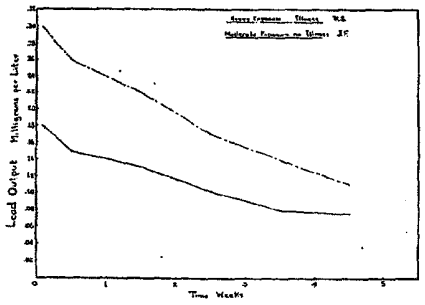
TABLE III

Urinary Excretion of Lead



tissues. Now as excretion continues, the amount of lead in the body diminishes, and the rate of excretion drops. Table III shows the results of similar observations on the urinary excretion on this subject and another, R. S., whose exposure was more severe—in fact enough to produce actual intoxication in a short time. The height and slope of the curves tell the story of the relative magnitude of the previous lead exposure. One cannot ignore the fact that the lungs probably contain lead in these cases, and that this lead is being continually absorbed into the blood and distributed in the tissues. Thus absorption is not entirely complete, and until it is complete we cannot obtain the true picture of the relationship of excretion to the lead content of the body. It would appear, however, that this factor is not of sufficient importance to seriously interfere with the drop in excretory rate. It may be possible to take this factor into account by a study of the lead in the blood, references to which will be made further on in our discussion.

The lead content of the blood, has not, to my knowledge, been used as a means of clinical interpretation. In the present state of our information, one must be cautious in arriving at conclusions as to its usefulness. It is entirely safe to say that lead in any considerable amount found in the circulating blood, furnishes evidence of significant lead exposure at some time. Table IV shows the result of analysis of the blood in a number of subjects with little or no exposure to lead. Table V represents a number of similar observations on a group of subjects whose exposure to lead at the time of sampling was severe. None of these men was ill at the time of study but all of them except the first, showed such signs of lead absorption, as lead line, considerable stippling of the erythrocytes and high faecal and urinary lead excretion. It would appear that even under conditions of severe exposure, measurable quantities of lead in the circulating blood are inconstantly found. The variation in this respect probably represents both sampling error and variation in the quantity of lead in the tissues. That is to say, a single subject may show lead in his blood at certain times and not at others, while one with a large lead content is likely to show a blood lead higher than one with a small lead content. This point will be referred to later.

Another means of obtaining information as to the extent of lead exposure and absorption is found in the various methods of recognizing the histological changes in the blood. I have not found any great superiority displayed by any one of these over the other. Variations in the reticulated and basophilic erythrocytes are apparently indicative of the same general type of change in the blood, as is shown by variation in the number of erythrocytes showing punctate basophilic stippling. Examination of the blood smears for stippling is somewhat easier than any other method. Its sensitivity for the purpose for which it is used is entirely satisfactory. As a matter of fact all the microscopical blood changes used to estimate the extent of lead absorption show a significant change prior to the development of symptoms of intoxication, except in instances

TABLE IV

LEAD IN CIRCULATING BLOOD

Subject	Present Exposure	Haemo-globin	Symp-toms	Stip/50 F	Pb/Mgs %
W.B.M.....	Slight	80	None	1	Trace
E.B.....	Slight	80	None	—	Trace
J.W.....	None	—	None	6	Nil
J.P.....	Slight	90	None	6	Nil
L.McD.....	Slight	95	None	6	Trace

TABLE V

LEAD IN CIRCULATING BLOOD

Subject	Present Exposure	Haemo-globin	Symp-toms	Stip/50 F	Pb/Mgs %
O.O.F.....	Moderate	82	None	26	Nil
M.M.....	Heavy	74	None	151	0.10
J.S.....	Heavy	75	None	71	Trace
P.R.....	Heavy	79	None	85	Trace
J.S.....	Heavy	70	None	89	Trace
W.D.....	Heavy	75	None	—	0.19
P.J.J.....	Heavy	70	None	—	0.42
E.M.....	Heavy	74	None	45	0.15
J.F.....	Moderate	67	None	40	0.15

DUP050315122

of sudden absorption of overwhelming amounts. Therefore it is merely a matter of convenience and experience as to which is used in following a group of workmen, or in arriving at a diagnosis. The only necessity in the use of these methods is that they be applied uniformly and quantitatively, in relationship to known standards. Table VI shows a comparison of stippling counts, made by a standard method, for several groups of men under observed variation of exposure. The significance of the figures shown is unquestionable. In ascribing significance to microscopic blood changes, however, it is necessary to recognize that none of them is specifically due to lead absorption. One must rule out other anemias and leukemias as well as the effects of the continued inhalation of benzol, gasoline, and perhaps certain other volatile solvents. Even variations in exposure to sunlight involve histological changes in the formed elements of the blood, and the limits of normal variation must be known more accurately than they are now, before we attempt to make refined conclusions on such findings.

