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TOXIC LEAD EXPOSURE IN THE URBAN ROCK DOVE

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ABSTRACT: Thirteen adult urban rock doves (*Columba livia*), 12 captured alive and one found dead, were studied from the Baltimore zoo. The mean concentration of lead in the blood for the 12 live birds was 184.5 ± 531.2 (range 10.5–1,870 μg/dl). Three of the 13 birds with high measured blood and tissue lead concentrations were found at necropsy with lead shot pellets in their gizzards. Correlations were not found between concentrations of lead in the blood and body weight or hematocrit. Conversely, high correlations were noted between concentrations of lead in the blood and measured liver and kidney concentrations ($r = 0.946$, $P < 0.01$; $r = 0.993$, $P < 0.01$, respectively). Numbers of intranuclear acid-fast inclusions per 10 consecutive fields (100× oil immersion lens) correlated well with measured kidney lead concentrations ($r = 0.990$, $P < 0.001$).

Key words: Lead, urban rock doves, *Columba livia*, toxicology, lead shot, renal lead inclusions, blood and tissue concentrations.

INTRODUCTION

Urban rock doves (*Columba livia*) form discrete flocks and remain faithful to specific feeding and roosting sites with little overlapping of territorial boundaries (Murton et al., 1972). Ohi et al. (1980) postulated that airborne lead fallout from automobile exhaust coats gravels which rock doves ingest to aid the gizzard in cracking seeds and grains. Lepow et al. (1974) reported that the highest concentrations of lead in dusts in urban areas were near the street where urban rock doves are seen feeding and graveling frequently. Tansy and Roth (1970) documented that urban rock doves accumulate lead in blood and tissues. However, the rock dove is quite resistant to the toxic effects of lead at these concentrations making the bird an excellent biomonitor of surface environmental lead (Barthalmus et al., 1977; Cory-Slechta et al., 1980).

Hutton and Goodman (1980) and others demonstrated that concentrations of lead in the blood of rock doves captured at specific urban sites were directly proportional to traffic density in major urban areas (Tansy and Roth, 1970; Ohi et al., 1974; Walser, 1984). DeMent et al. (1986) reported similar findings in Baltimore upon comparison of 40 inner city rock doves with 13 rock doves captured from sites removed from heavy traffic density. However, we later identified a flock of rock doves that had concentrations of lead in the blood and tissues out of proportion to what would be expected for their location relative to traffic density. Further examination of these birds identified lead shot ingestion as an additional source of environmental lead. Lead shot has been reported by Locke and Bagley (1967) to be toxic in a mourning dove (*Zenaida macroura*).

MATERIALS AND METHODS

Thirteen adult rock doves were studied from a relatively isolated roost site at the Baltimore zoo. The Druid Hill Park-Baltimore zoo complex comprises 600 acres in northern Baltimore and has limited motor vehicle access. Twelve birds were captured alive with baited funnel traps and examined within 12 hr of capture. The birds were provided with water ad libitum during the interval. A thirteenth bird was collected from the location dead, but without advanced rigor mortis and was necropsied.

All 12 live rock doves were weighed to the nearest g before blood was collected. Careful attention was taken in cleansing the left alar vein area in order to avoid metal contamination.

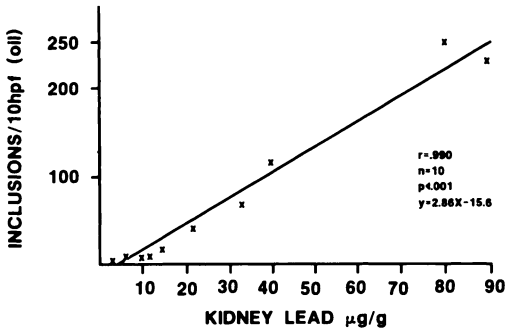

FIGURE 1. Concentrations of lead in the kidney plotted against the number of intranuclear lead inclusions present in the proximal convoluted tubule cells in 10 consecutive fields (100× oil immersion lens). Note that three points represent rock doves that had identifiable inclusions from this study. The remaining seven data points were derived from rock doves captured at other Baltimore locations that had measured kidney lead concentrations and identifiable lead inclusions on acid-fast stains.

