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BRAIN SURGEY WITH SOUND WAVES

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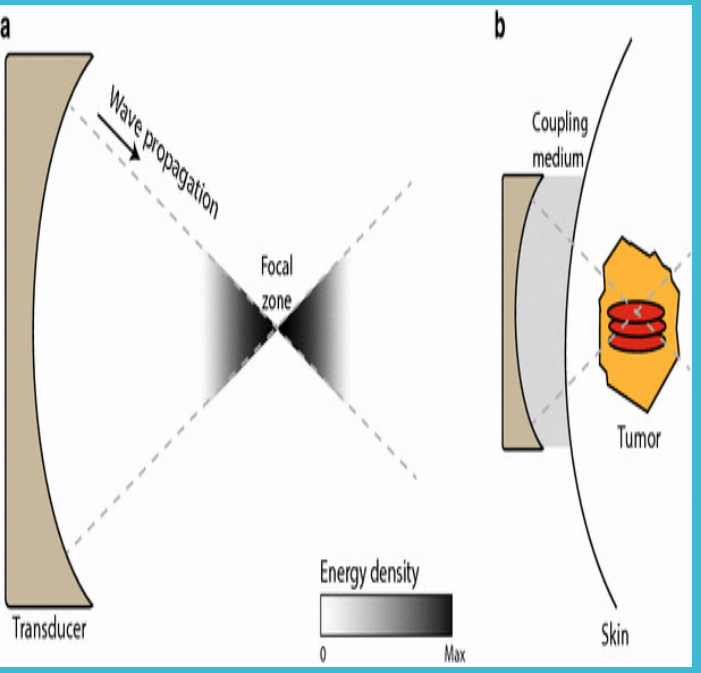


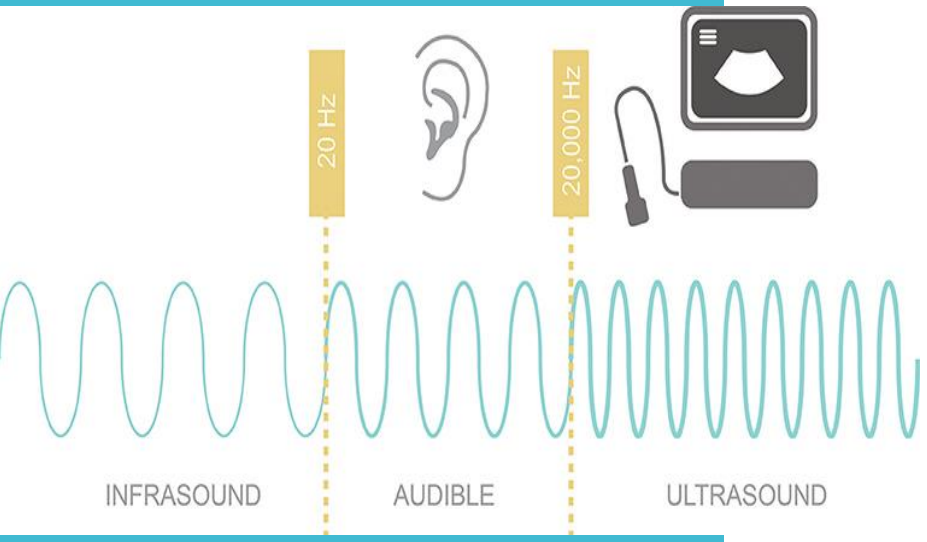
- HIFU employs an ultrasonic transducer, similar to those used in diagnostic imaging but with far more intensity. The transducer directs sound waves to produce heat at a single spot within the body, destroying the target tissue. In just 20 seconds, the tissue may reach temperatures of 150-200°F at the focal point of a transducer without damaging the surrounding tissues
- These sound waves are focused into a distinct focal point of roughly 3 mm x 3 mm x 11 mm by using this parabolic structure.