The foregoing evidences of exposure to lead, and consequent absorption, may not be used as a means of recognizing the presence or the likelihood of lead intoxication. All that can be established by the study of lead excretion, lead content of the blood, and histological variations on the blood is the extent of the individual's exposure. Obviously if his exposure can be shown to be of a type associated with the occurrence of lead poisoning, one may explain readily, perhaps too readily, the background of characteristic symptoms and physical findings.

In industrial practice, however, it is not possible to anticipate the development of lead intoxication in an individual case, by means of these or any other known methods of observation. It can be said only that under a certain set of conditions of exposure, cases of intoxication are certain to occur in time. Armed with this information the industrial physician can demonstrate the need of limiting the exposure of the men under his care.

This brings us to consider a question that has been at issue many times. When does lead absorption develop into lead intoxication? What are the earliest evidences of intoxication? In my experience the earliest signs of lead intoxication usually appear in the form of blood changes, except in those instances in which a sudden and large increase in exposure or a complicating illness bring about the sudden development of gastro intestinal or nervous system symptoms. If the exposure is comparatively regular and quantitatively constant, the first signs are likely to be a drop in the haemoglobin content of the blood. This is usually preceded by a progressive rise in the number of stippled erythrocytes, and followed by a diminution in the erythrocyte count. These occur very frequently without any subjective symptoms, or any other physical signs. On this basis, a steady rise in the number of stippled erythrocytes in any lead worker is to be regarded as a suggestive sign of impending intoxication, while a progressive diminution of the haemoglobin content of the blood is to be regarded as an actual evidence of intoxication, with or without associated subjective symptoms, except in those instances in which the blood changes are due to other causes.

TABLE VI

COMPARISON OF MEAN VALUES OF STIPPLING OF ERYTHROCYTES OF GROUPS WITH VARIABLE EXPOSURE

Subject	Stippled Erythrocytes per 50 fields	Number of Subjects
Medical Students	0.95	71
Workmen—No Known Exposure	1.35	84
Same Type Workmen—History of Previous Exposure	1.68	114
Auto Mechanics	1.70	70
Large Group Persons in Dusty Lead Industry	17.0	122
Selected Persons with Heavy Exposure	98.00	11

Susceptibility.

Very little can be said about the underlying nature of susceptibility to lead compounds as it is so dramatically observed in the case of certain individuals. Without attempting any explanation of the facts, it should be pointed out that there are certain conditions which are known to influence susceptibility. The most important of these are, (1) general vascular disease, (2) general hepatic disease, (3) tuberculosis, (4) active chronic infections in general, (5) starvation, and (6) fatigue. In addition to these, immaturity in both animals and men is an important

DUP050315123

factor. Any explanation of the mechanism concerned with lead poisoning must account for these facts. I mention them at this time only to point out the necessity for care in the exclusion from lead occupations, of persons in whom any of these factors are at work. In connection with vascular disease I cannot but state my tentative conclusion that lead intoxication is only doubtfully to be regarded as a cause of vascular disease. It rather appears that the incidence of arterio-sclerosis among lead workers is little if any higher than it is in a corresponding age group of the general population. On the other hand, the occurrence of lead intoxication in persons with arterio-sclerosis is high indeed. I suspect that it is only because so many lead cases have arterio-sclerosis that the orthodox cause and effect relationship has been said to exist.

SYMPTOMATOLOGY.

It has been stated by many persons that the symptoms in lead poisoning are due to lead in the circulating blood. Up to the present there has been no direct evidence that such is the case. In fact, previous attempts to discover lead in the blood have failed because of a lack of analytical methods of sufficient sensitivity. If the symptoms are due to lead in the blood it should be possible to find lead present. Furthermore, the continual excretion of lead in the urine presupposes some quantity of lead in the blood. Accordingly we have attempted to find what quantity of lead is present in the blood. The previous tables (IV and V) have shown that it may be found. Table VII further illustrates the point and shows that in all the cases of acute illness studied by us to the present, lead is uniformly found in the blood in measurable quantities. It may well be that a range of concentration may be found constantly associated with the presence of symptoms. At present it may only be said that more than traces of lead in the blood indicate the strong probability of recent exposure of a significant type.