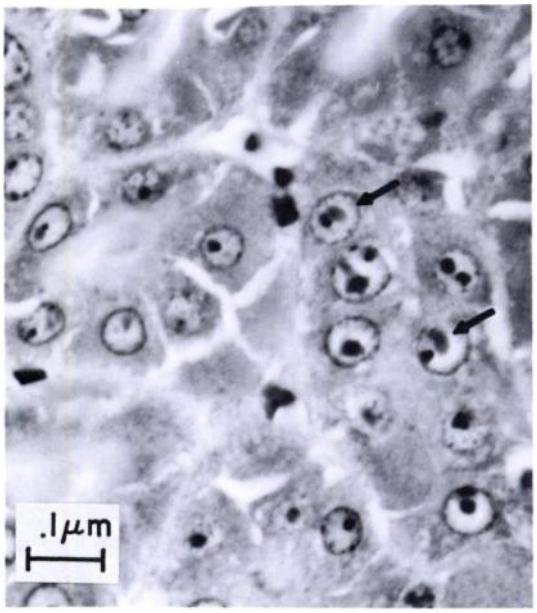

FIGURE 2. Intranuclear lead inclusions in the proximal convoluted tubules from rock dove 7 (arrows). The number and size of the inclusions increased in proportion to the measured concentration of lead in the kidney (acid-fast, carbol fuchsin stain.

Alcohol wipes were used. A 23 ga infusion set was used to collect approximately 3 ml of blood. Two ml were injected directly into a 2 ml potassium EDTA Vacutainer® tube. The remainder of the blood specimen was used to perform a microhematocrit and to prepare a blood film. Blood from both the right and left alar veins was collected from every third bird to control for possible specimen contamination. Blood films were stained with Wright stain and examined for the presence of erythrocyte basophilic stippling. Liver and kidney tissues were promptly collected from five birds after the birds were killed, placed in airtight plastic bags, frozen in liquid nitrogen, and stored at −25 C. Particular attention was given to examination of the crop and gizzard contents for lead shot or "canker." Additional tissues (liver, kidney, and organs with gross lesions) were collected from all rock doves, fixed in 10% buffered formalin for paraffin-embedding and sectioning at 4 µm. Hematoxylin and eosin and acid-fast (carbol fuchsin) stains were performed on liver and kidney sections. On the rock dove found dead, more extensive tissue sampling for histologic study was performed in order to identify the cause of death.

Whole blood preserved in potassium EDTA was analyzed within 5 days for concentration of lead by anodic stripping voltammetry (Environmental Science Associates, Inc., Model 3010A, Bedford, Massachusetts) (Morrell and Giridhar, 1976). Duplicate readings were taken on each blood sample and a mean value recorded.

Frozen liver and kidney samples from five birds were thawed partially and weighed to the nearest 0.001 g for wet weight lead determination. Low temperature wet digestion was performed. Tissue was placed immediately in 0.5 ml of ultrapure nitric acid and heated to 105 C. Ultrapure hydrochloric acid was added as a solvent and 30% hydrogen peroxide was used to complete the digestion process. Specimens were assayed for lead concentration by flamed atomic absorption spectroscopy (Instrumentation Laboratories, Inc., Model 551, Wilmington, Massachusetts). National Bureau of Standards standard reference material (SRM 1577—bovine liver, U.S. Department of Commerce, Room B 311, Chemistry Bldg., Gaithersburg, Maryland) was used as a positive control for lead analyses. Duplicate readings were taken on each sample of liver and kidney and a mean value recorded.

Paraffin-embedded kidney tissues were studied for the presence of intranuclear lead inclusions in the proximal convoluted tubule cells. The acid-fast (carbol fuchsin) stain was used. Each slide was examined at low magnification (4×) to locate focal concentrations of proximal convoluted tubules. High magnification (100× oil immersion lens) was used to examine 10 consecutive fields. The total number of inclusions

TABLE 1. Rock dove data.