Fig1. Principles of high-intensity focused ultrasound a HIFU ablation employs a transducer, which creates ultrasound beams focused to a single focal zone. The acoustic energy increases near the focal zone. b This energy can be used to generate ellipse-shaped thermal or non-thermal lesions in tumors in a noninvasive

HIGHT-INTENSITY FOCUSED TECHNOLOGY

- The size and form of this focus point, which is 3 to 4 cm away from the transducer, is determined by the energy released by the transducer, the geometric arrangement ofthe transducer, and the parameters of the tissue
- At the focal point of the transducer, ultrasound energy is concentrated, is absorbed by the tissue, and generates temperatures that can exceed 80° C, resulting in coagulative necrosis and the destruction of tissue.
- Strong ultrasound waves in the inaudible sound range and approximately 10,000 times stronger than diagnostic ultrasound are generated by a transducer with a parabolic configuration.
- It can be
- 1.Non-invasive (transcutaneous)
- 2.Minimally invasive (transrectal)

ULTRASOUND WAVES



Ultrasound waves are acoustic pressure waves with a frequency range that starts at the limit of human hearing at 20 kHz and extends well into the megahertz range. Pressure waves are either reflected or absorbed as they pass through human tissue. The most frequent ultrasound imaging approach in the body is based on reflected ultrasonic waves.
HIFU treatment varies from ultrasonic imaging in that the waves are stronger (more intense) and concentrated on a single location.

Fig2. Different sound frequencies: infrasound has sound waves with frequencies lower than 20 Hz; audible sound, which has sound waves with frequencies between 20 and 20,000 Hz; and ultrasound, which has sound waves with frequencies >20,000 Hz.

