

Resonant Circuits Limited DARTRIX Workshop The MACH System

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RCL

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Resonant Circuits Limited

- Resonant Circuits Limited (RCL) was founded in 2009 to provide bespoke consultancy and expertise in the field of magnetic hyperthermia and sensing.
- RCL is comprised of three core personnel and currently supports one PhD student at University College London.
- We are currently based at the Royal Institution of Great Britain, London.



Paul Southern
Founder & CEO



Quentin Pankhurst
Founder & Director



Simon Hattersley
Founder & Chief Designer



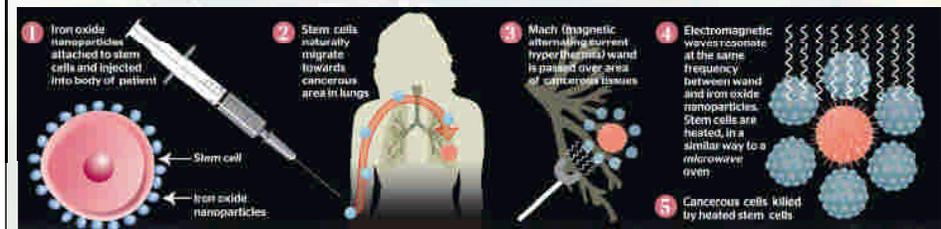
Fang-Yu Lin
PhD Student

Talk Summary

- Magnetic Hyperthermia
- The MACH system
- Clinical dose – the bioheat model
- Clinical issues – non-specific heating
- Clinical issues – remote monitoring the temperature

Magnetic Hyperthermia

- Magnetic hyperthermia offers the possibility to therapeutically heat malignant cells without any non-specific effects.
- Therapeutic temperatures anywhere between 40-60°C.
- Harnesses the power of a time-varying magnetic field.
- Only one clinically trialed system available from MagForce.



MACH system

- The MACH (Magnetic AC Hyperthermia) is a scalable magnetic hyperthermia system that RCL has developed.
- The core component is a patented drive circuit that can be paralleled up to deliver more power to the coil.
- The key feature to the MACH system is a self-tuning mechanism to ensure the magnetic field is always at resonance.
- Self-tuning can potentially provide useful feedback to the user i.e. optimal positioning of the coil.



Power supply

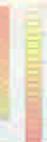
3kW DC power supply – normal plug/socket
Requirements 0-35V up to 100A

User feedback

Current in coil
Frequency of resonant system

Preliminary design

Frequency ~ 300-350kHz
Current ~ 500-600A
Voltage ~ 2kV
Central field ~ 5kA/m



Control drive circuits

Analogue feedback mechanism
No software control

Cooling

Water run to waste
or a chiller

Safety*

Temperature of coil
Loss of water flow, high/low pressure

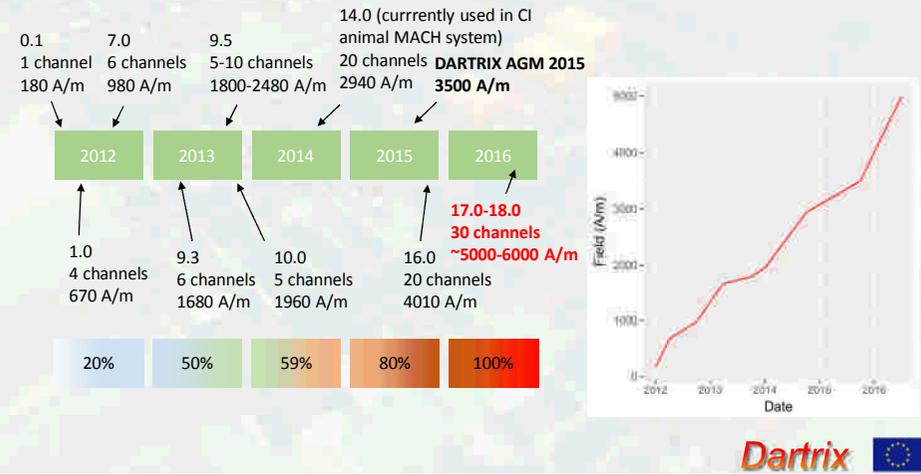
Clinical trials

DARTRIX – Glioblastoma 2017/18
NoCanTher – Pancreatic Cancer 2016-2021
Melanoma – 2017/18

