

EPR study of dose-rate-dependent radiolytic radical formation during ultra-high dose-rate irradiation *in vitro* and *in vivo*

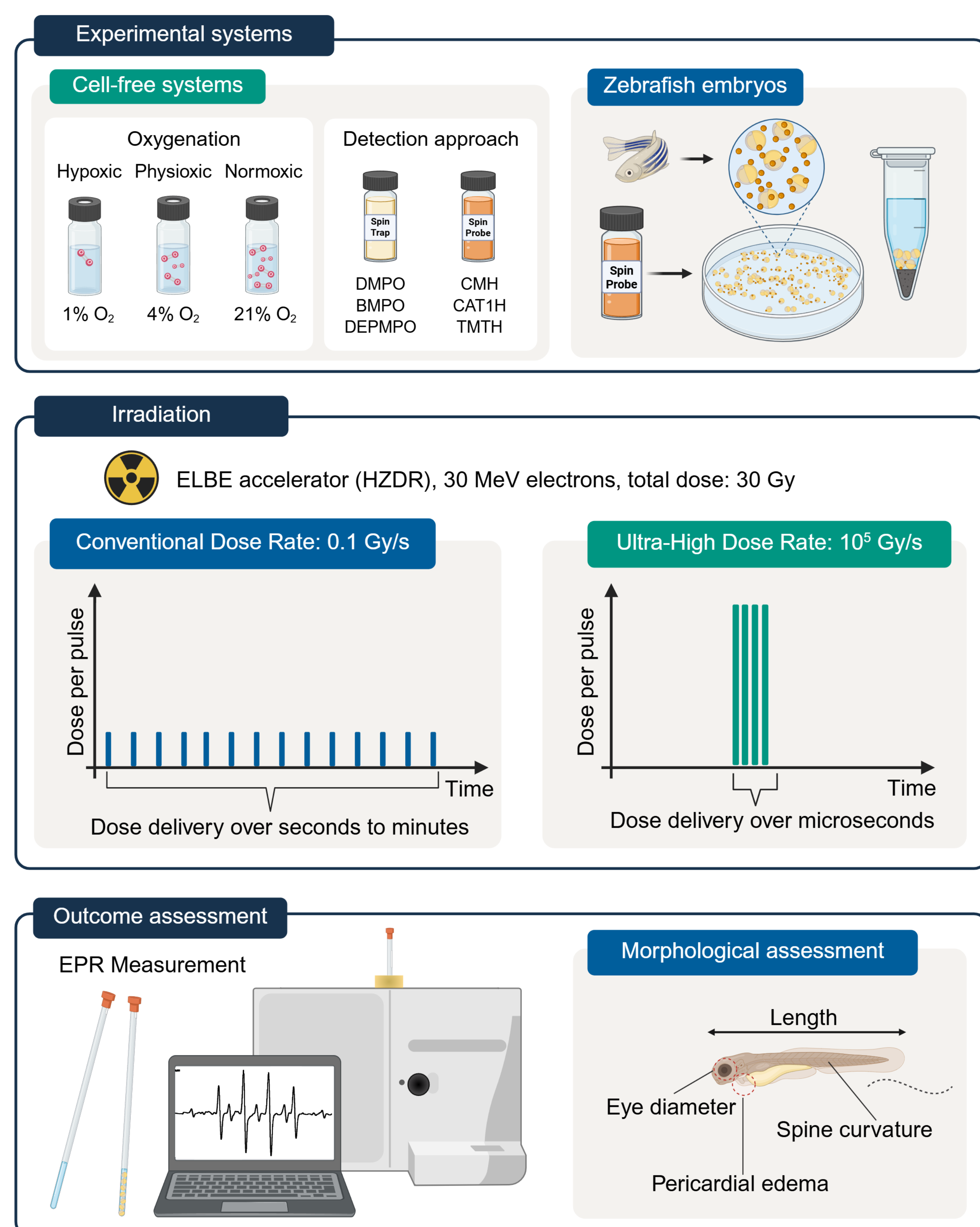
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Motivation

- Ultra-high dose rate (UHDR) irradiation (> 40 Gy/s) can reduce normal-tissue toxicity compared with conventional dose-rate (CDR) irradiation while maintaining tumour control, a phenomenon known as the FLASH effect.
- Enhanced radical-radical recombination at UHDR may alter the availability of reactive species and subsequent biological damage.
- We combine EPR measurements in cell-free systems (E3 medium) with zebrafish embryo (ZFE) experiments to investigate the link between early radiation chemistry and biological response.