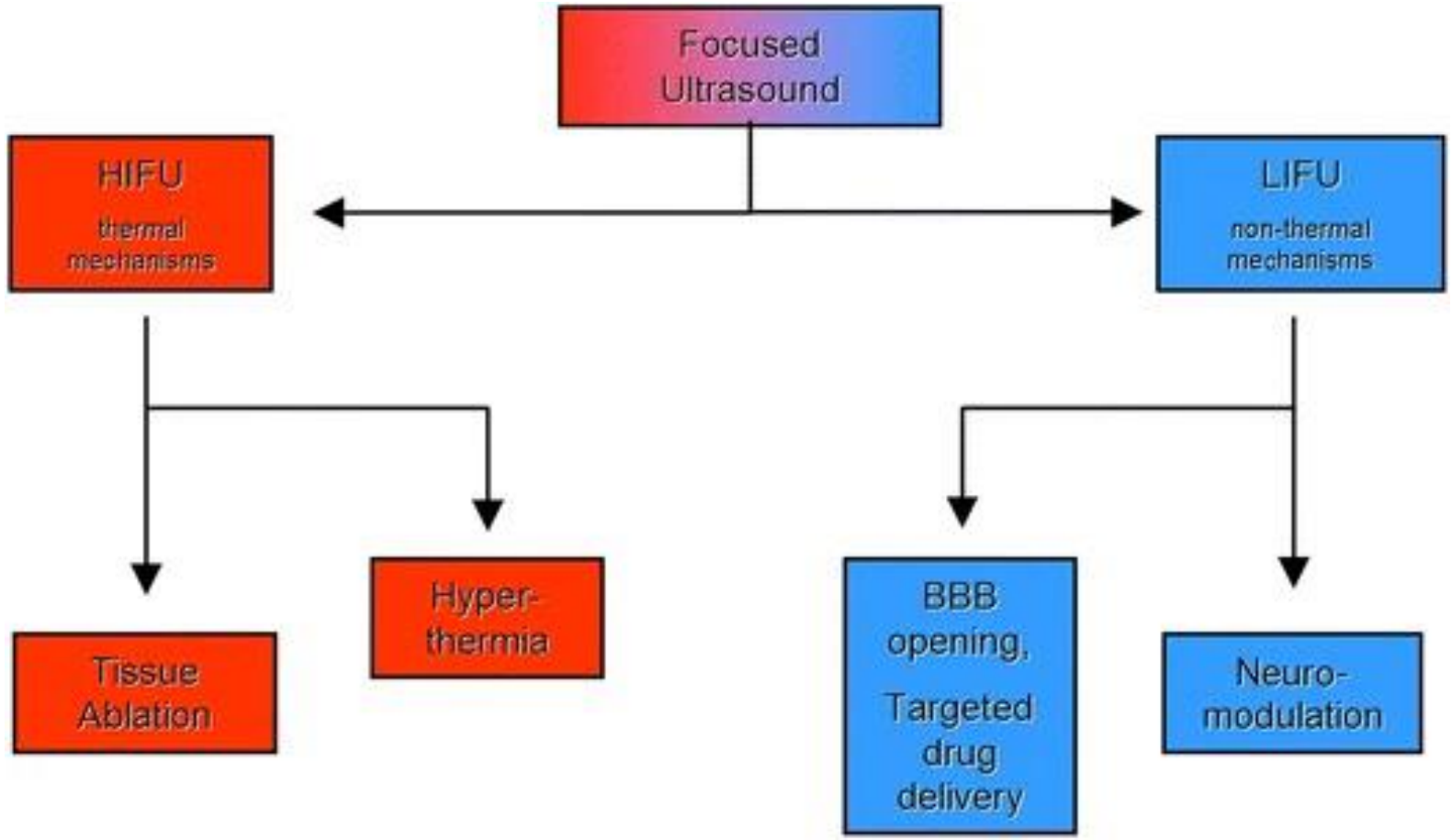
MECHANISM

- The therapeutic activity of HIFU is mediated by two mechanisms:

- 1.Mechanical energy to heat conversion (causes the tissue to heat up and kills the cell)
- 2.Mechanical cavitation of tissue pressure waves (causes the tissue to vibrate and mechanically stress the cells, causing them to also die)

* To start, the patient is placed in an MRI. While in the MRI, the patient stays awake to provide real-time feedback to the team. This helps in precisely target the brain region that controls involuntary tremors with ultrasound waves.
- There is less risk for the patient because there are no incisions and no devices implanted. This reduces risk of infection and shortens the downtime for recovery
* The ultrasound beams are focused on a specific point in the brain–the exact location depends on the condition being treated–that absorbs the energy and converts it to heat. This raises the temperature to about 130 degrees Fahrenheit and kills the cells in a region approximately 10 cubic millimeters in volume. The entire system is integrated with a magnetic resonance scanner, which allows us the precison target the correct piece of brain tissue.

Fig3.Principal physical properties of focused ultrasound and possible applications to the human brain. BBB blood–brain barrier HIFU high-intensity focused ultrasound, LIFU low-intensity focused ultrasound



BRAIN TUMORS

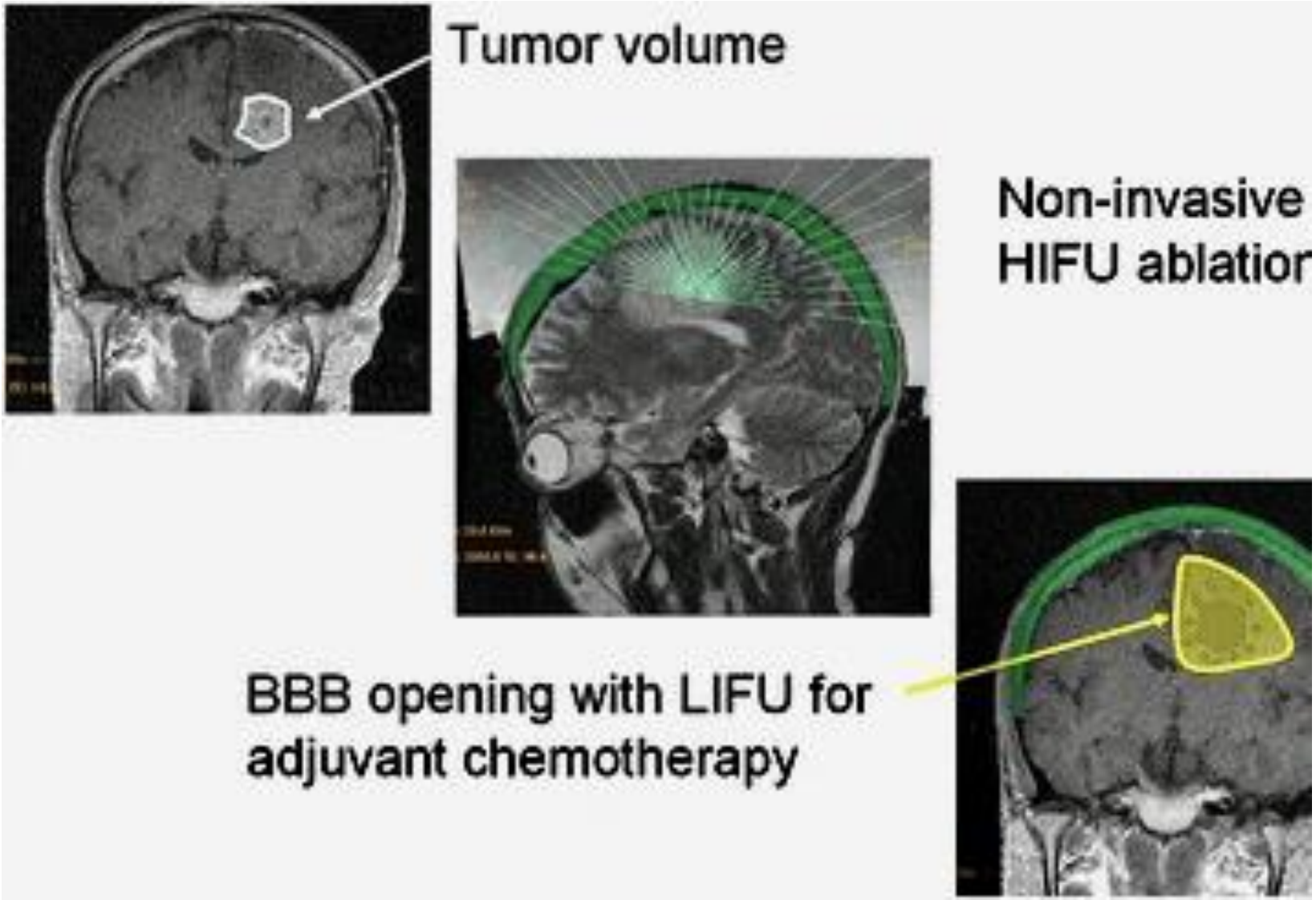
Neurosurgical excision is the first-line treatment for malignant brain tumors, followed by radiation and chemotherapy. However, the majority of individuals die as a result of a recurring malignancy.

