Investigating the systemic distribution of implant wear products in ovo using the hen's egg as a model

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ABSTRACT

Joint replacement is an established medical approach to improve the quality of life in patients who suffer from bone damage or osteoarthritis. The release of cobalt (Co) ions due to wear and corrosion in orthopedic implants has been extensively characterized and local tissue reactions are well described in literature[1]. In addition, elevated systemic levels of Co have been reported in blood while little is known about exact systemic distribution and possible accumulation in tissues and organs of the human body [2]. This study aims to investigate the systemic distribution of the orthopedic relevant metal Co by using the hen's egg as a vertebrate model. This model has several advantages such as the organisms independent development and appropriate control options. For qualitative and quantitative examination of Co distribution, synchrotron based micro X-ray fluorescence (SR-µXRF) analysis was employed. This information is meant to identify tissues and organs that might need special attention in a clinical context when the presence of joint implants are accompanied by elevated systemic metal levels.

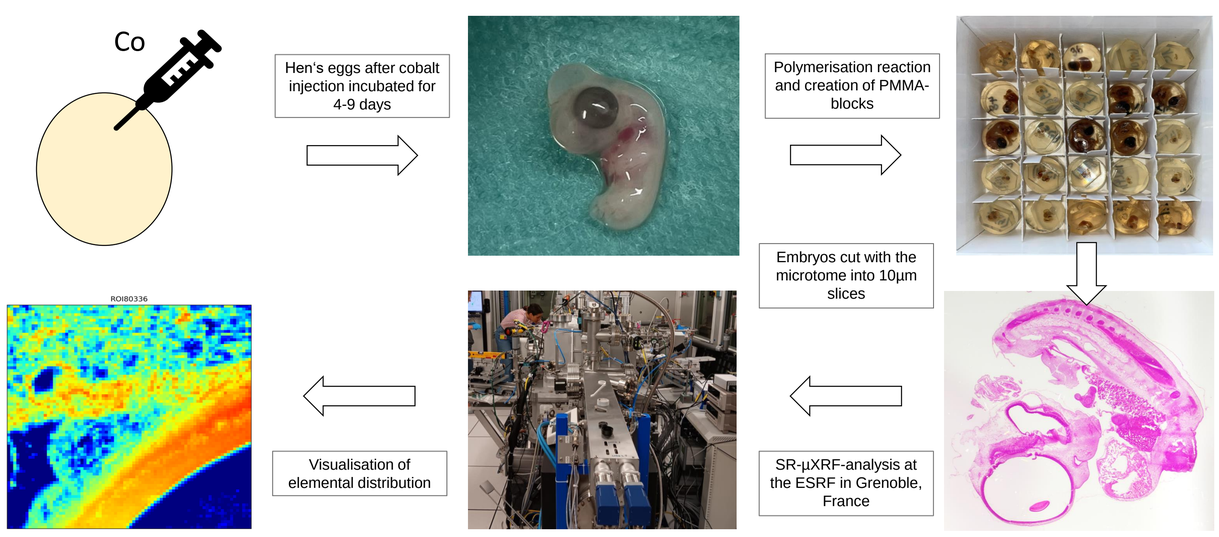

Figure 1. **Overview of the experimental procedure**

METHODS

Fertilised eggs were directly injected into the yolk sac with a Co solution to reach a final concentration of 0,05mg/L, while controls were injected with sodium chloride solution. The optimal route of exposure was determined in previous experiments, while the Co concentration aims to recreate clinical relevant systemic concentrations of Co [3]. Embryos were kept in a incubator for 4 to 9 days. After sacrificing, the embryos were fixated and subsequently embedded in polymethylmethacrylate (PMMA) for sectioning. Samples were investigated using µ-XRF instrumentation at the ID-21 beamline at the European Synchrotrone Radiation Facility (ESRF) for the spatial analysis of the elemental composition in thin sections. The HE-stainings of the specimens were used for identification of organs and tissues.

