A. COVER PAGE

Project Title: A Novel Portable KXRF Measurement System for In Vivo Metal Measurements	
Grant Number: 5 K01 OH012528-01	**Project/Grant Period:** 9/1/2019 - 7/31/2023
Reporting Period: 9/2019 - 8/2023	**Requested Budget Period:**
Report Term Frequency: Final	**Date Submitted:** 6/21/2024
Principal Investigator Information: Aaron J. Specht **Email:**	**Recipient Organization:** Purdue University

RPPR Checklist:
PI: Aaron Specht
Reporting Period: 9/2019-8/2023
Business Office Contact: Michelle Mariga

Section B. Accomplishments

B.1. What are the major goals of the project?

The major goals of the project are:

To build, optimize, and validate a novel portable KXRF system for measuring lead (Pb) in bone in vivo using lab samples. This includes building the system, optimizing the minimum detection limit and other parameters, and validating it against existing gold standard Cd-109 KXRF bone Pb measurements.

To validate the portable KXRF system for in vivo bone Pb measurement in a group of 100 people by comparing measurements from the portable system to a Cd-109 KXRF system at the same bone site.

To test the association between cumulative Pb exposure, as measured by the portable KXRF system, and motor function outcomes like tremor, balance, reaction time and rhythmic precision in the group of 100 subjects. This will demonstrate the utility of the portable system in studying health outcomes related to cumulative Pb exposures.

In summary, the major goals are to develop and validate a novel portable KXRF system for measuring bone Pb levels in vivo, and then demonstrate its utility by using it to study the relationship between cumulative Pb exposure and motor function. The new system aims to improve upon existing technologies by being more portable and accessible. Finally, the grant is to provide me training and career development to become a successful independent researcher.

B.1.a Have the major goals changed since the initial competing award or previous report?

The major goals remain the same.

B.2. What was accomplished under these goals?
We designed a collimator and shielding for the x-ray tube to create a pencil beam, as the high energy x-ray tubes available generally rely on large, diffuse x-ray beams. We limited the beam area to about 5 cm^2 at about 20 cm from the focal spot. This is key in lowering the dose when we use the x-ray tube for measurement, but also in limiting the scatter from parts of the beam that would not be hitting the person's bone. We tested different detectors: sodium iodide, silicon based, and cadmium zinc telluride (CdTe), for use in our final setup. All of these detectors are operable at room temperature to meet our goals in the project, but this mainly comes down to the resolution of each at the lead (Pb) energies of which we are primarily interested. The CdTe has the best properties for ease of use with good resolution properties. We also created standards out of plaster-of-Paris doped with varying levels of lead in order to simulate bone. This same process has been used in the past as a bone surrogate for these types of measurements. I verified the lead levels in these phantoms using inductively coupled plasma mass spectrometry (ICP-MS). We have also quantified cadaver bones of various levels of lead exposure, which we have tested with our device and have finished doing laser ablation ICP-MS and other XRF procedures to verify the concentrations. These cadaver sample measurements will be used to help verify the portions of the bone that are actually

measured and determine the cortical and trabecular range for each of the XRF devices capable of in vivo measurements.
We estimated a minimum detection limit with unrestricted radiation dose of 0.2 ppm from our device, which would be a factor of ten times lower than previous devices. When restricting by radiation doses less than 10 uSv (total body effective dose), which would be in-line with natural background radiation on a population level, this minimum detection limit increased to 6 ppm, which is still on par with conventional KXRF bone lead measurement systems. We maximized the count rate to the detectors at a 90-degree geometry and attempted to remove excess beam from the measurements using a background subtraction method. Normalization of the device from the Compton scattering interactions in the spectra allowed us to get a value that was less dependent on geometrical factors in our measurements. We compared the Cd-109 KXRF measurements to those with our portable KXRF and got reasonable agreement with a R^2=0.87 and p-value < 0.001.

