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Accuracy of Portable L-shell X-ray Fluorescence (L-XRF) Machines to Quantify Lead in Condor Bones In Vivo

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Critically endangered condors are exposed to lead (Pb) from ammunition embedded in the carcasses that they scavenge. Acute lead poisoning results in death for many of these animals through the paralysis of the neuromuscular system controlling peristalsis, as shown in Tom J. Cade's 2007 "Exposure of California Condors to Lead From Spent Ammunition" in the *Journal of Wildlife Management*. Researchers have been using blood lead levels as biomarkers of exposure. Cade (2007) notes that the half-life of blood lead in condors is approximately 13 days, which means blood lead in general reflects current or short-term exposure. On the other hand, bone has a low turnover rate. Lead can be stored in bone for decades in humans, and bone lead contains over 90% of the total lead body burden. Hence, it is important that researchers look at bone lead content instead to assess long-term cumulative exposure and the chronic effects of the lead toxicity.

Dr. Linda Nie's lab has been working on the development of a portable L-shell x-ray fluorescence (L-XRF) device to quantify lead in bone in human in vivo. The purpose of this project is to determine the accuracy of the portable L-XRF machine in measuring the lead content of condor cadaver bones. While the K x-ray fluorescence (K-XRF) machine is the most accurate machine to measure lead content in vivo because it has sufficient energy to overcome soft tissue attenuation, it is not very practical for use in a research lab with animals or for researchers covering the large migratory territory of condors (from California to Arizona). The portable L-XRF machine is lightweight; does not require continuous maintenance, a radioisotope source, or nitrogen cooling; and provides immediate spectra for analysis.

I calibrated the system with Pb-doped bone-equivalent phantoms that were covered with 0.54 mm Lucite to mimic the effects of soft tissue attenuation. The detection limit was calculated to be 1.9 ppm with 0.54 mm Lucite thickness. Seventeen condor cadaver bones were measured twice (for reproducibility), and the spectra were analyzed with our in-house spectral fitting program written with MATLAB. Significant correlation was observed between the bone Pb concentrations measured by the portable XRF and ICP-MS ($R^2 = 0.62$) and the linear regression of the K-XRF results versus the second set of bone measurements at Purdue, which gave an R^2 value of 0.84. In conclusion, we found that the portable XRF is an accurate method to measure Pb in condor bone. Two measurements of the same set of bones gave rise to a strong correlation with an R^2 of 0.93, which shows a great reproducibility of the results. Further work on reproducibility will be conducted by measuring the condor bones of different lead levels multiple times at different Lucite thicknesses.

Research advisor Linda Nie writes: "Emma has been working on a portable x-ray fluorescence (XRF) technology to measure lead (Pb) in condor bones. She found that it was feasible to quantify Pb in condor bone in vivo within 3 minutes using this technology with a detection limit (sensitivity) of about 2 ppm. This is significant because it means that this technology can be used to determine Pb exposure for condors and to help saving a critically endangered species from a common pollutant."

Sample condor bone fragment is placed in a portable L-shell x-ray fluorescense device.

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