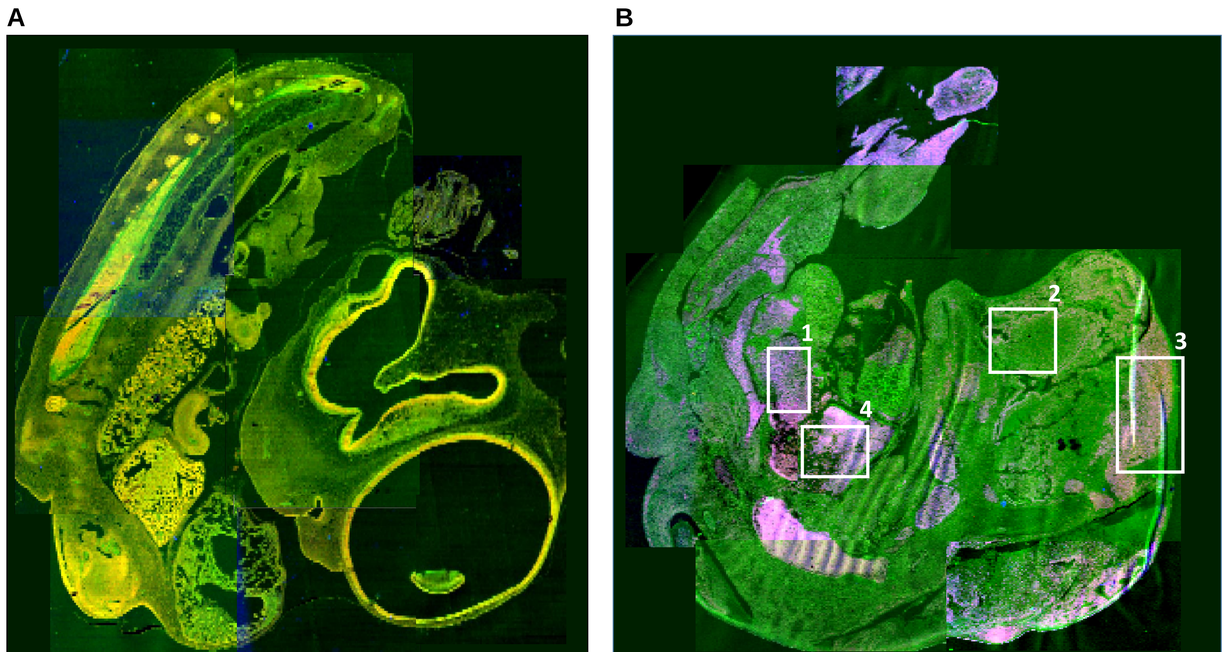

Figure 2. **SR-µXRF overall scan.** Comparison of control group (**A**) and Co-exposed embryos (**B**)

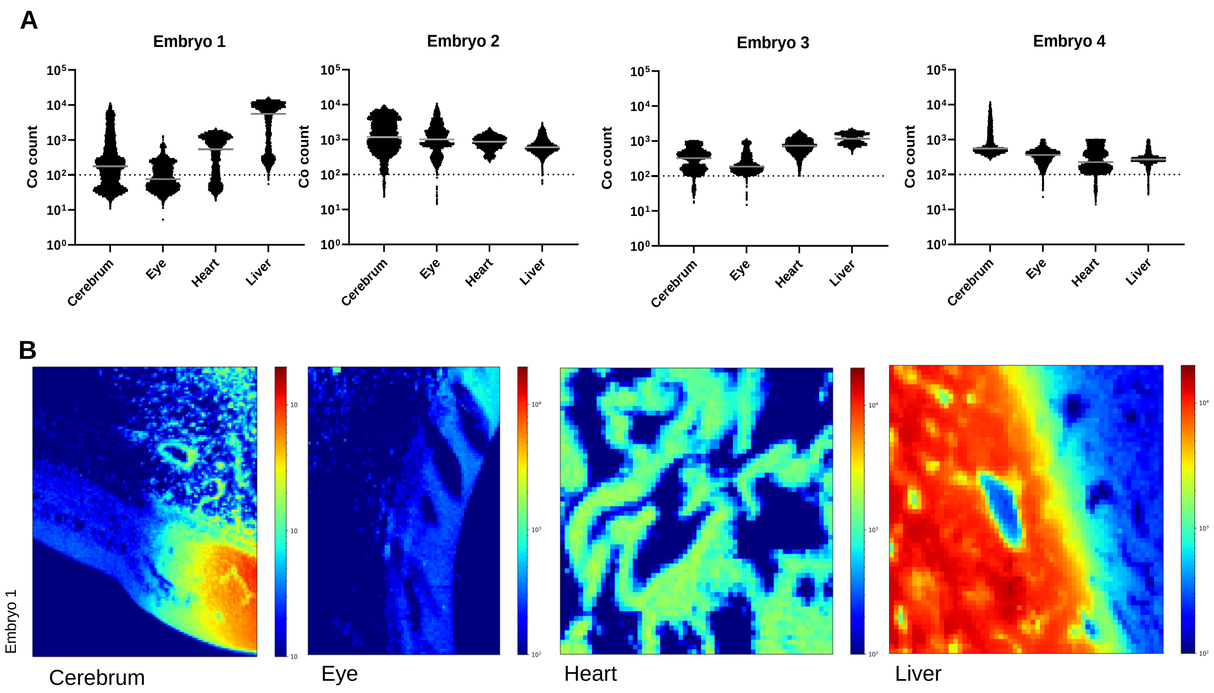

Figure 3. **Analysis of the Co concentration on developement day 5.** Co amount (arbitrary units) shown in different compartments in 4 chicken embryos (**A**) and the distribution of Co in the cerebrum, eye, heart and liver in embryo 1 (**B**) represented as heat maps showing spatial Co distribution within target compartments.