*The system has been tested at the medical physics department at UCH and has demonstrated safe operation within a clinical setting with no interference to monitoring equipment: electrocardiogram (ECG) machine, ultrasound machine, a pulse oximeter and an automatic non-invasive blood pressure monitor.

MACH progress timeline

Target is 5000 A/m using 30 channels – achieved 5.1kA/m August 2016
Treatment volume ~ human head.

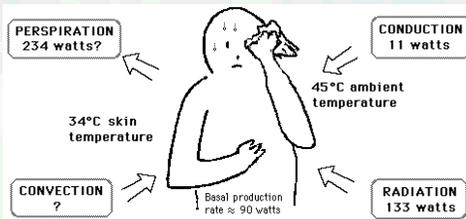


MACH flexibility



Dose calculation - Bioheat modelling

Energy loss inside tissue is complicated and we have many factors to consider:

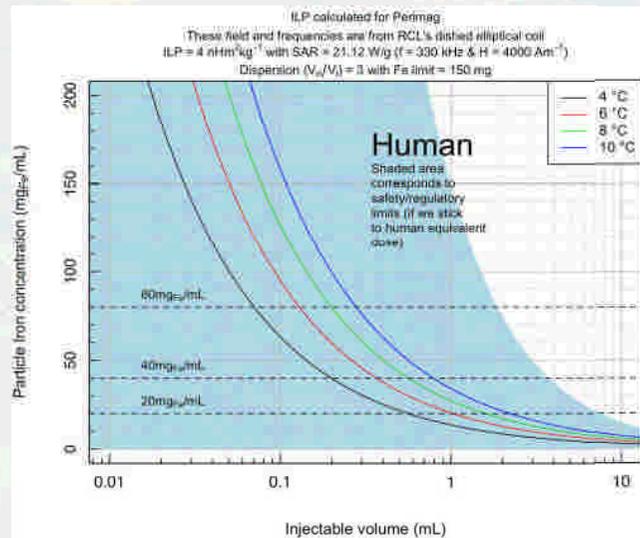


- Specific loss power (the rate in which the nanoparticles generate energy)
- Tissue conduction
- Spread of nanoparticles
- Non-specific heating (eddy current heating)
- Blood perfusion

$$\Delta T = \text{SLP} \cdot c \cdot R^2 / (3\lambda) \quad (\lambda = 0.64 \text{ WK}^{-1} \text{ m}^{-1})$$

is the heat conductivity of tissue).

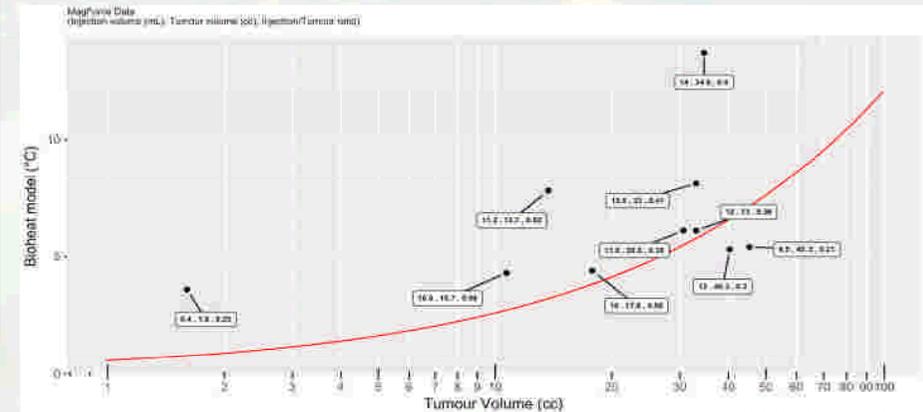
Bioheat model



Bioheat model – clinical data

- Applied the bioheat model to data from MagForce (field = 4.5kA/m)