As a result, the development of a new strategy for treating this dreadful disease is required, and a concerted effort has been made to develop targeted therapies for malignant glioma.

Although radiation cannot be repeated indefinitely, chemotherapeutic efficacy is impeded by limited access to the tumor due to reduced penetration across the BBB, despite the fact that most malignant brain tumors, including metastases, lack an intact BBB.

However, the permeability of the vasculature of malignant brain tumors varies, and infiltrating cancer cells and tiny metastatic seeds may be shielded by arteries with intact BBB of surrounding normal tissue.

Fig4.Combined tcMRIgFUS brain tumor therapy using high-intensity ultrasound (HIFU) for bulk tumor ablation and low-intensity ultrasound (LIFU) for opening of the blood–brain barrier (BBB) and targeted drug therapy.



BRAIN TUMOR cont.

- Preclinical investigations have shown that therapeutic quantities of chemotherapeutic drugs, such as doxorubicin,
- may be obtained in the brain following noninvasive BBB opening in the presence of preformed microbubbles utilizing pulsed LIFU.
- As a result, a future scenario in tcMRIgFUS brain tumor therapy may include a combination of bulk tumor ablation with HIFU and BBB opening in the tumor's penumbra with LIFU for enhanced chemotherapy.

MEDICAL USE

Since tcMRIgFUS allows the tissue temperature and exposure time to be manipulated precisely, it is well suited for applying hyperthermia to enhance the sensitivity of tumor cells as an approved adjuvant for radiotherapy or chemotherapy or for targeted drug delivery with temperature-sensitive liposomes

HIFU treatment is often guided by MRI.

1.Break up kidney stones by lithotripsy.
2.Cataract treatment by phacoemulsification.
3.Its ability to stimulate bone-growth.
4.Its potential to disrupt the blood-brain barrier for drug delivery.
5.Non-invasive treatment option for patients suffering from symptomatic fibroids (symptomatic relief is sustained for two plus years)
6.Benign thyroid nodules and hypertrophic parathyroid glands ablation
7.Breast fibroadenoma ablation.
8.Non-invasive treatment of various brain disorders such as neuropathic pain and parkinson’s diseas

[WHY HIFU ?]

A procedure called as deep brain stimulation is the conventional therapy for essential tremor. Drilling holes in the skull while the patient is awake and running wires into the brain from a device permanently implanted in the chest are required. Because the surgery is so intrusive, many people would rather live with their tremor.

Fig.5 A patient's tremor is tested in the operating room during DBS surgery.