RESULTS

Co ions accumulate in the chicken embryo after injection into the egg yolk. In contrast of the control group the Co-exposed embryos have high Co concentrations found in different areas of the body. (Fig. 2). Specific depositions of Co have been found within the cerebrum, eye, heart and liver (Fig. 3). The ions do not remain local but are distributed throughout the entire chicken embryo. There is a clear decrease of the Co concentration from development day 4 to 9 in the cerebrum and the eye (Fig. 4).

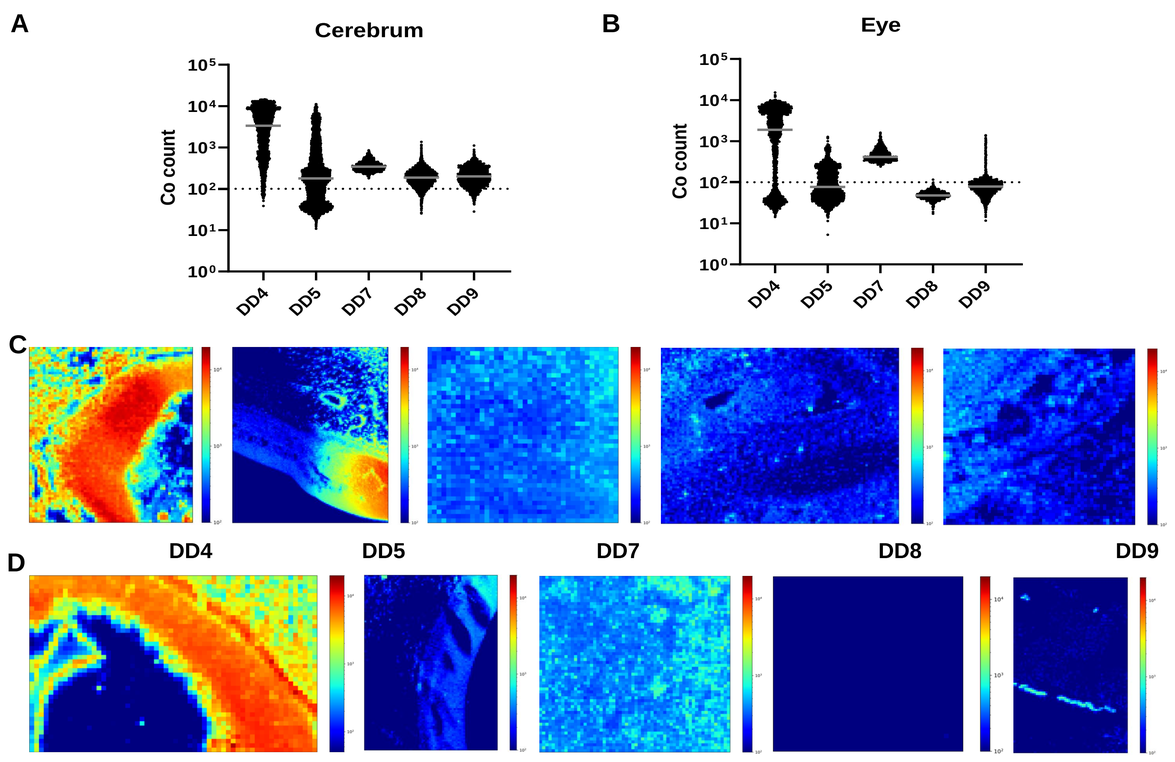

Figure 4. **Timeline of the Co concentration.** Comparison of the quantitatively difference between developement day 4, 5, 7, 8 and 9 (**C**, **D** from left to right) in the cerebrum (**A**, **C**) and the eye (**B**, **D**) of the chicken embryo.

CONCLUSION

The results presented confirm the systemic distribution and specific accumulation of Co in the chicken embryo following direct injection into the yolc sac. The high levels of Co in cerebrum, eye, heart and liver demonstrate that these organs are especially prone to Co accumulation after systemic distribution. In addition, the decreasing Co concentration over time hints on active and passive processes that can influence Co deposition which needs to be investigated further in more detail. Our data indicates that systemic exposure with Co ions can lead to Co accumulation in specific organs. This information would need further confirmation and may aid in better patient care for people that suffer from elevated Co levels in their blood due to joint replacement wear.

REFERENCES

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