Rock dove number	Body weight (grams)	Sex	Lead concentration, blood (μg/dl)	Lead shot gizzard	Lead concentration, liver (μg/g)	Lead concentration, kidney (μg/g)	Hematocrit (%)	Renal inclusions
1	354.2	F	95.0	1	5.16	14.43	56.0	16
2	366.0	M	24.5	0	—*	—	65.0	0
3	345.0	F	35.5	0	—	—	70.0	0
4	285.3	M	13.0	0	0.36	0.56	57.0	0
5	317.3	F	20.0	0	—	—	61.0	0
6	378.8	M	10.5	0	—	—	67.0	0
7	377.9	M	1,870.0	3	12.67	81.06	52.0	245
8	353.7	F	16.5	0	—	—	65.0	0
9	347.2	F	37.0	0	2.15	3.84	62.0	1
10	283.3	F	33.5	0	—	—	59.0	0
11	311.4	M	30.0	0	1.58	2.69	55.0	0
12	261.2	M	31.5	0	—	—	57.0	0
13	260.0	F	—	2	—	—	—	684
Mean ± SD	331.7 ± 39.5		184.5 ± 531.2				60.5 ± 5.4	

* Tissue was not available for examination.

counted in these 10 fields was plotted against the measured kidney tissue lead concentration in 5 birds. Since only three rock doves had identifiable inclusions, seven additional rock doves collected from other Baltimore sites with inclusions present and measured kidney lead concentrations were used to obtain a sample size of 10 (DeMent et al., 1986). A regression equation and a correlation coefficient were derived. Significance was determined at $P \leq 0.05$.

RESULTS

Concentrations of lead in the blood for the 12 live birds was 184.5 ± 531.2 μg/dl (range 10.5–1,870.0 μg/dl). Liver and kidney tissue lead concentrations were measured in five rock doves and ranged from 0.4 and 0.6 μg/g (13.0 μg/dl blood lead concentration) for the lowest to 12.7 and 81.1 μg/g (1,870.0 μg/dl blood lead concentration) for the highest liver and kidney lead concentrations, respectively (Table 1). Concentrations of lead in the liver and kidney showed significant correlation with concentrations of lead in the blood (r = 0.946, $P < 0.01$; and $r = 0.993$, $P < 0.01$, respectively). The number of lead inclusions in the kidney also showed strong correlation with measured kidney lead concentrations (Fig. 1). Inclusions were not identified by light microscopy until an approximate concentration of 4 to 6 μg/g was reached in the kidney, which roughly corresponds with data reported by Murakami et al. (1983). A regression equation derived from the plotted data points was used to estimate the kidney lead concentration in the one dead rock dove. A lead concentration in the kidney of 230 μg/g was estimated based on 684 inclusions counted over 10 consecutive fields (100× oil immersion lens) from acid-fast stained paraffin-embedded tissues (Fig. 2).

The mean hematocrit for the 12 live rock doves was 60.5 ± 5.4% (range 52.0–70.0%). A correlation of −0.505 ($P > 0.05$) was noted between hematocrit and concentration of lead in the blood. Body weight ($\bar{x}$ = 331.7 ± 40.0 g, range 260.0–379.0 g) did not show a correlation with concentration of lead in the blood ($r = 0.373$, $P > 0.05$). Erythrocyte basophilic stippling was not observed in the rock doves as reported by Anders et al. (1982).

The one adult rock dove found dead (pigeon 13, Table 1) was necropsied. Frozen tissues for lead measurements were inadvertently discarded. The body weight was 260 g and the female bird was mark-

edly emaciated. The gizzard contained grit and two (1 mm) malleated metal fragments compatible with spent lead shot. The digestive tract contained a scant amount of fecal material without esophageal or crop dilation or "canker." Microscopic examination of this bird was remarkable for erythroid hyperplasia of the bone marrow, non-specific pericholangitis of the liver, numerous lead inclusions in the kidneys as well as non-heme pigment deposition of the proximal convoluted tubules (Cook and Trainer, 1966).

Two of the 12 live rock doves which were captured and necropsied showed lead shot in their gizzards. The gizzard coatings in both birds were greenish-black in color. In pigeon 1 a single lead shot was found in the gizzard. Relatively high concentrations of lead in the blood, liver, and kidney were noted compared to the other rock doves. Also pigeon 7 was noted to have three lead shot in its gizzard and had much higher blood and tissue lead concentrations compared to the other live birds (Table 1). There was no evidence of crop or esophageal dilation or "canker" in any of the live pigeons despite their *Trichomonas gallinae* infections and/or toxic lead concentrations.