Prior to in vivo measurements we did in beam analysis of the radiation dose. We have completed a thorough dosimetry assessment of the 140 kV beam for the proposed study of heavy metals with measurements in vivo. Our findings indicate that this would represent a minimal dose for a measurement time of up to 20 minutes. Two 10-minute measurements would represent a represent a total body effective dose of 16.5 uSv from this instrument from upon direct contact with the outgoing beam. This measurement was performed using a Thermo Scientific RADEYE B20 radiation survey meter. Measurements were taken using the shielding that was optimized for the device measurements, which are expected to be in place during any in vivo measurements. In the procedures, it is noted that the x-ray aperture will be a few millimeters at least from the individual being measured. Thus, this radiation dose represents a conservative view of the potential radiation dose during a given measurement. A radiation dose of 16.5 uSv represents minimal radiation dose with a negligible risk to the individual. Using the total body effective dose, we can estimate the risk of radiation-induced cancers. The increased risk for cancer and other inheritable effects from radiation has been found to be 5% per Sievert of total body effective dose. Given the doses we found from the 3-minute portable XRF measurement, this would mean a 0.00008% increased risk of cancer.
We have finished recruitment for our study of motor function and lead exposure in a group of active-duty soldiers. These soldiers had bone lead measurements done using our portable KXRF, nail lead measurements, and blood lead measurements with detailed exposure histories. Finally, they completed a motor function test using a CATSYS system, which is used clinically to test for fine motor precision and tremor. Preliminary analyses of this data indicate that lead impacts some of the motor function tests more than others, such as tremor and rhythmic precision.

B.4. What opportunities for training and professional development has the project provided?

In terms of training, I completed a class to learn methods for evaluating environmental exposures to chemical mixtures and reviewing statistical approaches in this context. The class went over major statistical approaches for dealing with mixed exposures such as principle component analyses, weighted quantile sum, LASSO and elastic net, and more complex analyses using Bayesian kernel machine regression. Stemming from this class, I have finished analyses using Normative Aging Study data to determine the mixed association and synergisms between elements measured in toenails and neurological outcomes measured using the mini-mental state examination (MMSE). This results from my analysis of this data indicates there are significant interactions between manganese and mercury impacting cognition via MMSE. We also found that of the five metals included in our analysis (mercury, manganese, lead, cadmium, and arsenic), lead and mercury were the only ones to have significant impacts on MMSE. In addition, I completed a class on responsible conduct in research and regulatory and data compliance in typical research settings involving humans. I have been having regular meetings with my advisors to support my training and research projects and seek advice on moving into independent research positions. I have completed two years of my tenure-track position at Purdue University. Finally, in terms of training, I presented my work at more than 36 separate presentations since the start of the award.

B.5. How have the results been disseminated to communities of interest?

I presented my work at many scientific conferences and presentations since the start of the award. Major presentations are listed below. Underlined names are my trainees and my names are bolded.

