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LEAD EXPOSURE IN AN "URBAN" PEREGRINE FALCON AND ITS AVIAN PREY

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ABSTRACT: Necropsy of a 7-yr-resident peregrine falcon (*Falco peregrinis*) from Baltimore showed a *Pseudomonas* infection involving the pharynx as the immediate cause of death. Concentrations of lead in liver and kidney measured 0.74 and 1.40 ppm, respectively. A survey of lead exposure was performed on 40 urban rock doves (*Columba livia*). Thirteen additional rock doves were collected from sites removed from lead contamination and served as controls. The mean concentration of lead in the blood of the urban rock doves was 0.96 ppm (range 0.29–17.0 ppm) compared to 0.05 ppm (0.01–0.07 ppm) for control birds. Ninety-eight percent (39/40) of the urban rock doves had elevated concentrations of lead in their blood, while 27% (11/40) had sublethal concentrations. None of the control birds had increased concentrations of lead in their blood. Concentrations of lead in liver and kidney of 13 urban rock doves were 3.48 ppm and 9.53 ppm, respectively, compared to concentrations of 0.43 ppm and 0.50 ppm for four control rock doves. From these data a mean total concentration of lead per rock dove was calculated at 4.60 ppm for urban birds and 0.33 ppm for control birds.

INTRODUCTION

An estimated one million dollars per yr are devoted to restoration of the endangered peregrine falcon in North America (Hilton, 1983). A major effort has been directed toward the establishment of a population of urban peregrine falcons in the continental United States (Cade and Dague, 1984). Although the peregrine falcon is well known for its susceptibility to environmental pollutants (e.g., pesticides), effects of urban pollutants have not been determined (Hilton, 1983). Accumulation of surface lead in the inner cities has been shown to pose a major hazard to the health of children (Charney et al., 1983; Mielke et al., 1983), and is reflected accurately in concentrations of lead in the blood of urban rock doves (Tansy and Roth, 1970; Ohi et al., 1974; Hutton and Goodman, 1980). The effects of sublethal chronic ingestion of lead on the rock dove are not clear, but such exposure has been determined to be detrimental in higher quantities to many animals including raptors (Koller and Brauner, 1977; Ohi et al., 1980; Cory-Slechta et al., 1980; Reiser and Temple, 1981; Feierabend and Myers, 1984). Sublethal ingestion of lead in raptors has been associated with Gram-negative infections (Reiser and Temple, 1981), and a 1,000-fold increase in susceptibility to bacterial infections has been demonstrated in mice (Koller and Kovacic, 1974).

The diet of a 7-yr-resident peregrine falcon in Baltimore, Maryland was determined to consist of urban rock doves almost exclusively (Barber and Barber, unpubl. data). Necropsy findings of a Gram-negative infection as the immediate cause of death for this bird prompted a study of sublethal accumulation of lead through the ingestion of rock doves as an indirect cause of death.

MATERIALS AND METHODS

A necropsy was performed on the peregrine falcon with particular precaution taken to prevent contamination by metals. There was a postmortem interval of approximately 4 hr. Bacterial and fungal cultures, and touch preps for

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Gram stain were taken from the necrotic mass in the pharynx. Histologic sections were fixed in 10% buffered formalin for paraffin embedding and sectioning at 4 μm. Approximately 1 g of fresh unfixed samples of liver and kidney was collected and placed immediately in air-tight plastic bags and frozen in liquid nitrogen.

Fifty-three adult rock doves were collected from seven sites, five of which were within five city blocks from the known peregrine roost site to the north, south, east, and west where the falcon had been seen feeding regularly on rock doves (Barber and Barber, unpubl. data). The remaining two collection sites were from an agricultural area remote from significant accumulation of surface lead and the Baltimore Zoo where the birds live in a protected environment and are fed daily. Rock doves from these two sites served as controls. Birds were collected by two methods: whole kernel corn baited funnel traps or hand netting with fishing nets.

