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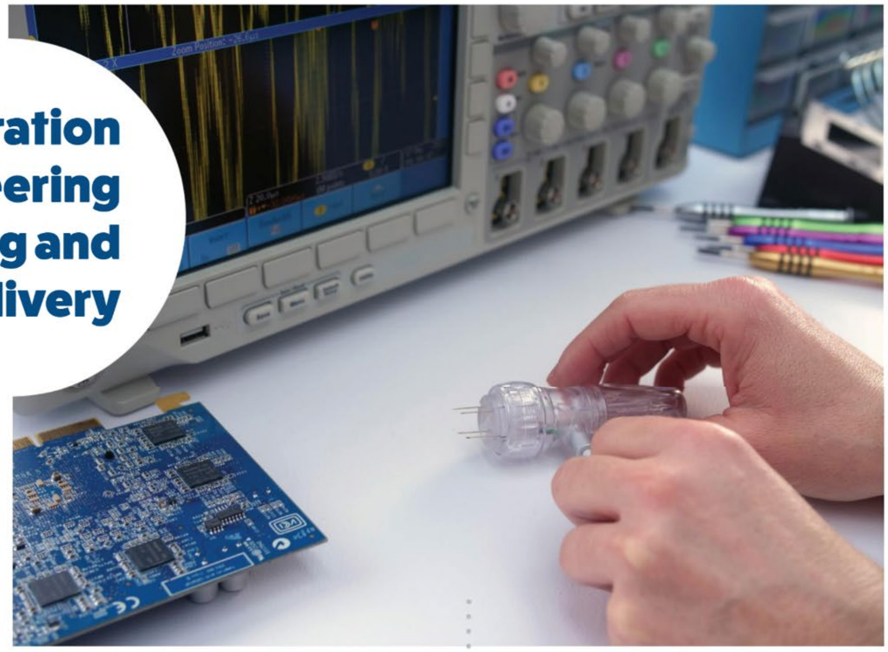
In vivo electroporation is an engineering solution for drug and gene delivery

Why the new buzz about an old technique? Harness the potential of an existing technology for modern medicine.



Electroporation involves using an external electrical device to apply a prescribed electric field to tissue. This transiently opens pores in cell walls, allowing transport of drugs, DNA, and gene therapies.
Photo courtesy of Minnetronix Medical

Daniel Friedrichs
Minnetronix Medical

Reversible electroporation is the use of an electric field to open pores in a cell wall, allowing transport of drugs, DNA or other "cargo" into a cell — in particular, allowing delivery of chemically large molecules and transport of DNA vaccines and customized gene therapies.

In the 40 years since its invention, electroporation has become a mainstay technique in biological sciences. Only recently, however, has wide interest taken hold when it comes to in vivo (human clinical) electroporation. Compared to other delivery vectors and carriers, electroporation stands apart as a particularly elegant engineering solution to a biologic problem, offering safe, convenient and efficacious delivery of a wide array of cargos.

Like any new technology, adoption has been slow. Companies that adapt to this new paradigm will be at the forefront of realizing the profound benefits of this technology.

Recent developments and electroporation-enabled therapies pipeline

In fact, electroporation-enabled gene therapies and nucleic acid vaccines are leading contenders to be paradigm-shifting technologies.

COVID-19 clearly demonstrated the need for quick-to-develop vaccines that can be transported without cold-chain storage. Electroporation-delivery of such a DNA vaccine is drawing wide attention and robust funding. Companies working in this space have raised significant capital, and hundreds of clinical trials are ongoing.

Diseases for which there is ongoing research into the use of electroporation-delivered therapies include a wide range of neoplasms, several viral infectious diseases and even some degenerative diseases. A sampling of these conditions includes advanced melanoma; HIV; Lassa fever; wet macular degeneration; human papillomavirus-caused cervical, head, and neck cancers; prostate cancer; certain breast cancers; and more.

How electroporation works

Using electroporation as a delivery vector is quite simple. As an example, there are currently ongoing trials where a drug is administered intramuscularly with a standard hypodermic needle and syringe, then an electroporation application is performed, which causes the cells to form temporary pores, dramatically increasing the volume of that drug which ends up inside the cells.

In this case, the electroporation application involves using a separate device (that looks something like an electric toothbrush) that has pairs of needles that puncture the skin near the injection site and apply a series of electrical pulses. The process only takes a few seconds. Depending on the specifics, it can create a mild buzzing sensation for the patient but is otherwise benign.

In other devices, the injection needle is also used as part of the electroporation circuit, which makes for a more complicated delivery device but removes variability in administration.

Opportunities and challenges

Today's most common in vivo electroporation applications use needle electrodes for intra-tumoral or intramuscular administration of electroporation pulses. However, research shows the ability to use "paddle" type electrodes (which don't even need to pierce the skin) or electrodes on the surface of, for example, a flexible catheter for intraluminal or surgical applications. As electroporation matures as a delivery technology, it is likely we will see even more innovation in this space.

Developing an in vivo electroporation device requires consideration of both biologic and electro-mechanical factors. Clinical efficacy of electroporation relies on achieving specific electric field strengths, which can be influenced by varying impedance of tissue or sample. Specialized measurement equipment and protocols improve accuracy and performance, which is why an experienced design partner is invaluable. Additionally, like any medical device, such a system must be designed to be safe, effective and compliant to regulations.

Today, in vivo electroporation may seem like a niche tool, but if history is any guide, it may soon join the ranks of technologies like autoinjectors and smart inhalers — indispensable medical devices that leverage electro-mechanics to improve drug delivery for profound patient impact.

DANIEL FRIEDRICHS, Ph.D., leads development engineering efforts at Minnetronix Medical for the commercialization of surgical energy devices including in vivo electroporation systems and other energy-based medical, surgical, and drug-delivery therapies. He is named on more than 35 patents and has worked with an extensive network of clients seeking to commercialize a wide array of technologies.