UNIKLINIK RWTH AACHEN
Department of Diagnostic
and Interventional Radiology

What is Electroporation?

How do tumour therapies based on electroporation work?

Andreas Ritter[1,2]
Department of Diagnostic and Interventional Radiology, RWTH Aachen University, Aachen, Germany
Institute of Applied Medical Engineering (AME), Helmholtz Institute of Biomedical Engineering, Aachen, Germany

Background – tumor therapies

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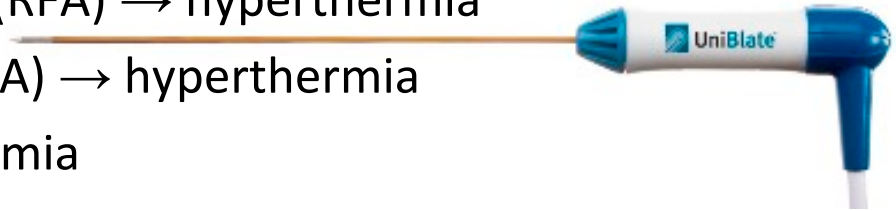
WHO 2014:
14 mio / year
new cases
8.2 mio / year
cases of death

Standard tumor therapies

- Resection, Radiation, Chemotherapy

Minimally invasive therapies (MIC)

- Radiofrequency ablation (RFA) ⟶ hyperthermia
- Microwave ablation (MWA) ⟶ hyperthermia
- Cryoablation ⟶ hypothermia

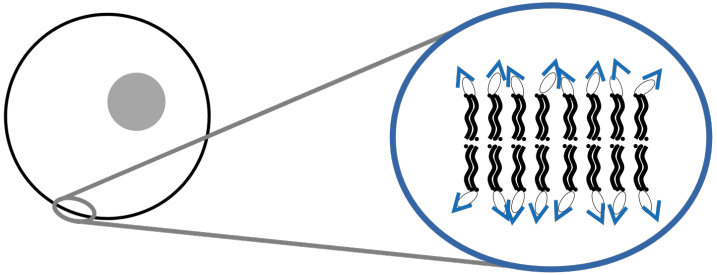


New non-thermal therapies based on electroporation

- IRE – **Ir**reversible **E**lectroporation
- ECT – **E**lectro**c**hemo**t**herapy

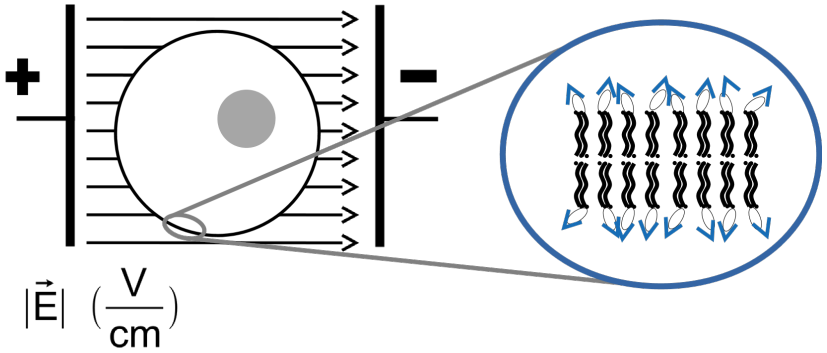
hepatic cancer
≈ 30 %

Background – What is Electroporation (EP)



- Local destruction of the lipid bilayer

Background – What is Electroporation (EP)