1. CJ Burgos, M Khan, TR Grier, MG Weisskopf, KM Taylor, **AJ Specht**. Dosimetry of a portable x-ray tube based KXRF system to measure lead in bone. Health Physics Society. July 25, 2023. National Harbor, MD.
2. M Khan, CJ Burgos, TR Grier, MG Weisskopf, KM Taylor, **AJ Specht**. Experimental design of a portable x-ray tube based KXRF system to measure lead in bone. Health Physics Society. July 25, 2023. National Harbor, MD.
3. C Hoover, **AJ Specht,** D Hemenway. Firearm Licensure, Lead Levels and Suicide in Massachusetts. National Research Conference on Firearm Injury Prevention. November 30, 2022. Washington D.C.
4. C Hoover, **AJ Specht**. Firearm-Related Pediatric Lead Exposure and Mental Health: An Overview of the Firearm Exposure Research Team. HSCI Research Seminar. November 22, 2022. Purdue University. West Lafayette, IN.
5. **Specht AJ.** 2-Dimensional Benchtop X-ray Fluorescence Approaches to Exposure Assessment. International Society of Exposure Science. September 27, 2022. Lisbon, Portugal.
6. **Specht AJ.** 2-Dimensional Benchtop X-ray Fluorescence Approaches to Exposure Assessment. International Society of Environmental Epidemiology. September 19, 2022. Athens, Greece.
7. **Specht AJ*.** Introduction to X-ray Fluorescence for Community Health Applications. Argonne National Lab Community Outreach. December 21, 2021. Lemont, IL.
8. **Specht AJ*.** Introduction to X-ray Fluorescence Applications. University of Louisville Neurotoxicology Group. October 27, 2021. Louisville, KY.
9. **Specht AJ*.** Portable x-ray fluorescence bone lead measurements of live condors in field to assess cumulative lead exposure. Raptor Research Foundation Conference. October 10, 2021. Boise, Idaho.
10. **Specht AJ*.** Desktop XRF as a novel tool for exposure assessment. MEMCARE Series, Harvard T.H. Chan School of Public Health. Oct. 4, 2021. Boston, MA
11. **Specht AJ*.** Cumulative Lead Exposure Resulting from Coal Power Plants in India. International Society of Environmental Epidemiology. August 18, 2021. New York, NY.
12. X Zhang, **AJ Specht**, EM Wells, MG Weisskopf, J Weuve, LH Nie. In vivo Quantification of Bone Lead and Strontium using Portable X-ray Fluorescence (XRF). International Society of Environmental Epidemiology. August 18, 2021. New York, NY.
13. **Specht AJ***. Applying Novel Exposure Assessment Tools in Health Studies. Purdue, School of Health Sciences. April 19, 2021. West Lafayette, Indiana.
14. **Specht AJ***. Applying Novel Exposure Assessment Tools in Health Studies. Wayne State University, Environmental Health and Justice. March 2, 2021. Detroit, Michigan.
15. **Specht AJ***. Applying Novel Exposure Assessment Tools in Health Studies. Brown University, Epidemiology. February 11, 2021. Providence, Rhode Island.
16. **Specht AJ***, et al. Mixed metal exposures measured from toenail in relation to mini-mental state examination scores in the Normative Aging Study. International Society of Environmental Epidemiology. Aug. 26, 2020. Baltimore, MD (virtual).
17. VT Nguyen, **AJ Specht**, F Bidlack, T Punshon, BP Jackson, MG Weisskopf. Reliability and Variability of Metal Measurements in Permanent Tooth Enamel. International Society of Environmental Epidemiology. Aug. 26, 2020. Baltimore, MD (virtual).
18. **Specht AJ***. Applying Novel Exposure Assessment Tools in Health Studies. University of Arizona, Environmental Health Sciences. May 19, 2020. Tucson, Arizona.
19. **Specht AJ***. Applying Novel Exposure Assessment Tools in Health Studies. University of Illinois - Chicago, Environmental and Occupational Health Sciences. March 25, 2020. Chicago, Illinois.
20. **Specht AJ***. Applying Novel Exposure Assessment Tools in Health Studies. George Washington University, Environmental and Occupational Health. March 11, 2020. Washington, DC.

21. **Specht AJ***. Applying Novel Exposure Assessment Tools in Health Studies. University of Michigan, Environmental Health Sciences. February 11, 2020. Ann Arbor, Michigan.
22. **Specht AJ*,** Nie LH. Bone Pb, Blood Pb, Biokinetics, and Chelation Therapy Efficacy in a Group of Lead Poisoned Children in China. Montefiore Lead Poisoning Prevention and Treatment Program. November 1, 2019. Bronx, New York.
23. **Specht AJ*.** Novel x-ray fluorescence approaches to ease trace metal biomarker measurements in field and low- and middle-income countries. ISTERH. September 23, 2019. Bali, Indonesia.
24. Nie LH, **Specht AJ**, Lin Yanfen, Weisskopf M, Yan C, Hu H, Xu J*. Bone Lead (Pb), Blood Pb, and Pb Biokinetics in Pb- poisoned Children. Abstract published and work presented in the 13th International Society on Trace Element Research in Humans (ISTERH) meeting, Sep. 22-26, 2019, Bali, Indonesia
25. **Specht AJ*.** Mixed Metal Exposures and Cognition in the Normative Aging Study. Seminar in Occupational and Environmental Health Research. September 6, 2019. Boston, MA.
26. **Specht AJ*,** Weisskopf MG. Feasibility of lead exposure assessment in blood spots using x-ray fluorescence. August 26, 2019. Utrecht, The Netherlands.
27. **Specht AJ***. Applying Novel Exposure Assessment Tools in Health Studies. Boston University, Environmental Health. July 8, 2019. Boston, MA.
28. **Specht AJ***. Applying Novel Exposure Assessment Tools in Health Studies. University of Alabama, Environmental Health Sciences. March 1, 2019. Birmingham, Alabama.

In addition, I have had various meetings with health departments and stakeholders in lead exposure to let them know about the availability of this technology. We have many active projects utilizing the technology in the future and plans to continue to make it more widespread.

B.6. What do you plan to do during the next reporting period to accomplish the goals?
N/A

Section C. Products

C.1. Are there publications or manuscripts accepted for publication in a journal or other publication (e.g., book, one-time publication and monograph) during the reporting period resulting directly from this award?