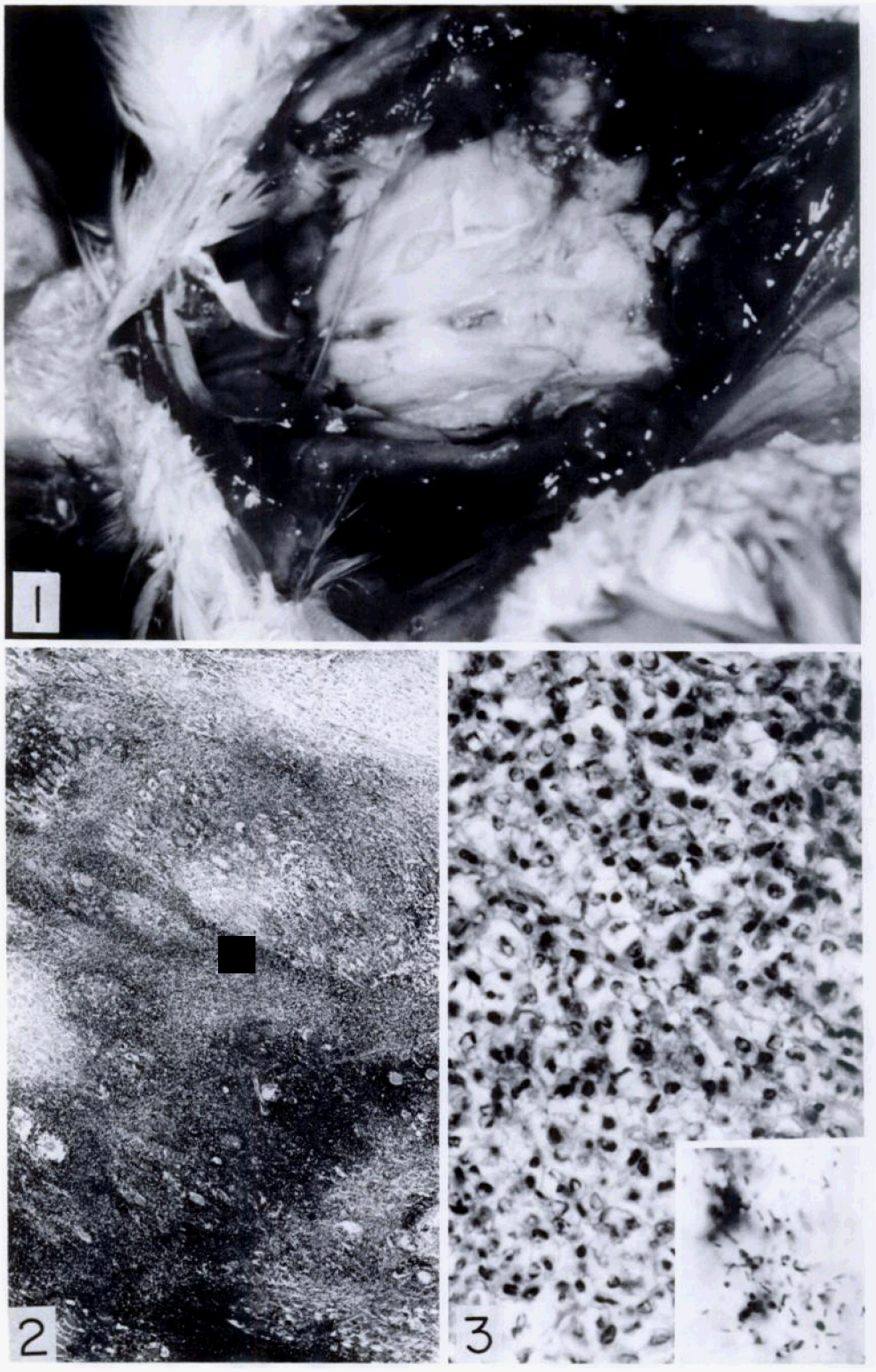
Rock doves were examined within 12 hr of capture and given water ad libitum during the interval. Care was taken to cleanse thoroughly the left alar area with alcohol wipes before venipuncture to prevent contamination by lead. Approximately 3 ml of blood was collected from the left alar vein from each pigeon with a 23-gauge infusion set, and placed directly into a 2-ml potassium EDTA Vacutainer® tube. Blood from both the left and right alar veins was collected from every fifth bird to control for possible contamination. The specimens were refrigerated. Birds were killed by cervical dislocation. Necropsies were performed on the 53 rock doves with precautions taken to prevent contamination by metals. Approximately 1 g of fresh unfixed samples of liver and kidney was collected from each rock dove and placed immediately in plastic air-tight bags and frozen in liquid nitrogen. Specimens were stored at −25 C. Additional tissues were fixed in 10% buffered formalin for paraffin embedding and sectioning at 4 μm.

