PEMF as a Potential Therapy for Soft Tissue Wound Repair via Angiogenesis

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Abstract:

The potential therapeutic benefits of pulsed electromagnetic fields (PEMFs) to promote blood vessel growth (angiogenesis) was previously demonstrated with human umbilical vein endothelial cells *in vitro*. Our research employs an *in vivo* fertilized chicken egg angiogenesis model to evaluate response to PEMFs. Helmholtz coils were interfaced to a waveform generator and signal amplifier. The generator was used to create PEMFs of specific frequencies, amplitudes, and shapes. Eggs were divided into two groups (control, and treatment) and placed into compact incubators. Incubators were placed within active or sham Helmholtz coils and the treatment group was exposed to PEMF. Blood vessels were imaged within the egg and after eggshells were dissolved away. CAIMAN, a MATLAB image analysis toolkit was used for image pre-processing, segmentation, post-processing and calculation of vessel parameters. Our research findings could contribute to the development of novel therapies utilizing PEMFs to promote tissue repair and regeneration.

Procedure:

1. Eggs were imaged in-shell or shell-less (after shells were dissolved away using CLR Calcium, lime & Rust Remover).
2. Various lighting methods were tested for imaging – We found fluorescent ceiling lighting was best for shell-less eggs (reflectance mode, Figs 3 & 4) and commercial egg candlers or lasers (transmission mode, Figs 1 & 2) was best for in-shell eggs, but also worked for shell-less ones.
3. Background was removed with image editing software to minimize interference (Paint 3D's Magic Select tool).
4. Images were analyzed using CAIMAN blood vessel analysis software(Figs 2 - 4).

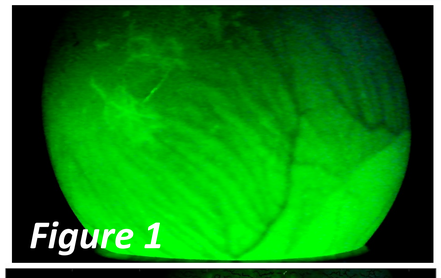

Figure 1

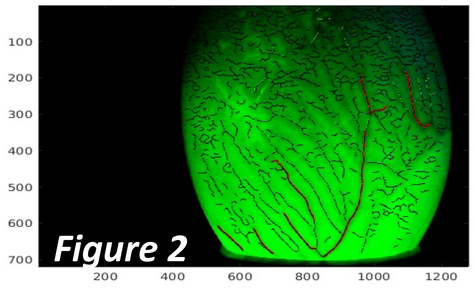

Figure 2

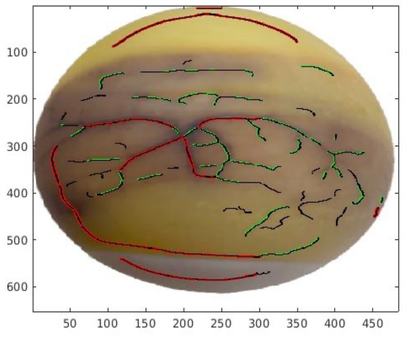

Figure 3

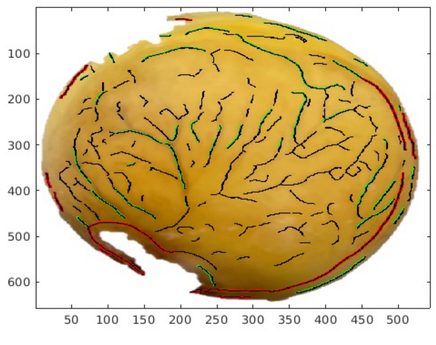

Figure 4

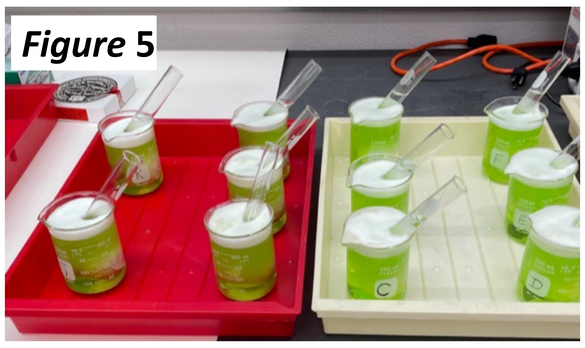

Figure 5

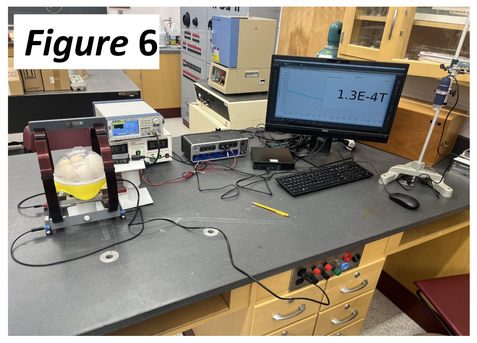

Figure 6

Figure 5: Dissolving eggshells away, prior to imaging. Raw eggs were submerged in CLR for 2-3 hours. Strong vinegar (10%) required more than a day to remove the eggshell.

$$CaCO_3 + 2H^+ \rightarrow Ca^{2+} + H_2O + CO_2$$

Figure 6: PEMF workstation, including waveform generator, signal amplifier, Helmholtz coils and compact egg incubator.

Future Research:

Herein, we developed a workflow for evaluating PEMFs, to monitor in vivo angiogenesis in chicken chorioallantoic membrane (CAM). We propose testing specialized PEMFs, including ones approved by the FDA for bone healing, to determine if any promote angiogenesis in this model system. With appropriate PEMF waveforms, we believe a medical device could be devised that treats soft tissue wound healing and repair in humans. For example, pressure injuries (bed sores) affect 2.5 M patients per year in the US and can become persistent and chronic, frustrating healthcare providers due to adverse impact on patient quality of life. We hope our device will quickly resolve such injuries by promoting collateral blood vessel growth at the injury site.

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