Mathematicians report a way to optimize post-stroke therapy

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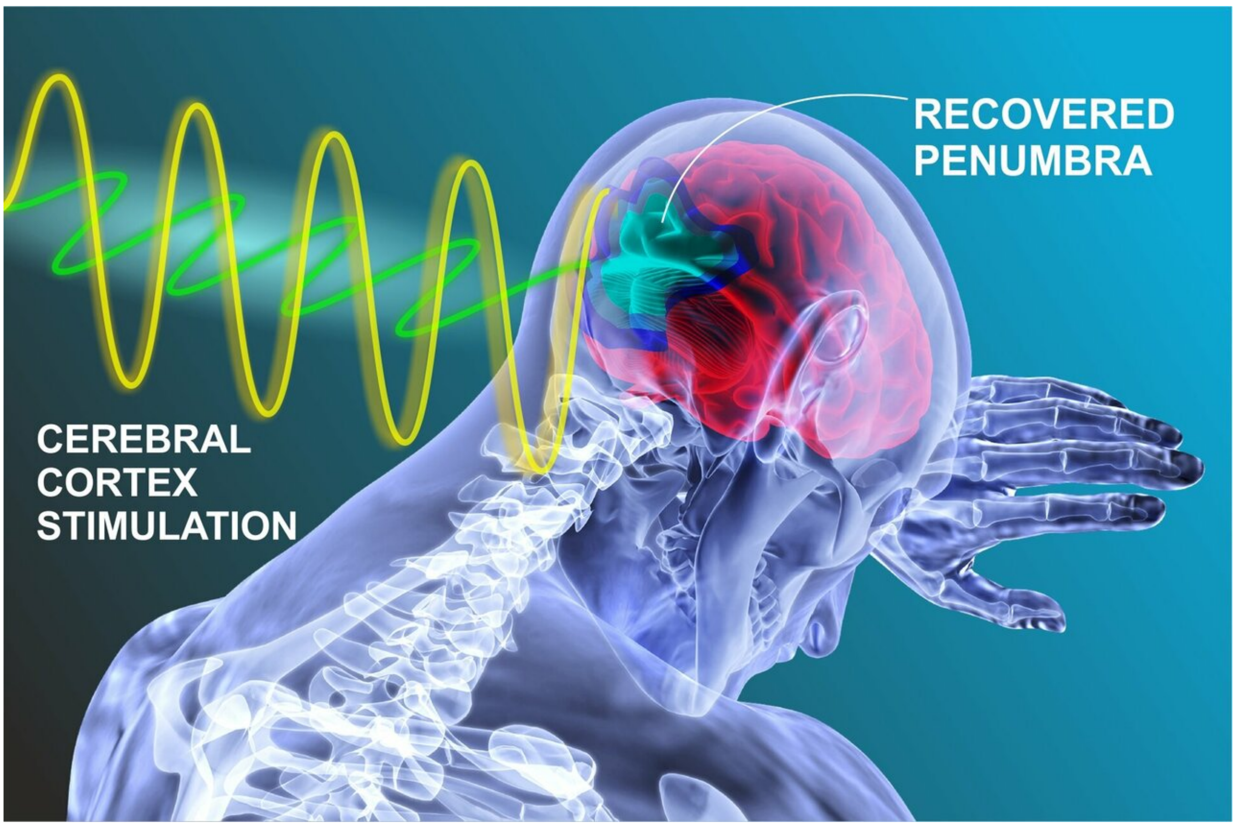

Credit: Natalia Deryugina/VSRao

RUDN scientists have created a mathematical model describing changes in the properties of brain tissues after stroke. The development will help clinicians to optimize post-stroke therapy by stimulating brain neurons and taking into account each patient's individual situation. The results of the study were published in *Mathematical Biosciences*.

Over 15 million people have strokes each year. A stroke is an acute blood circulation failure in the brain that kills neural cells. Patients who suffer a stroke often face partial or total speech loss, and find it difficult to move their limbs or the whole body. One rehabilitation method after a stroke is cerebral cortex stimulation with brain-implanted electrodes or magnetic impulses. The success of the therapy depends on many factors, including the area of the brain that is stimulated and the types of signals used. Currently, optimal therapy parameters are selected manually. RUDN mathematicians have created a theoretical model to base such selection on exact calculations.

"Our task was to develop a theoretical model describing how the speed of a nervous impact propagation (i.e. the excitation of the tissue) fades down due to post-stroke damage to the cerebral cortex. Moreover, we demonstrated that in certain cases electric stimulation of the brain may compensate for this process," said Vitaly Volpert, the author of the article, and the head of the laboratory of mathematical modeling in biomedicine at RUDN.

After a stroke, a so-called penumbra forms in the brain. It is an area where the blood supply is reduced compared to requirements for normal functioning, but which is still higher than the critical level after which an irreversible change occurs. Penumbra cells become less excitable and lose connection with other neurons, leading to changes in the shape and speed of the excitation wave. RUDN mathematicians calculated the conditions at which the speed of neural impulses may be restored to normal levels with the help of external stimulation.

The model is based on the continual nerve tissue theory. The idea is that the cerebral cortex tissue is presented as a thin, flat surface. This assumption can be made due to high density of neurons (around 100,000 per 1 mm^2) and the thickness of the cortex, which amounts to only 2.5 mm.

When developing the model, RUDN mathematicians introduced the so-called connection function. It shows that two points on the surface of the cerebral cortex are connected depending on the distance between them. The electric potential at each point is expressed as an indeterminate function depending on the time and the coordinates of the point. For this function, the scientists wrote the main integro-differential equation of the model. Its main parameters include the neurons' excitation threshold (a minimal amount of energy required to "irritate" a neuron) and the amplitude of excitation. When a brain is electrically stimulated, these two parameters are affected. Therefore, clinicians need to find out how the solution changes with different equation parameters. The authors studied the equation and deduced a number of conditions (mathematical equations and inequations). When they are met, external cerebral cortex stimulation may fully compensate for the consequences of a stroke.

"The suggested model is built in view of recent mathematical calculations, cutting-edge technologies, and data on brain properties. Using our development, doctors can tailor cerebral cortex stimulation to each patient's needs, i.e. make post-stroke therapy consistent with personalized medicine standards," added Vitaly Volpert.

More information: A. Beuter et al. Modeling of post-stroke stimulation of cortical tissue, *Mathematical Biosciences* (2018). DOI: 10.1016/j.mbs.2018.08.014

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