Frozen samples of liver and kidney were thawed partially and weighed to the nearest 0.0001 g for wet weight lead determinations. Low temperature wet digestion was used. Tissue was placed immediately in 0.50 ml ultra pure nitric acid and heated to 105 C and the digestion was completed with subsequent additions of ultra pure hydrochloric acid and 30% hydrogen peroxide. Specimens were assayed for lead by flamed atomic absorption spectroscopy. National Bureau of Standards certified reference material (CRM 1577—bovine liver) was used as a positive control for lead analyses. Duplicate readings were taken on each sample of liver and kidney from both the rock doves (n = 17, representing four from controls and 13 from urban birds) and the peregrine falcon (n = 1).

Whole blood was analyzed within 5 days for concentrations of lead by anodic stripping voltammetry (ESA model 3010A) (Morrell and Giridhar, 1976). Duplicate determinations were performed on each sample and an average was taken for the reported data points.

RESULTS AND DISCUSSION

The peregrine falcon was observed hunting without limitations early on the morning of her death. She was found later in a moribund state and died shortly thereafter. At necropsy the bird weighed 625 g and was emaciated. The pectoral muscle was about half the expected mass. There was a green staining around the vent and tenacious mucus draining from the mouth. The posterior pharynx showed marked constriction by a whitish necrotic mass approximately 2 cm in thickness and 2 cm in anterior–posterior extent (Fig. 1). No evidence of trauma to the oropharynx was seen. Upon examination of the skull, no involvement of the brain through the base was noted. Gram stain of the mass showed numerous Gram-negative rods, subsequently identified as *Pseudomonas aeruginosa*. Microscopic examination of the pharyngeal mass showed a necrotic inflammatory infiltrate composed of red cells, granulocytes, and mononuclear cells. Clusters of Gram-negative bacterial rods were noted also within the mass on histologic sections stained with Gram stain. No other organisms were seen, despite extensive search for trichomonads on touch preparations and Giemsa stained paraffin embedded sections. The esophagus contained grasses and leaves as did the ventriculus. No food material was found in the intestines. Other organs were normal grossly. There was hemosiderin deposition in the liver tissues. In the kidneys there was hemosiderin deposited in the proximal convoluted tubules without intranuclear eosinophilic inclusions, despite careful examination with carbol fuchsin



staining under a 100× oil immersion lens. Concentrations of lead in samples of liver and kidney were 0.74 ppm and 1.40 ppm, respectively. The immediate cause of death was determined to be obstruction of the pharynx secondary to *Pseudomonas* infection and subsequent starvation.

Concentrations of lead in the blood of control rock doves were significantly lower ($P < 0.01$) than those in urban rock doves (Table 1). Normal concentrations of lead in the blood of the rock dove (0–0.19 ppm) as defined by previous reports (Ohi et al., 1974; Hutton and Goodman, 1980), and a sublethal concentration of lead in blood (0.60 ppm) in the bald eagle (*Haliaeetus leucocephalus*), as defined by the National Wildlife Federation (Feierabend and Myers, 1984), were used to determine relative elevations in the rock doves studied. By these criteria 98% (39/40) of the urban rock doves had elevated concentrations of lead in blood while 27.5% (11/40) showed sublethal concentrations (Table 1).