1. JE Celis, W Espejo, IY Montes, M Sandoval, **AJ Specht**, A Banegas-Medina. First report of some rare earth elements and trace elements in sands from different islands located in the Marine Natural monument Archipelago Cayos Cochinos, Caribbean Sea. Marine Pollution Bulletin. Volume 196, Nov 2023. 115648. (**Impact factor = 7.0)**
2. J Peng, Z Gao, J Xu, Y Lin, **AJ Specht,** S Chen, LH Nie, L Huang, C Yan. Concurrent Assessment on Blood Lead in Young Children and Toy Lead in Shanghai. Exposure and Health. Nov. 2023. 2451-9685. (**Impact Factor = 8.8)**
3. JO Hampton, MY Loht, **AJ Specht,** D Nzabanita, J Hufschmid, L Berger, K McGinnis, J Melville, E Bennett, JM Pay. Lead exposure of mainland Australia's top avian predator. Environmental Pollution. 2023. (332), 122004. **(Impact Factor = 10.0)**
4. **AJ Specht***, DW Steadman, M Davis, SM Bartell, MG Weisskopf. Bone lead variability in bone repository skeletal samples measured with portable x-ray fluorescence. Science of the Total Environment. Science of the Total Environment. 2023 Jul 1:880:163197. **(Impact Factor = 10.8)**
5. CG Hoover, AS Dickerson, **AJ Specht**, GG Hoover. Firearm-related lead exposure and pediatric lead levels in Massachusetts: A decade of evidence (2010–2019). Environmental Research. 2023 227(115719). **(Impact Factor = 8.4)**
6. D Sowers, J Frandsen, E Caffrey, **AJ Specht,** JT Harris, T Dant, B Hamrick. The United States Navy and Employees with Cancer: The Time for Change is Now. Health Physics. Aug 2023 125(2):147-151.. **(Impact Factor = 1.0)**