Experimental design



Conclusion

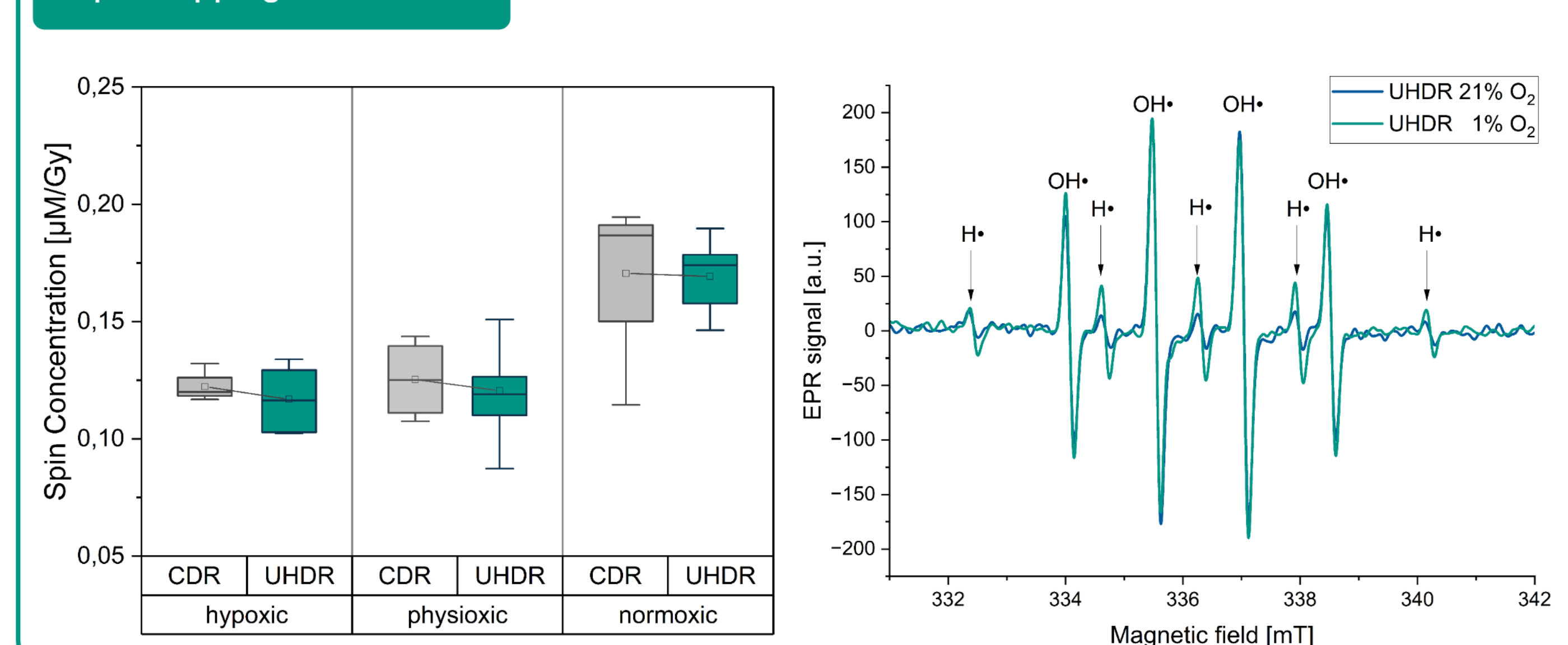
- Dose rate and oxygenation affect the detectable EPR response in E3 medium, with the observed differences depending on the detection approach.
- Spin traps and spin probes offer complementary, not interchangeable insights into radical chemistry.
- Increasing biological complexity may modify or mask these effects: EPR measurements were feasible in ZFE, but no significant differences were detected.