TABLE VII

LEAD IN CIRCULATING BLOOD

Subject	Present Exposure	Haemo-globin	Symp-toms	Stip/50 F	Ph/Mgs %
R.R.....	Heavy	56	Slight	247	0.19
J.L.B.....	Sl.Prolonged	75	Slight	0	0.12
C.G.H.....	Heavy	—	Encephalopathy	—	0.21
C.G.H.....	Heavy	—	Encephalopathy	—	0.13
C.G.H.....	Heavy	—	Colic	—	0.04
R.S.....	Heavy	70	Colic	149	0.37

TABLE VIII

THE FIXATION OF LEAD IN THE CENTRAL NERVOUS SYSTEM

Rabbit No.	Lead in Brain Mgs/%	Ratio of Conc. in Brain to Conc. in Entire Carcass	Time in Days After Treatment
86	1.62	2.0	1
16	0.72	0.6	3
38	1.15	6.0	150
47	1.45	16.0	330
60	1.31	18.0	270
74	2.08	52.0	420
75	1.56	23.0	240
40	1.69	42.0	300
78	1.27	53.0	510

The seriousness of nervous system symptoms as a result of lead absorption justifies some special consideration. Lead encephalopathy is the most dangerous manifestation of lead intoxication, and the most unsatisfactory from the point of view of treatment. Furthermore lead palsy, while usually not serious as to life, presents a gloomy prognosis as to the return of normal function. It is probable that this is due to a quality of nervous tissue, which is apparently not shared by any other tissue of the body. Nervous tissue has a striking ability of fixing such lead as reaches it. This is shown in Table VIII, in which a series of rabbits treated in various ways, but with considerable quantities of lead, have been killed for analysis after various periods of time. Even after seventeen months, during which practically all the other lead of the body has been lost, the brain of Rabbit No. 78 still retains an amount which is almost as great as that found in the brain of any animal of the series. It is interesting to note that the skeleton of this animal contained no detectable quantity of blood.

The importance of this lies in the fact that if one has absorbed lead into the brain, he may presumably develop encephalopathy at any time afterward. Thus may be explained the occasional development of central nervous signs of lead intoxication years after lead exposure has been discontinued.

Just what occurs to enable lead in the brain to produce symptoms may not be stated with any certainty, but that symptoms are associated with lead in the brain tissue is shown by the following table

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TABLE IX

DISTRIBUTION OF LEAD (CLINICAL ENCEPHALOPATHY) CASE J. G.

Tissue	Weight in Grams	Lead Found Milligrams	Lead Mgs per 100 gms tissue	Mgs% in carcass*
Rib Bone.....	15.00	1.95	13.000	31.71
Long Bone....	12.25	0.98	8.000	19.51
Bone Marrow	6.50	0.18	2.769	6.75
Cartilage	5.00	0.23	4.600	11.22
Suprarenal ..	5.00	Nil	Nil	Nil
Fat	20.00	Nil	Nil	Nil
Pancreas	50.00	0.18	0.360	0.88
Spleen	150.00	1.29	0.860	2.10
Heart	425.00	0.58	0.137	0.33
Kidneys	300.00	0.65	0.217	0.53
Liver	1300.00	9.20	0.708	1.73
Lung (rt).....	650.00	0.68	0.105	0.26
Lung (lt).....	800.00	0.44	0.055	0.13
Brain	1250.00	4.35	0.348	0.85
Spinal Fluid..	13.75	Nil	Nil	Nil
Blood	75.30	0.10	0.133	0.32
	5077.80	20.81	0.410	1.00

*This ratio between the concentration in a particular tissue and that in the carcass as a whole represents a selective affinity for lead, which we have called an "index of selective absorption".

