Development of a magnetic stimulation system for patients with depression
(治療憂鬱症之磁刺激系統之開發)

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Introduction

- Transcranial magnetic stimulation (TMS) is an exciting development in the field of psychiatry. As a non-invasive technique, this was initially introduced in 1985 for inducing motor movement by direct magnetic stimulation of the brain.

- The modality is used mainly in the treatment of depression. In spite of newer antidepressant drugs, significant percentages of depressed individuals do not respond to treatment. TMS provides the patients with the same beneficial effects without the side effects of ECT.

※ ECT: Electro Convulsive Therapy (電痙攣療法)
(Advantages)

1) No touch
2) Non-invasive
3) Painless
4) In depth
5) convenient
(Problems)

1) Few patient feel uncomfortable
2) With a noise more than 100 dB around the coil.
3) Electromagnetic stimulation used for a long time, may change gait, blood pressure, pulse, blood and endocrine instability.
4) There is strict constraint on frequency and intensity.
Introduction – Mental illness (1/2)

- Mental illness
  1) Psychosis (精神病)
  2) Neurosis (精神官能症)
     - Hysteria disorder (歇斯底里症)
     - Anxiety disorder (焦虑症)
     - Depressive disorder (憂鬱症)
     - Panic disorder (恐慌症)
     - Obsessive-compulsive disorder (強迫症)
Brain—Neurotransmitter

- Serotonin (血清素)。
- Norepinephrin (腎上腺皮質素)。
- Dopamine (多巴胺)。
Introduction – Depression (2/2)

- Biological factors:
  - Brain-
    - Limbic system (邊緣系統)
    - Neurotransmitter (神經傳導介質)
  - Hormone and the endocrine system (賀爾蒙與內分泌系統)
Brain-Limbic system

- Management of emotional, physical, sexual and stress response.
  - Hypothalamus (下視丘): Management of body temperature, sleep, appetite, libido, stress response, pituitary (Hormone regulated)
  - amygdala (杏仁核)
  - hippocampus (海馬迴)

Fig 1. The location of Hypothalamus
Hormone and the endocrine system

- **Hypothalamus (Neurotransmitter)** → Pituitary → Secretion of hormones.
- **Hypothalamus (CRH)** → Pituitary (ACTH) → Adrenal gland (Cortisol).

![Fig 2. Hormone and the endocrine system](image)
**Fig 3. Mechanism and effect to organism of magnetic stimulation**

Papers review

- Stimulation waveform -
  - rTMS (repeat Transcranial Magnetic Stimulation)
  - PEMF (Pulsed Electromagnetic Field)
  - SEMF (Sinusoidal Electromagnetic Field)

- Device circuit -
  - Charge/Discharge
  - V/I convertor

- Coil construction -
  - Figure-8 Coil
  - Helmholtz Coil
  - Slinky Coil
Stimulation waveform - rTMS

- rTMS (repeat Transcranial magnetic stimulation), continuous release the signal of stimulation waveform after an order.

- Widespread application; *Assessment of clinical neural pathways* (神經通路臨床評估)、*Rehabilitation and mental illness treatment* (康復治療精神疾病治療)、*Epilepsy research* (癲癇探討) and *Brain research* (腦功能研究)..等。

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Stimulation waveform - PEMF

- PEMF (Pulsed Electromagnetic Field) is a modulation or combination waveform based on pulse wave, has less intensity than TMS but widespread frequency bandwidth. Therefore, it’s performance focus on the Biological window effects.

- Application: Bone fracture healing, Stimulate calcification (鈣化組織) of the fibrocartilage (纖維軟骨), Accelerate wound healing.

Fig 4. Pulsed electromagnetic field.

Evidence have been collected showing both low frequency sinusoidal magnetic fields which induce electric fields well below the thermal noise threshold and weak static magnetic fields, for which there is no induced electric field, can have biological and clinical significant effects.

Fig 5. SEMF waveform

Device circuit - Charge/Discharge

- Used Charge/discharge capacitor for save energy. Control the capacitor to discharge by electronic switch.
- Three parts of the system:
  1) Charge circuit
  2) Discharge circuit
  3) Control circuit

Charge/Discharge circuit
Used OP amplifier for gain the signal of input voltage, via the V/I circuit to convert voltage into current.

It’s could present different waveform on the load by different input signal.
Coil construction - Figure-8 Coil

- It's a kind of 8 font coil, the feature that lossless EMF on a small area avoid to increase the distance.

*Fig 6. Stimulation model for figure-8 coil.*

Figure-8 Coil (cross section)

- Shows the magnitude of the magnetic flux density at radial 5cm on the surface at 3mm above the coil. The focus ability of model 1 is the worst, and the others is better than model 1.

Fig 7. (left) The cross section of the four circular coils. (right) Radial distribution of magnetic flux density.

From (Guizhi Xu, et. at all, IEEE Eng. in Med. Bio., 2005.)
Figure-8 Coil (configuration)

- the radial distributions of magnetic flux density of types of model 2 with the currents in the same direction respectively.

Fig 8. (Top) Figure-8 coil configuration. (under) Distribution of magnetic flux density.


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Coil construction - Helmholtz Coil

- Two parallel O font and continuous coil.
- The important definition is the distance of two coil, must be apart half of diameter from one to another.
- Cause of the definition, when the sample is largest, the space must needs largest too.
Helmholtz Coil
Coil construction - Slinky Coil

- Put more than one O font and continuous coil in sector.
- The coil’s EMF could display like single O font coil’s EMF or 8 font coil’s EMF.

Fig 9. Distribution of magnetic flux density of two types coil.

Fig 10. Slinky coils and the measuring position versus coordinate system.

Fig 11. Electric field strength distribution of slinky-1 though slinky-5 coils.

Stimulation parameter

- **Position**, **Frequency** and **Intensity**.

- Stimulation Position is an important point, judged based on Anatomy Atlas or Physician experience.
Frequency (Level)

- It's chose depend on the device properties, different level with different application. In Theory, high frequency is used to *Excitor* (興奮神經); low frequency is used to *Inhibitory nerves* (抑制神經).
Intensity (Flux density)

- When the EMF over than 50 T will caused the concentration of calcium ion, gene and cell transmitter to change.
- When the EMF promoted to 100 T, It’s discovered the pathway of cell transmitter was changing.
Conclusions

- Currently, there is no completely research to point out the danger of exposed in EMF with a long time. But, have recorded the EMF research for healing.
Conclusion

- From technical viewpoint, existing magnetic stimulator had problems of power consumption is excessive, coil heating is speedy, expensive, unstable.
- As those problems, the development of a new improvement is the goal of the research.
Future work

- For the goal of nerve stimulation. The EMF stimulator needs the higher frequency bandwidth. For the condition, the device better combined PEMF signal with V/I circuit. For the coil i chose average Type of Helmholtz Coil.


Thank you for your attention