Mean concentrations of lead samples of blood, liver, and kidney were measured in ppm for urban rock doves ($n = 13$) as follows: blood (0.860 ± 0.499, range 0.51–2.1), liver (3.48 ± 1.9, range 1.62–7.95), kidney (9.53 ± 8.77, range 1.71–33.6). A positive correlation between concentration of lead in liver and kidney was noted (correlation coefficients 0.902 and 0.865, respectively) (Figs. 4, 5). Regression equations were determined and the line of best fit plotted from the equations (Figs. 4, 5). The mean concentrations of lead in blood samples from the urban rock doves (0.96 ppm, $n = 40$) were used to determine mean concentrations of lead in liver and kidney tissue from regression equations.

TABLE 1. Mean concentrations of lead in blood of rock doves from six collection sites in Maryland.

Location	*n*	Mean ± SD ppm	*P* value vs. controls[a] Control 1	Control 2
Urban, north	14	0.717 ± 0.666	<0.01	<0.01
Urban, west	6	0.481 ± 0.164	<0.01	<0.01
Urban, east	9	0.496 ± 0.188	<0.01	<0.01
Urban, south	11	1.91 ± 4.99[b]	<0.01	<0.01
Control 1	7	0.030 ± 0.028	—	>0.05
Control 2	6	0.065 ± 0.061	>0.05	—

[a] *P* values were determined by independent *t*-testing.
[b] One rock dove had 16.95 ppm lead in its blood as determined by ASV, substantiated by determinations of concentrations of lead in the kidneys, liver and brain.

These expected values for the urban rock dove were determined to be 3.90 ppm and 11.8 ppm for liver and kidney, respectively, which closely agreed with measured concentrations of lead in liver and kidney in the selected rock doves. In addition, Figures 4 and 5 were used to determine an approximate concentration of lead in blood for the peregrine falcon (different species), based on measured concentrations of lead in liver (0.74 ppm) and kidney (1.40 ppm) for this bird. The concentration of lead in blood for the falcon was estimated to be 0.14 ppm.

Benson et al. (1974) calculated mean concentrations of lead in total body tissue in a prairie falcon (*Falco mexicanus*) and a great horned owl (*Bubo virginianus*). Although they included concentrations of lead in bone in their total mean, we noted a negligible difference when concentrations in bone were excluded and replaced by concentrations in blood. Since Benson et al. (1974) reported that bone would be regurgitated and digested minimally by

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FIGURES 1–3. 1. Inferior perspective of 2-cm obstructing mass in posterior pharynx from a peregrine falcon. 2. Photomicrograph of inflammatory mass showing infiltration of skeletal muscle in a peregrine falcon. H&E, ×45. 3. Photomicrograph of the inflammatory mass in a peregrine falcon composed of granulocytes and lymphocytes. H&E, ×450. Inset: Gram stain of organisms within the inflammatory mass showing Gram-negative rods which proved to be culture positive for *Pseudomonas aeruginosa*. ×900.

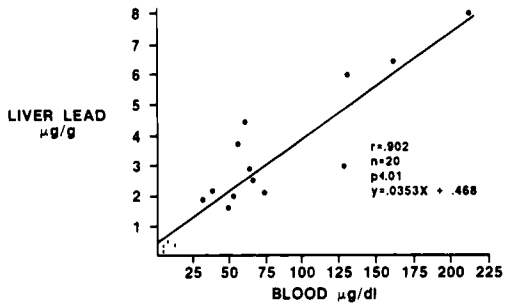

FIGURE 4. Concentrations of lead in blood plotted against concentrations in liver of rock doves. × = control rock doves, and ● = urban rock doves.

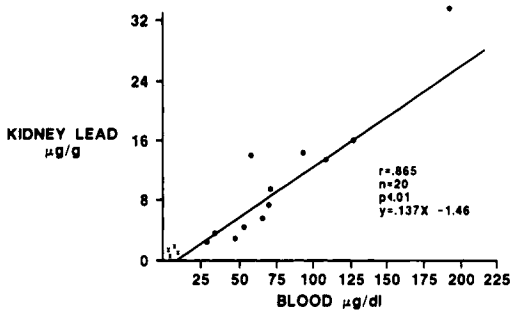

FIGURE 5. Concentrations of lead in blood plotted against concentrations in kidneys of rock doves. × = control rock doves, and ● = urban rock doves.

the raptors, we felt that the concentrations of lead in the bones of rock doves could be excluded in the calculation of mean concentration of lead in tissues of rock doves consumed by peregrine falcons. Using this method mean concentrations of lead of 4.60 ppm/rock dove for the urban rock doves and 0.33 ppm/rock dove for control rock doves were calculated from measured mean concentrations of lead in blood, liver, and kidney for the 13 urban rock doves and four control rock doves, respectively.