(Table IX) illustrative of the distribution of lead in the tissues of a typical fatal case. It should be noted that the small amount of spinal fluid contained no lead, or at most an amount too small to detect. A terminal lobar pneumonia in the necropsy findings in this instance, does not exclude lead intoxication as a primary cause, though it may be supposed that the pneumonia contributed to the picture. In fact there is quite commonly a contributing factor in the development of lead encephalopathy. I have seen lead encephalopathy develop after prolonged anaesthesia, and again what appeared to be lead encephalopathy followed an illness resembling epidemic influenza. Here the differential diagnosis is a matter of some doubt, but the cerebral symptoms were distinctly more characteristic of lead than of a post influenzal encephalitis. That such conditions as produce cerebral anoxemia are effective in influencing the development of acute brain symptoms due to lead is strongly suggested by these facts.

It is not my purpose to discuss the symptomatology of lead intoxication, except to the extent that it is possible to introduce new experimental evidence relating to it. The clinical picture in lead poisoning is too well known, and too readily available to justify further discussion. Accordingly I pass over the protean manifestations of lead intoxication to touch briefly on certain considerations as to the treatment.

Treatment.

It has been my observation that in most instances of early lead intoxication, recovery occurs spontaneously when exposure to lead compounds is discontinued. Most cases which do not respond thus are either complicated by ailments which need medical attention, or are the result of repeated or prolonged injury from exposure over a considerable period of time.

The first requirement of good therapy, then, is to avoid doing anything which may interfere with the normal processes of recovery. To accomplish even this requires some understanding of the nature of these processes. One of the important factors in recovery has to do with the elimination of lead from the body. Attention has been called to the fact that lead is steadily eliminated in both the faeces and urine, and that the rate of excretion bears a relationship to exposure, or presumably, to the amount of lead in the body. Thus the patient, left alone, will tend to eliminate from his body the offending agent. In time he will excrete all of the lead except that portion which is firmly bound in his tissues. At present, there is no evidence that lead is fixed in any tissue of the body, with the exception of the central nervous system. Therefore there is no need for the use of therapeutic measures which will aid in the elimination of lead from the tissues, except in the case of the brain. Here unfortunately, no such measures are known, though it is likely that experimentation will discover them.

However, it is possible to remove unabsorbed lead from the alimentary tract,

TABLE X

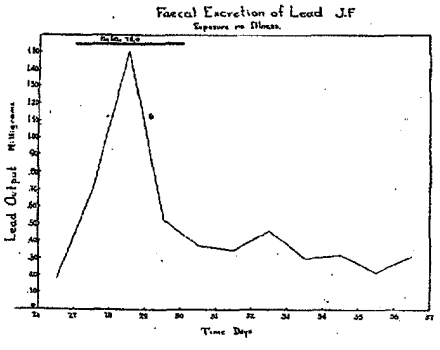

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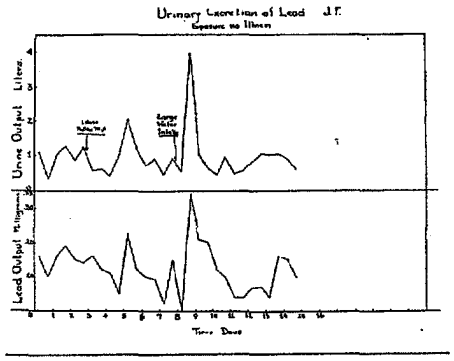
TABLE XI



and also to maintain rapid evacuation of such lead as is excreted into the intestinal tract so as to avoid its re-absorption. Magnesium sulphate has long been used orally in cathartic doses for this purpose. Table X shows its effectiveness for this purpose.

The use of the generally recommended measures for increasing lead elimination from the tissues during the period of lead intoxication, is dangerous and unnecessary. There is one means which may be employed effectively and without risk, which has not received attention. Table XI shows the extent to which lead excretion by the kidneys depends upon water excretion.

The diminution of the symptoms of lead intoxication which usually follows on removal from exposure is not due solely to the excretion of lead. On the contrary, much of the effect is due to factors which work to some extent in the opposite direction. Under normal conditions lead disappears out of the circulating blood very rapidly. There is evidence that this occurs initially through the influence of the liver. However, whatever be the mechanism, a large amount of absorbed lead appears shortly in the bones, with smaller amounts in the liver, muscles, connective tissue and fat. The normal type of distribution is illustrated in Table XII.