7. D Nzabanita, JO Hampton, D Nugegoda, J Hufschmid, SD Toop, J Flesch, H Dunstan, AJ Bengsen, **AJ Specht**. Expanding the use of portable XRF to monitor lead exposure in Australian waterbirds two decades after a ban on lead shot. Science of the Total Environment. 2023 Jan 25;869:161803. **(Impact Factor = 10.8)**
8. C Hoover, **AJ Specht,** D Hemenway. Firearm Licensure, Lead Levels and Suicide in Massachusetts. Preventative Medicine. 2023 Jan;166:107377. **(Impact Factor = 4.0)**
9. S Paudel, **AJ Specht,** H Hu, J Danziger. Association of environmental lead toxicity and hematologic outcomes in patients with advanced kidney disease. Nephrology Dialysis and Transplantation. 2022 Dec 22;gfac336. **(Impact Factor = 7.2)**
10. X Zhang, **AJ Specht,** EM Wells, MG Weisskopf, J Weuve, LH Nie. In vivo quantification of strontium in bone among adults using portable x-ray fluorescence. Journal of Trace Elements and Minerals. 2022 Dec;74:127077. **(Impact Factor = 3.8)**
11. SS Wise, H Lu, RM Speer, JP Wise Jr, J Young, JH Toyoda, I Meaza, TJ Croom-Perez, JC Kouokam, **AJ Specht**, KJ Liu, GW Hoyle, JP Wise Sr. Chromium distribution in oropharyngeal aspiration model for hexavalent chromium in rats. Toxicology and Applied Pharmacology. 2022; 457:116294. **(Impact Factor = 4.3)**
12. K Ahmid, **AJ Specht,** L Morikawa, G Poudrier, D Ceballos, S Wylie. Lead and other toxic metals in plastic play foods: Results from testing citizen science, lead detection tools in childcare settings. Journal of Environmental Management. 321(115904). 2022 **(Impact Factor = 5.8)**
13. CD Golden, J Ayroles, JG Eurich, JA Gephart, KL Seto, MK Sharp, P Balcom, HM Barravecchia, KK Bell, KD Gorospe, J Kim, WH Koh, J Zamorain-Mason, DJ McCauley, H Murdoch, N Nair, K Neeti, S Passarelli, **AJ Specht**, EM Sunderland, A Tekaieti, A Tekiau, R Tekoaua, E Timeon. Study Protocol: Interactive Dynamics of Coral Reef Fisheries and the Nutrition Transition in Kiribati. Frontiers in Public Health. June 2022. **(Impact Factor = 6.0)**
14. Johnson KM, **Specht AJ,** Hart JM, Salahuddin S, Erlinger AL, Hacker MR, Woolf AD, Hauptman M, Karumanchi SA, O'Brien K, Wylie BJ. Risk-factor Based Lead Screening and Correlation with Blood Lead Levels in Pregnancy. Maternal and Child Health Journal. 2022 Jan;26(1):185-192. **(Impact Factor = 1.8)**
15. Bhatia M, **Specht AJ*,** Ramya V, Sulaiman D, Konda M, Balcom P, Sunderland E, Qureshi A. Portable XRF as a rapid determination tool to detect mg/kg (ppm) levels of heavy metals (Ni, Zn, As, Se and Pb) in human nails: a case study from South India. Environmental Science and Technology. 2021, 55, 19, 13113–13121 **(Impact Factor = 11.4)**
16. C Hoover, GG Hoover, **AJ Specht*.** Firearm Licenses Associated with Elevated Pediatric Blood Lead Levels in Massachusetts. Environmental Research. 2021; 202:11642. **(Impact Factor = 8.4)**
17. **AJ Specht*,** X Zhang, A Young, VT Nguyen, DC Christiani, DM Ceballos, JG Allen, J Weueve, LH Nie, MG Weisskopf. Validation of in vivo toenail measurements of manganese and mercury using a portable x-ray fluorescence device. Journal of Exposure Science and Environmental Epidemiology. 2021. **(Impact Factor = 5.6)**
18. JO Hampton, **AJ Specht,** JM Pay, MA Pokras, AJ Bengsen. Portable X-ray fluorescence for bone lead measurements of Australian eagles. Science of the Total Environment. 2021 Oct 1;789:147998. **(Impact Factor = 10.8)**
19. **AJ Specht***, JF Obrycki, Maitreyi Mazumdar, MG Weisskopf. Feasibility of lead exposure assessment in blood spots using energy dispersive x-ray fluorescence. Environmental Science & Technology. 2021, 55, 8, 5050–5055. **(Impact Factor = 11.4)**
20. DM Ceballos, AS Young, JG Allen, **AJ Specht**, VT Nguyen, J Craig, M Miller, T Webster. Nail salon technician exposure to metal impurities from nail products. International Journal of Hygiene and Health. 2021 Mar;232:113687. **(Impact Factor = 7.4)**
21. AS Young, R Hauser, TJ Todd, BA Coull, H Zhu, K Kannan, **AJ Specht**, MS Bliss, JG Allen. Impact of "healthier" materials interventions on dust concentrations of per- and polyfluoroalkyl substances, polybrominated diphenyl ethers, and organophosphate esters. Environment International. 2021 May;150:106151. **(Impact Factor = 13.4)**

22. Zhang X, **Specht AJ**, Nie LH. Evaluation of a portable XRF device for in vivo quantification of lead in bone among a US population. Science of the Total Environment. 2021; 753;142351. **(Impact Factor = 10.8)**
23. Johnson KM, **Specht AJ,** Hart J, Salahuddin S, Erlinger AP, Hacker MR, Woolf A, Hauptman M, Karumanchi A, Wylie B, O'Brien K. Lead exposure and association with angiogenic factors and hypertensive disorders of pregnancy. Pregnancy Hypertension. 2020. 22:93-98. **(Impact Factor = 1.2)**
24. JC Nwanaji-Enwerem, E Colicino, **AJ Specht**, X Gao, C Wang, P Vokonas, MG Weisskopf, EW Boyer, AA Baccarelli, J Schwartz. Individual species and cumulative mixture relationships of 24-hour urine T metal concentrations with DNA methylation age variables in older men. Environmental Research. 2020; 186:109573. **(Impact Factor = 8.4)**
25. Johnson KM, **Specht AJ,** Hart J, Salahuddin S, Erlinger AP, Hacker MR, Woolf A, Hauptman M, Karumanchi A, Wylie B, O'Brien K. Risk-factor based lead screening and correlation with blood and bone lead levels in pregnancy. Obstetrics and Gynecology. 2020; 135:120s-121s. **(Impact Factor = 5.0)**
26. **Specht AJ***, Dickerson AS, Kponee K, Kpobari N, Weisskopf MG. Toenail metal exposures in fishermen from Bodo City, Nigeria. Bulletin of Environmental Contamination and Toxicology. 2020; 104:90-95. **(Impact Factor = 2.7)**

C.2. Website(s) or other internet site(s).