RESULT AND DISCUSSION

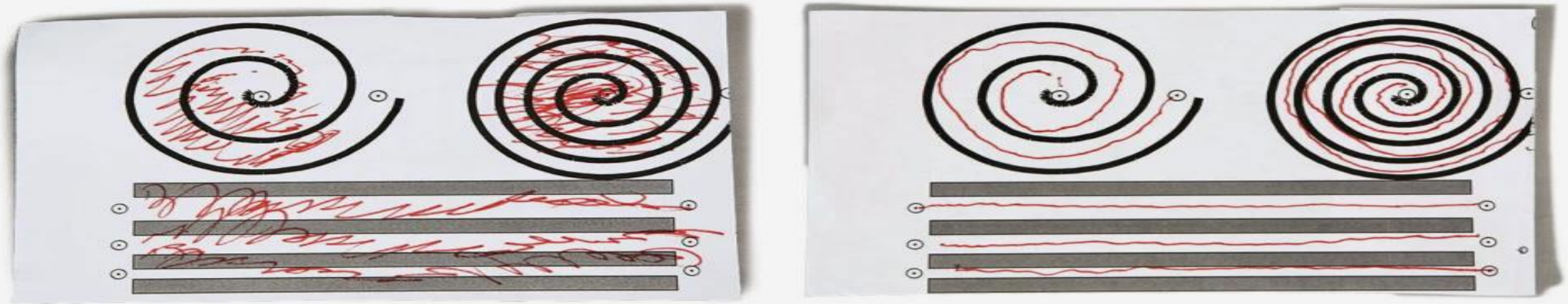
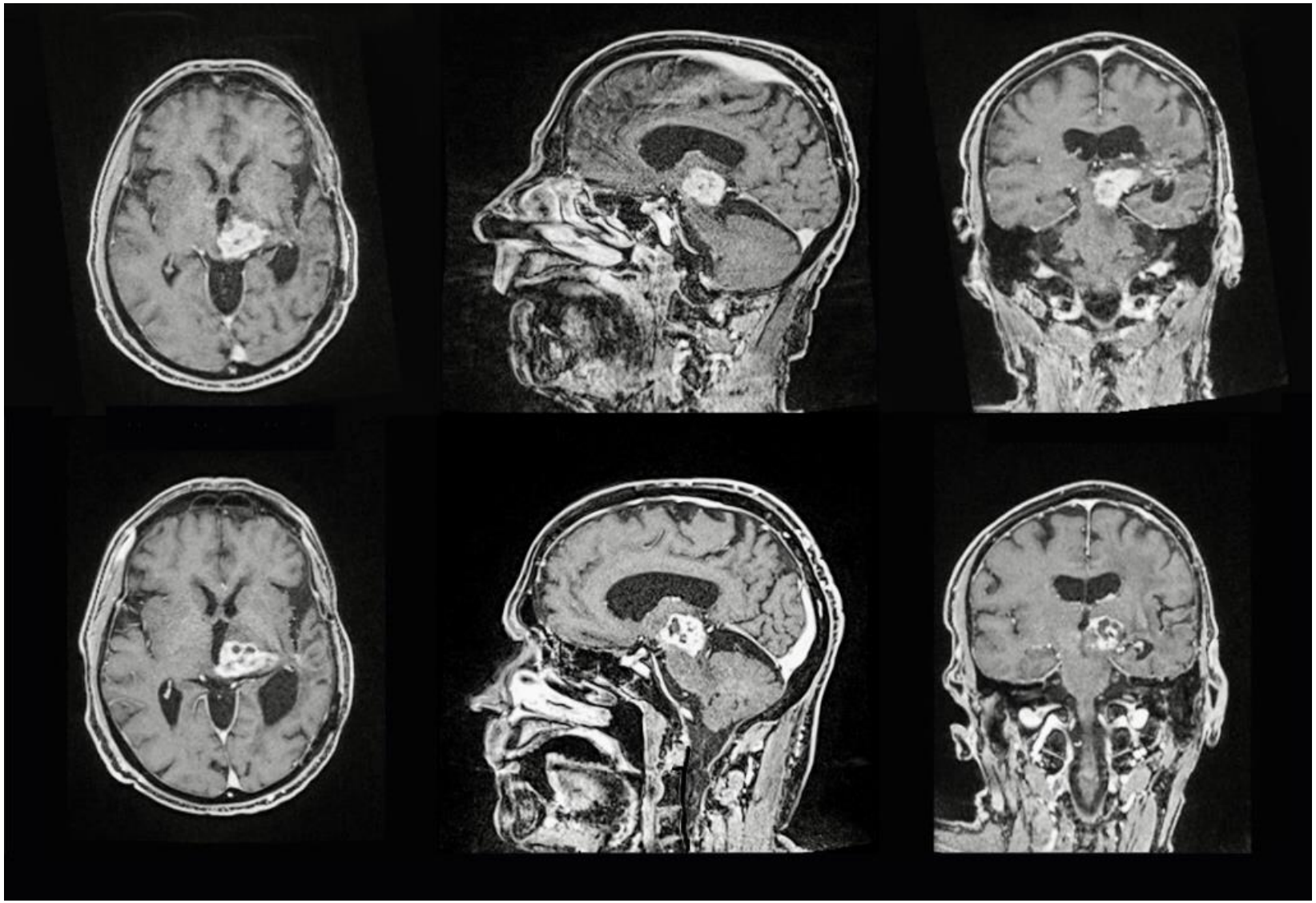