Murton et al. (1972) reported that urban rock doves form discrete flocks and remain faithful to specific feeding and roosting sites. Based on this study there should be no significant overlap into agricultural areas by urban birds. Therefore, birds trapped in rural areas served as controls. Examination of blood samples from the 53 rock doves supported previous reports of high concentrations of lead in birds with proximity to centers of traffic density for major cities (Hutton, 1980; Walser, 1984).

Anders et al. (1982) reported that concentrations of lead in blood are labile and fluctuate in response to intake of lead. This observation means that determinations of lead in blood may not be an accurate means of assessment of chronic lead exposure. However, Ohi et al. (1980) estimated that 3 mo were required to reduce significantly the concentrations of lead in blood upon removal of the source of lead. Therefore, given a relatively constant concentration of environmental exposure to lead at each collection site, concentrations of lead in blood would be expected to be accurate reflections of environmental exposure. Measured concentrations of lead in tissues of 17 rock doves also substantiated the concentrations of lead in blood at these moderate levels of exposure to lead in the city.

The peregrine falcon from Baltimore was known to feed predominately on rock doves (93%) in the immediate proximity to its roost site which was at the center of traffic density of the city (Barber and Barber, unpubl. data). A daily consumption of one rock dove, except during the nesting season was observed (Barber and Barber, unpubl. data). Based on regular sightings of feeding activity of the peregrine falcon in all four areas where rock doves were sampled, the 40 urban rock doves would be expected to represent approximately a 40 day exposure to lead via rock doves. Although the falcon would be challenged occasionally by rock doves with exceptionally high concentrations of lead (one rock dove had a concentration of lead in blood of 17 ppm) these events appear to be separated by many rock doves with lower concentrations of lead. Many days between excessive exposures to lead would allow for adequate clearance of lead by the kidney and thus prevent excessive ac-

cumulation in bone or tissue (Ohi et al., 1980; Anders et al., 1982). Stendell (1980) demonstrated that exposure of kestrels (*Falco sparverius*) to ducks fed lead shot resulted in sublethal concentrations of lead in blood. The mean total concentration of lead for the ducks fed lead shot was 40.8 ppm (Stendell, 1980), which demonstrates the profound effect of lead shot ingestion on concentrations of lead in tissue (Feierabend and Myers, 1984). Franson et al. (1983) fed 10 ppm lead acetate per day to female kestrels for 5–7 mo, resulting in mean accumulations of lead in the liver of 0.76 ppm without adverse effects. By comparison, we found an approximate daily lead exposure of 4.60 ppm/rock dove/day for the peregrine falcon with a measured concentration of lead in the liver in the falcon of 0.74 ppm. Although Franson et al. (1983) did not include concentrations of lead for the kidney, no intranuclear inclusions were observed in the proximal convoluted tubules of these raptors, which is in agreement with our findings. At the predicted concentration of lead in blood of 0.14 ppm and measured concentrations of lead in tissues for this peregrine falcon, no significant increased risk to infection would be expected based on previous studies in raptors (Reiser and Temple, 1981; Stendell, 1980; Franson et al., 1983; Benson et al., 1974). Therefore, the possibility of sublethal lead exposure as the predisposing factor for the infection in the peregrine falcon is remote.

In summary, chronic exposure of low concentrations of lead by consumption of rock doves is greater for urban peregrine falcons than for falcons feeding on rock doves in rural areas. However, the increase in exposure does not appear to be significant at approximately 4.60 ppm/rock dove/day. Based on similar concentrations of lead in blood reported for rock doves in other major cities, the data appear to apply not only to the two remaining peregrines in Baltimore, but also peregrine falcons now residing in Los Angeles, Salt Lake City, New York, and Atlantic City (Cade and Dague, 1984).

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