The speed with which the lead is removed from the blood—this being done almost quantitatively, when lead is absorbed by way of the alimentary tract—saves the other tissues from the effects of high concentration over long periods of time. This is shown by Table XIII,

TABLE XII

DISTRIBUTION OF LEAD

Rabbit No. 242

Tissue	Wt. of tissue in Grams	Lead Found Milligrams	Lead Mgs per 100 gms tissue	Mgs % Mgs % in carcass
Kidneys	13.0	Nil	Nil	Nil
Liver	102.0	0.25	0.246	1.09
Spleen	1.5	Nil	Nil	Nil
Fat	29.0	Lost in Preparation		
C. N. S.	14.0	0.13	0.930	4.13
Skin and Hair	283.5	0.60	0.210	0.93
Blood	92.0	0.17	0.185	0.82
Muscle	794.0	0.35	0.044	0.20
Remainder	425.0	0.71	0.167	0.74
Bone	227.0	3.35	1.475	6.55
Int. Tract	255.0	0.14	0.055	0.25
Contents of Int. Tract	397.0	0.21	0.053	0.24
	2633.0	5.91	0.225	1.00
Total lead excreted		5.16		
Total lead recovered		11.07		
Total lead injected		12.00		

which compares the distribution of lead in a series of animals treated intravenously with lead and killed at variable periods after treatment. The eventual distribution is the same as if the lead had been administered orally except that certain tissues, notably the brain, have absorbed lead brought to it by blood which had not passed through the liver. Under conditions which permit of the carrying out of this normal type of distribution of lead in the tissues, symptoms of intoxication are likely to disappear rapidly. In fact it is doubtful if symptoms occur so long as lead is distributed in this normal fashion. It would be of the utmost importance, therefore, to understand fully the factors necessary for this normal distribution. The existing data are inadequate to define these factors. We must

TABLE XIII

RELATIVE DISTRIBUTION OF LEAD*—TIME EFFECT

	R. No. 243 10 min., 6 mg.	R. No. 236 30 min.	R. No. 238 2 hrs.	R. No. 237 16 hrs.	R. No. 190 65 hrs.	R. No. 242 2 wks., 12 mg.	R. No. 251 1 mo., 12 mg.
Kidney	20.75	trace	3.22	1.64	0	0	0
Liver	4.28	6.24	2.95	4.73	3.00	1.09	1.68
Spleen	Nil	74.07	13.83	0	—	0	trace
Fat	9.47	trace	0.36	0	—	—	0
C. N. S.	0.43	1.23	6.45	trace	0	4.13	0
Blood	2.68	3.70	12.40	trace	—	0.82	0
Muscle	0.20	0.27	0.33	0.12	—	0.20	0.40
Bone	0.96	3.26	1.46	3.66	3.00	6.55	5.22
Int. Tract	0.43	2.19	1.47	1.78	—	0.25	0.34

*The figures above represent the ratio between the concentration in any one organ and that in the total carcass, in each instance. Thus one can see the shifting which occurs with time. Thus the lead is out of the blood after 16 hours. It has reached practically the normal distribution after 65 hours.

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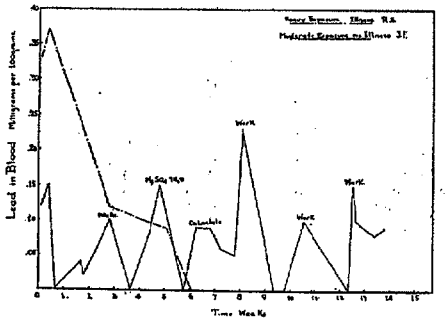
TABLE XIV

Lead in Blood



content ourselves, for the moment, with the recognition of certain things which modify the normal processes.

In general it may be said that an increase in the lead content of the blood, and in the excretion of lead, indicates the existence of conditions which operate against the normal distribution of lead in the tissues. Table XIV shows a number of factors which influence the lead concentration of the blood. The broken line shows the drop in the blood concentration following cessation of exposure, in an untreated subject. The solid line shows the variations coincident with several types of treatment of another subject. Table II shows the variation in the faecal and urinary excretion of lead under these same influences.

Tables XV and XVI show the influence of activity on lead excretion. The heavy lines in the horizontal axis on Table XV indicate night, the thin lines daytime. Lead is thus excreted more rapidly during the activity of the day.