None.

C.3. Technologies or techniques.
We developed a potential new technique for identifying bone density using our x-ray tube.

C.4. Inventions, patent applications, and/or licenses.
Have inventions, patent applications and/or licenses resulted from the award during this reporting period?

We are seeking a patent and have a preliminary patent application in for our portable KXRF system.

C.5. Other products and resource sharing.
None.

Section D. Participants

D.1. What individuals have worked on the project?

Key Personnel
Name: Aaron James Specht
Senior/Key Personnel: Yes
ERA Commons ID: ajspecht
Degree: PhD
Role: PD/PI
Person Months: Academic: 5 Summer:3
Foreign Affiliation: N/A
SS: N/A

D.2.a. Level of Effort
Will there be, in the next budget period, either (1) a reduction of 25% or more in the level of effort from what was approved by the agency for the PD/PI(s) or other senior/key personnel designated in the Notice of Award, or (2) a reduction in the level of effort below the minimum amount of effort required by the Notice of Award?
No

D.2.b. New Senior/Key Personnel
Are there, or will there be, new senior/key personnel?

No

D.2.c. Changes in Other Support
Has there been a change in the active other support of senior/key personnel since the last reporting period?
No

D.2.d. New Other Significant Contributors
Are there, or will there be, new other significant contributors?
No

Section E. Impact

E.2 What is the impact on physical, institutional, or information resources that form infrastructure?

Not Applicable

E.4. What dollar amount of the award's budget is being spent in foreign country(ies)?

None

Section F. Changes

F.2 Actual or anticipated challenges or delays and actions or plans to resolve them

Not Applicable

F.3.a Human Subjects
No change

F.3.b Vertebrate Animals
No change

F.3.c Biohazards

No change

F.3.d Select Agents
No change

Section G. Special Reporting Requirements

G.1. Special Notice of Award and Funding Opportunity Announcement Reporting Requirements
Nothing to report

G.5 Human Subjects Education Requirement
Are there personnel on this project who are or will be newly involved in the design or conduct of human subjects research?

Nothing to report

G.6. Human Embryonic Stem Cells (hESCs)
Does this project involve human embryonic stem cells?

No

G.9. Foreign Component
Has significant scientific activity for this grant been performed outside of the United States, whether or not grant funds were expended?

No foreign component

G.10.a Is it anticipated that an estimated unobligated balance (including prior year carryover) will be greater than 25% of the current year's total approved budget?

No

H. Budget

H.1 Budget Form

I. Outcomes of the Award

Project: A novel portable KXRF measurement system for in vivo metal measurements
Contact PI: Aaron Specht
Organization: Purdue University

This research project focused on the validation of a new device for measurements of lead in bone using K-shell x-rays and an x-ray tube source. Key accomplishments involved obtaining concrete data to ascertain the detection limits of the proposed experimental device for bone lead measurements. Significant advancements were made, such as optimizing the setup to generate a pencil beam, effectively limiting radiation exposure to the subject and optimizing the detector for lead's K-shell x-rays.

The project meticulously designed a collimator and shielding for the x-ray tube to generate a precise x-ray beam over the bone – crucial in reducing dose and minimizing scattered radiation during measurements. Testing and comparison of various detectors, including sodium iodide, silicon-based, and cadmium zinc telluride (CdTe), were performed to determine the optimal choice based on resolution properties at lead energies of interest. We performed radiation dose assessments, shielding, and validation of the prototype system, demonstrating minimal radiation exposure during in vivo measurements, ensuring the safety and viability of the device for intended applications.

After extensive testing and refinement, the device showcased promising detection capabilities, with a remarkable detection limit estimate of 0.6 ppm for lead in plaster-of-Paris phantoms. With optimized dose measures, we used a lower power output for the x-ray tube and calculated a detection limit of 6 ppm – still lower than conventional systems for bone lead measurement. Further developments are planned to enhance this limit and validate its effectiveness through comprehensive testing with multiple detectors with larger active areas. Finally, we successfully completed recruitment for our bone lead biomarker measurements and validation for the study sets. Additionally, this sets the stage for pilot results on neuromotor function related to lead. We have a subsequent publication of results, providing a valuable contribution to the field and hopefully leading to more use of this device in the future.