Results

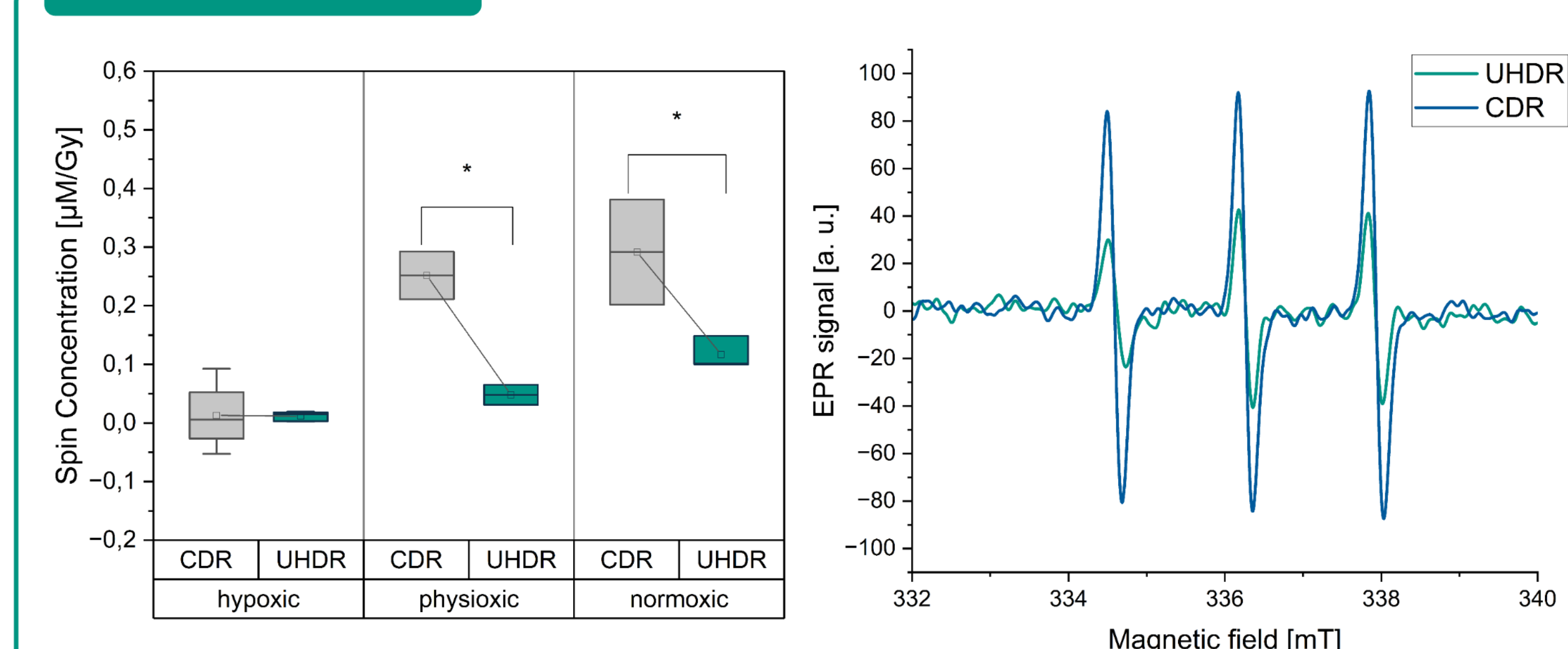
Cell-free systems

- Spin probes revealed differences between CDR and UHDR irradiation, whereas no clear dose-rate dependence was observed with spin traps.
- The EPR response varied with oxygen concentration.