DISCUSSION

The major source of surface lead accumulation is atmospheric lead fallout from automobile emissions (Nriagu, 1979). There has, however, been a significant decline in atmospheric lead from automobile emissions in recent years with the increased use of unleaded gasoline (United States Environmental Protection Agency, 1986). The urban rock dove has been demonstrated to accurately monitor surface lead accumulation from automobile emissions in cities (Ohi et al., 1974; Hutton and Goodman, 1980; Walser, 1984). However, additional sources of surface environmental lead have been identified in major urban areas such as lead smelter atmospheric fallout (Roels et al., 1980), which could alter the predicted surface lead accumulations based on known traffic densities. We found an additional, unexpected source of environmental lead when examining a group of rock doves from an urban site removed from heavy traffic density. Previous rock doves examined from a nearby roost site showed low concentrations of lead in the blood as would be predicted for the level of traffic density (3.0 ± 2.8 μg/dl whole blood, DeMent et al., 1986). Identification of spent lead shot in the gizzards in three of the 13 rock doves proved to be an additional source of lead at the Baltimore zoo roost site described in this report. To our knowledge lead shot exposure has not been reported in urban rock dove lead pollution studies and should be included as a possible source, particularly in birds studied from large city parks or recreation areas where shooting may have occurred in the past.

The rock dove is reported to be quite resistant to high concentrations of lead compared to other animal species (Barthalmus et al., 1977). Lethal lead concentrations in the blood of rock doves range from 624 to 3,414 μg/dl (Barthalmus et al., 1977). Barthalmus et al. (1977) postulated that formation of intranuclear lead inclusions in erythrocytes (only seen ultrastructurally) may enable the rock dove to tolerate 50 to 100 times higher lead concentrations in the blood compared to sheep, mice, rats, and monkeys. Murakami et al. (1983) reported that formation of intranuclear inclusions in the kidney may also be protective. However, behavioral changes have been demonstrated in rock doves with lead concentrations of about 300 μg/dl in the blood (Barthalmus et al., 1977). Cory-Slechta et al. (1980) noted crop stasis and dysfunction associated with toxic concentrations of lead in the blood (459–2,060 μg/dl). Overt toxicity and death from starvation was associated directly with blood lead concentration. However, birds with concentrations of lead in the blood of 137–196 μg/dl were asymptomatic. The investigators concluded that behavioral

changes induced by lead in pigeons cannot be attributed to CNS dysfunction alone, but are probably a combination of neurologic and digestive damage (Cory-Slechta et al., 1980).

Since the reported mean concentrations of lead in the blood of urban rock doves in areas of high traffic density have ranged for the most part from 33.0 to 71.7 μg/dl, it is not surprising that behavioral changes have not been reported at these levels of exposure (Ohi et al., 1974; Hutton and Goodman, 1980; DeMent et al., 1986). Lead shot ingestion, on the other hand, is associated with much higher blood and tissue lead concentrations in bird species with significant morbidity and mortality reported (Cook and Trainer, 1966; Locke and Bagley, 1967). Ingested lead shot was observed in three of our rock doves with a predicted lead concentration in the kidney of 230 μg/g in the rock dove that probably died from lead poisoning. The concentration of lead in the blood of 1,870 μg/dl in one of the other two rock doves was well within the toxic and lethal ranges reported (Barthalmus et al., 1977; Cory-Slechta et al., 1980).

In conclusion, rock doves can be used to monitor not only surface lead accumulation from automobile emissions, but also to identify other more serious sources of environmental lead. Rock doves that have ingested spent lead shot can exhibit behavioral changes associated with increased morbidity and mortality. These chronically lead intoxicated rock doves are easy prey for domestic dogs and cats as well as natural predators such as migrating and resident predatory birds that prey on debilitated, weakened animals. Ingestion of these lead intoxicated rock doves with retention of lead shot in their digestive tracts may expose these predators to toxic lead concentrations (Benson et al., 1974). Endangered species such as the peregrine falcon (*Falco peregrinis*) which have been introduced into cities may be particularly vulnerable. Fortunately, the Baltimore peregrine falcon population has not been observed hunting at the "high risk" area identified in this report (DeMent et al., 1986). In addition, galliformes such as wild bobwhite (*Colinus virginianus*) might ingest lead pellets directly at "high risk" sites. Westemeier (1966) has reported possible lead poisoning in a bobwhite that had ingested four lead shot. Identification of these "high risk" locations for lead exposure may minimize further danger to animals and provides evidence in support of initiation of lead chelation therapy in suspected cases of lead poisoning.

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