Red- & Near-Infrared Light Therapy Post-Craniectomy Improves Recovery Timelines in Rodent TBI Model

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Background

Traumatic Brain Injury (TBI) is a leading cause of mortality and long-term disability, affecting over 50 million people worldwide each year. TBI often results in persistent motor, cognitive, and sensory deficits.[1] **Decompressive craniectomy (DC)** is a common surgical intervention that alleviates intracranial pressure (ICP) by removing part of the skull, allowing the brain to expand.[2] While DC can improve outcomes for severe TBI patients, it does not fully address neural recovery and can lead to complications such as permanent deficits and **syndrome of the trephined (SoT).**[3-5]

This study explores the potential of **photobiomodulation (PBM)** therapy, specifically using red (660 nm) and near-infrared (850 nm) light, as an adjunctive treatment post-DC to enhance neurorehabilitation. PBM has shown promise in other contexts for reducing inflammation and promoting healing, suggesting it may improve neurological recovery outcomes in a rodent TBI model.[6-9]

Aims/Hypothesis

Aims:

- To investigate the effects of **red light (RL)** & **near-infrared light (nIRL)** therapy on post-craniectomy recovery in a rodent TBI model.
- To evaluate whether RL & nIRL therapy can improve neurological outcomes following decompressive craniectomy.
- To explore novel adjuvant treatments that address the unmet needs in TBI recovery, potentially improving neurorehabilitation and quality of life.

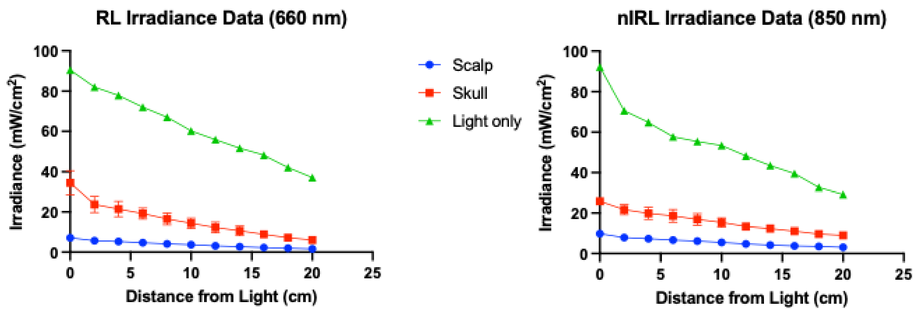
Hypothesis:

- We hypothesize that rats receiving **RL** or **nIRL** therapy post-TBI and craniectomy will show accelerated recovery, reduced inflammation, and improved motor and cognitive function compared to control groups without light therapy.

Methods: Power Density

The power density (mW/cm^2) of the RL (660 nm) and nIRL (850 nm) was measured at 2 cm increments ranging from 0 to 20 cm. Three sets of measurements were recorded:

- **Light Alone**: power density was measured without any intervening material to establish a baseline.
- **Through Skull**: measurements were taken with the light passing through an excised skull segment to assess attenuation caused by bone.
- **Through Scalp**: measurements were taken with the light passing through excised scalp tissue to determine the impact of soft tissue on light penetration.



Methods: Beam Walk

Baseline Training: Long-Evans rats were trained until proficient on a one-meter beam walk. Before interventions, baseline performance data, including slips on each paw and time to cross the beam, were collected.

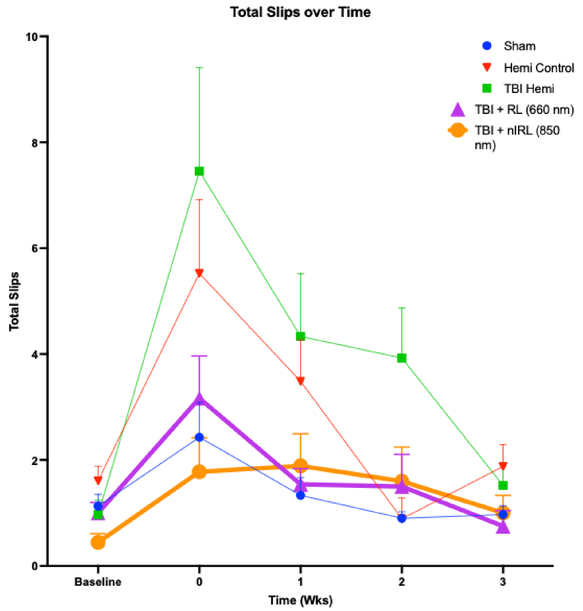
Experimental Groups: rats were randomly assigned to four groups:

1. Sham control with incision only.
2. Sham control with incision, TBI, and hemicraniectomy.
3. TBI and hemicraniectomy with RL therapy (660 nm).
4. TBI and hemicraniectomy with nIRL therapy (850 nm).

Surgery: experimental groups received a controlled TBI via impact to a closed cranial vault, targeting a consistent anatomical location anterior to the left ear, followed by an immediate hemicraniectomy to mimic real-world TBI scenarios.

Light Therapy: RL (660 nm) and nIRL (850 nm) therapies were administered to the craniectomy site in two 30-minute sessions daily (morning and evening) for five days.

Motor Function Assessment: motor deficits were evaluated using the Beam Walk Test, beginning 3-4 days post-surgery and continuing weekly. Rats were placed on an aversive platform and motivated to cross the beam to a "home cage." Performance data, including slips on forelimbs and hindlimbs, time to traverse the beam, and near falls, were recorded by two independent observers positioned on either side of the beam.



Results

- **Initial Impact (Week 0)**: all groups, except the sham, showed increased foot slips immediately post-TBI, with the TBI + hemicraniectomy group peaking at around 8 slips.
- **Week 1 Improvements**: both PBM groups (RL and nIRL) began showing foot slip reductions. The RL group (660 nm) reduced slips more quickly than the nIRL group (850 nm) initially.
- **Continued Recovery (Week 2)**: the RL group demonstrated a significant reduction in foot slips, nearing sham levels. The nIRL group also showed continuous improvement, surpassing the hemicraniectomy control group.
- **Sustained Benefits (Week 3)**: by Week 3, the nIRL group exhibited the lowest foot slips among all groups, closely followed by the RL group. Both light therapy groups outperformed the TBI + hemicraniectomy and hemicraniectomy control groups.

Discussion

Findings: PBM with red light (660 nm) and near-infrared light (850 nm) significantly improved motor recovery in rats post-TBI and hemicraniectomy. Both therapies reduced foot slips by Week 2, with near-infrared light showing the greatest improvement by Week 3, suggesting PBM may aid neurorehabilitation beyond standard surgical care.

Clinical Implications: hemicraniectomy, a common trauma intervention, provides a unique opportunity to apply PBM therapy directly to the brain. This approach likely offers greater benefits than if the skull were intact, highlighting a novel therapeutic advantage of the procedure.

Future Research: further studies should optimize PBM parameters (e.g., wavelength, power density, duration) and explore its effects on cognitive and sensory recovery. Understanding PBM's mechanisms, including its impact on inflammation and neurogenesis, will aid in refining its clinical use.

Limitations: this study used a rodent model focused on motor outcomes; thus, human studies and broader assessments are needed to confirm PBM's full therapeutic potential.

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