Spin trapping with DMPO



Spin probing: CAT1H

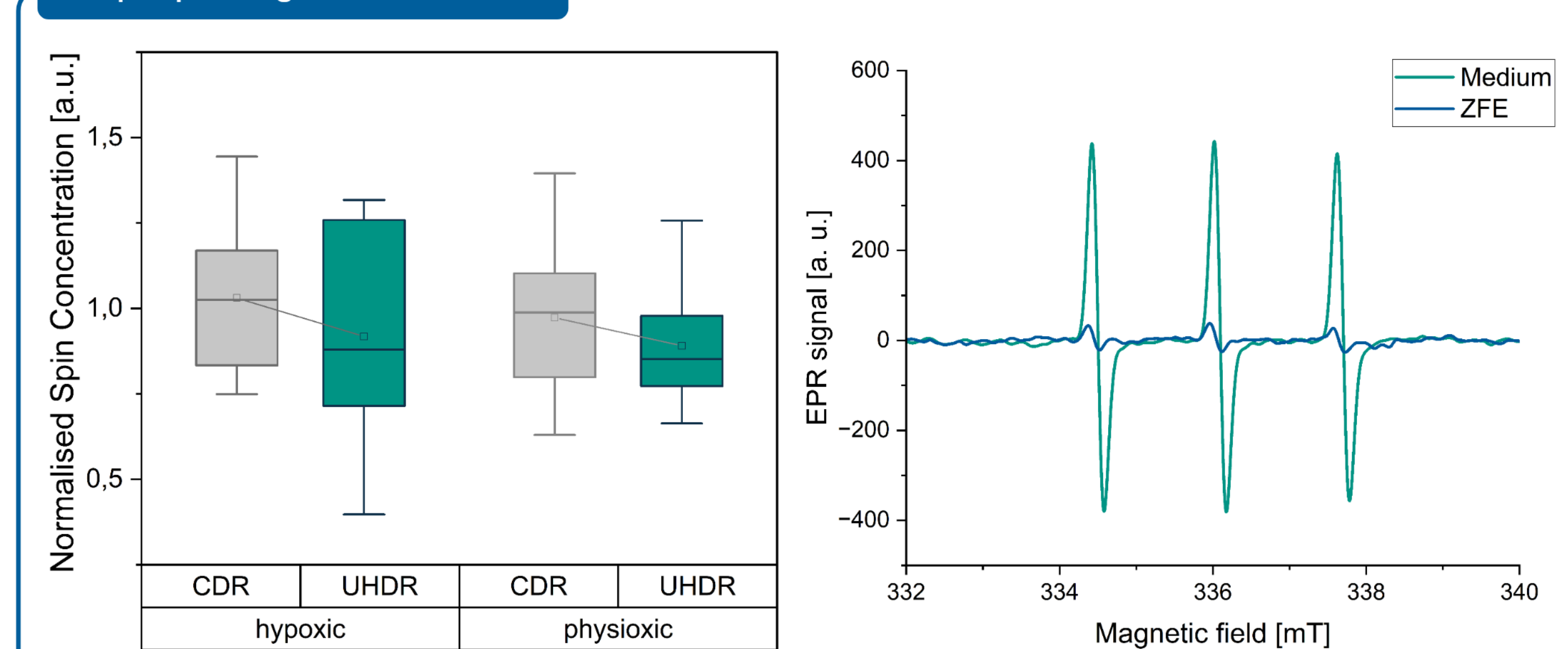


Quantified spin concentrations under different oxygen and dose-rate conditions, together with representative EPR spectra. **p* < 0.05.

Zebrafish embryos

- Spin-probe exposure and EPR measurement had no significant effect on the assessed biological endpoints.
- EPR signals were detected under all conditions, but were approximately 90% lower in ZFE than in the surrounding medium.
- No significant dose-rate- or oxygen-dependent differences were detected in the EPR response of ZFE.

Spin probing in ZFE: CMH



Normalised spin concentrations in ZFE under different oxygen and dose-rate conditions, together with representative EPR spectra of ZFE and E3 medium.