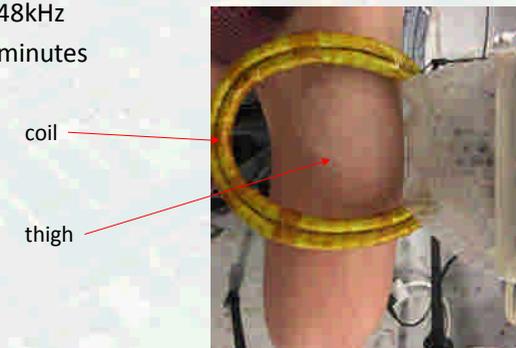
Johannes, M., Gneveckow, U., Thiesen, B., Taymoorian, K., Cho, C. H., Waldöfner, N., et al. (2007). Thermotherapy of Prostate Cancer Using Magnetic Nanoparticles: Feasibility, Imaging, and Three-Dimensional Temperature Distribution. *European Urology*, 52(6), 1653–1662. <http://doi.org/10.1016/j.eururo.2006.11.023>



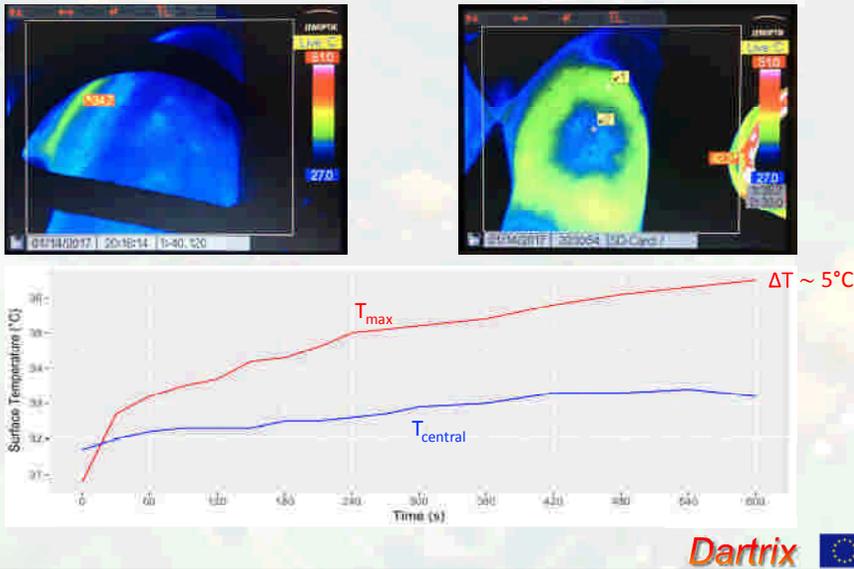
Non-specific heating at 4kA/m

Experimental conditions

- 5 boards with coil current = 470A
- Central field (5cm into skin) = 4kA/m
- Frequency = 348kHz
- Duration = 10 minutes



Non-specific heating at 4kA/m



Outlook & Conclusions

- The MACH system is a scalable and portable magnetic hyperthermia system that works within a clinically acceptable field and frequency regime.
- Demonstrated a clinically scaled up system capable of delivering 5 kA/m over a volume of a human head.
- Clinical studies – Resonant Circuits Limited as co-applicant:
 - EU FP7 DARTRIX – Glioblastoma 2017/2018
 - EU H2020 NoCanTher – Pancreatic cancer 2019/2020
- Complementary technique to estimate the mass of magnetic material within a sample/animal/human.