Fig6. Images demonstrating a patient's ability to draw before (left) and after undergoing a procedure using focused ultrasound on the brain to treat essential tremor. Photo Courtesy of Focused Ultrasound Foundation

Fig5. Series of MRI images of a brain tumor patient before (top row) and after treatment (bottom row) that shows the ablated tissue in the brain tumor .

Photo Courtesy of Focused Ultrasound Foundation



CONCLUSION

- After more than half a century of targeted ultrasonic treatments to the brain, there are now just a few institutions that conduct clinical studies on chosen individuals. To finally bring this novel therapeutic device as a noninvasive neurosurgical alternative to clinical acceptance, sophisticated technical developments for advanced MRI guidance, real-time temperature measurements, and, most importantly, precise transcranial ultrasound energy transmission without causing scalp burns were required.A number of factors have contributed to this advancement, including advances in transducer design, more accurate measurement and calibration of acoustic power, and careful experiments to determine the precise nature of chemical processes occurring during and after tissue exposure to ultrasound. Some fields where ultrasound is used have seen significant advancements, including physiotherapy, surgical instruments, chemotherapy, drug delivery, and, more recently, high intensity focused ultrasound (HIFU). In this research with this New techniques to the treatment of brain malignancies are urgently needed. Focused ultrasound, with its capacity to precisely target and kill sick areas while sparing healthy neighboring brain tissue, could be the breakthrough that patients and doctors have been waiting for.

REFERENCES

Heimburger RF. Ultrasound augmentation of central nervous system tumor therapy. Indiana Med. 1985;78(6):469–76.

Warwick R, Pond J. Trackless lesions in nervous tissues produced by high intensity focused ultrasound (high-frequency mechanical waves). J Anat. 1968;102(Pt 3):387–405.

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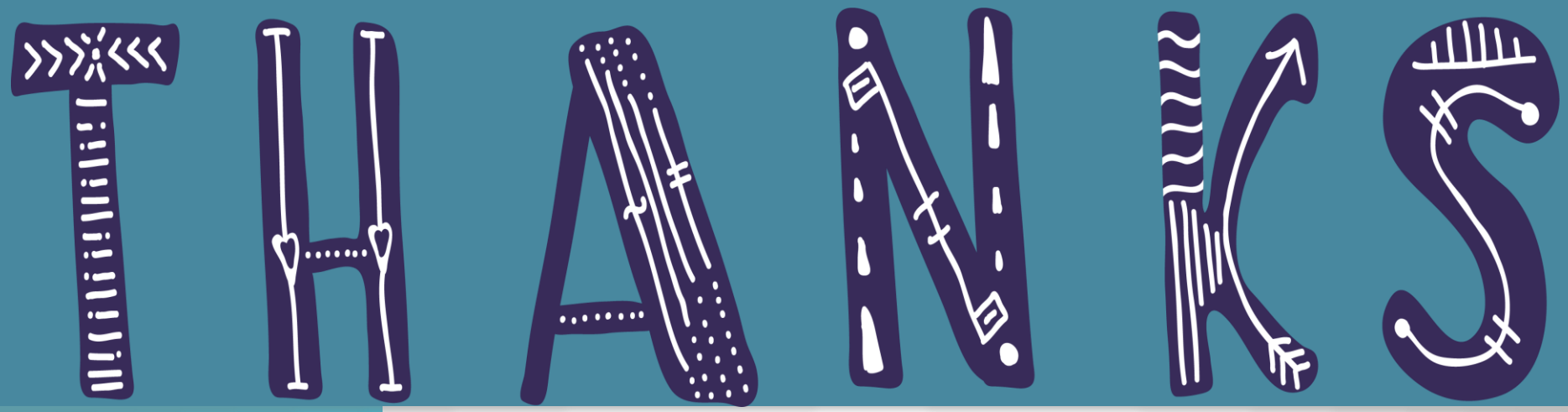
THANKS