TABLE XV

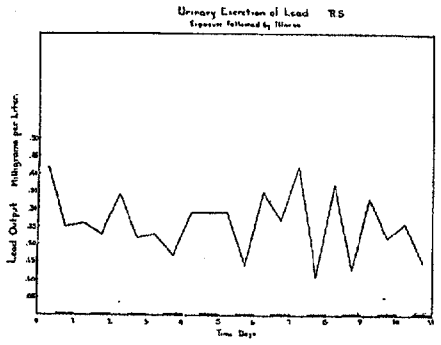
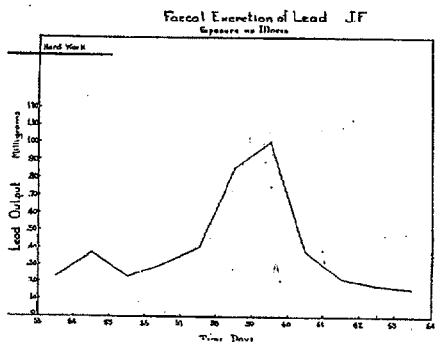


TABLE XVI



It is plain from the combination of blood and excretory findings following the effect of exercise, that a condition of rest is favorable to the distribution of lead in the tissues, while exercise promotes excretion. Some interesting speculations are prompted by these observations. The most characteristic physiological responses in exercise are an increased utilization of oxygen and an increased production of lactic acid. One can scarcely refrain from relating the increased output of lead to one or the other of these factors. It is especially significant that lead compounds are peculiarly soluble in lactic acid. It seems likely that the increased lactic acid in the tissues brings about an increased solubility of lead, which escapes into the blood, to be subsequently removed by the liver and excreted after some delay into the alimentary tract.

Whatever be the explanation, we cannot but conclude that exercise is bad for the patient suffering from lead intoxication. On the other hand the activities of the lead worker promote elimination and combat accumulation. In the same terms, fatigue doubtless contributes to the production of symptoms.

The foregoing facts, although presented very briefly, permit the laying down of a few general principles for the treatment of lead poisoning. The patient should be removed from all exposure to lead compounds, and he should be put in a condition of rest. The alimentary tract should be freed of its unabsorbed lead through the use of such a cathartic as Epsom Salts. The free emptying of the alimentary tract should be mantained throughout

DUP050315127

the duration of the symptoms, to prevent reabsorption of lead excreted into it. Water should be given in large quantities to promote excretion of lead, and a sufficient amount of calcium, potassium, and sodium salts should be given to maintain a proper salt balance in the tissues, during the high water intake. Large quantities of citrus fruit juices are particularly advantageous in obtaining both increased water and salt intake. A full mixed diet should be provided so as to promote and maintain as nearly normal physiological state of the body as possible. All agents which are believed or known to promote a quick release of lead from the tissues should be strictly avoided.

In the case of cerebral involvement, the above regime is not likely to prove successful. Here, one must resort to procedures which are to some degree empirical. I have regarded this condition as due in part to edema of the brain, and, in one or two cases, I have had encouraging results from intravenous injections of hypertonic salt solutions. Two percent Magnesium Sulphate was especially effective in one case, in that it suppressed a delirium and restored normal consciousness each time it was used. That edema is usually present in these cases is not to be doubted, and although combatting the edema does not constitute an entirely adequate treatment, it is the best I can recommend on present information.

When the acute symptoms subside, the most important measure is to eliminate any chronic disease which may be present. Especially important is the cleaning up of the badly infected mouth that is so commonly seen. Chronic infections in general are serious obstacles to complete recovery and should be treated as completely as is possible.

Even at this time, attempts to eliminate lead rapidly from the tissues are unnecessary. If the patient is let alone the lead will be eliminated, and without the necessity of constant medical care. The latter is often impossible, while without it, rapid lead elimination is unsafe. There is usually no advantage in sacrificing safety for speed in these cases. The patient should be cautioned against excesses in effort, and in his use of alcohol. He should be advised as to the danger of recurrence of his symptoms as a result of undue fatigue, or the occurrence of acute infections within the succeeding few months. Thus he should avoid exposure to cold and unclement weather conditions, and in every respect he should live as carefully as is possible. He should understand that it is inadvisable for him to resume his exposure to lead compounds.

With the above attention, the typical case of lead poisoning without involvement of the central nervous system, will recover uneventfully, and in most instances will show little or no residual effects from his experience.

DUP050315128