- Local destruction of the lipid bilayer
- Cell in electric field

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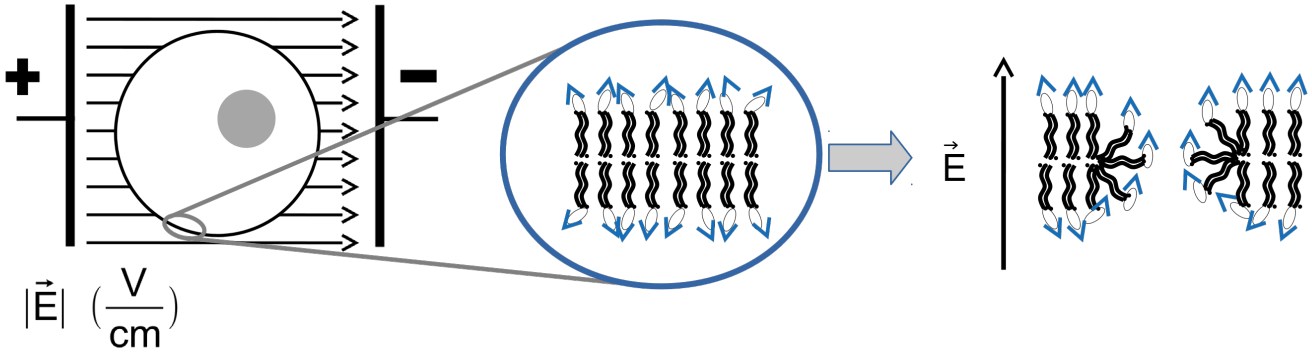
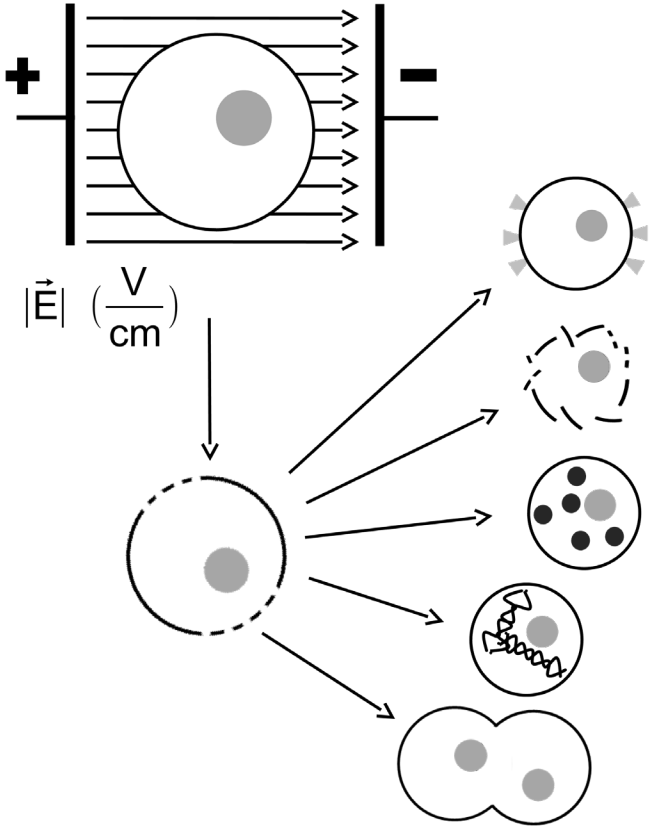


- Local destruction of the lipid bilayer
- Cell in electric field
  - ⟶ Inducing “nanopores” (Ø ≈ 6,2 [1] - 186 nm [2])
  - ⟶ Increase membrane permeability (σ / w)
  - ⟶ Increase transmembrane passage of hydrophilic substances

[1] Characteristics of the osmotically induced mem-brane rupture, Baumann, Grebe 1998
[2] Electroporation of unilamellar vesicles studiedby using a pore-mediated electron-transfer reaction, Correa, Schelly 1998

Background – EP in medical usage



Usage of EP in biology

Delivering proteins into cells

Irreversible, permanent destruction of cell membrane

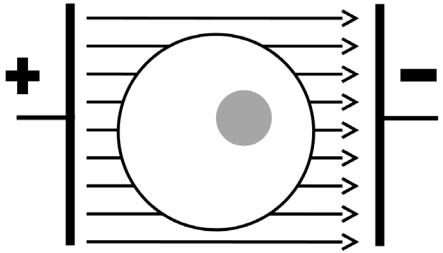
Insert small molecules: drugs

Insert big molecules: genes

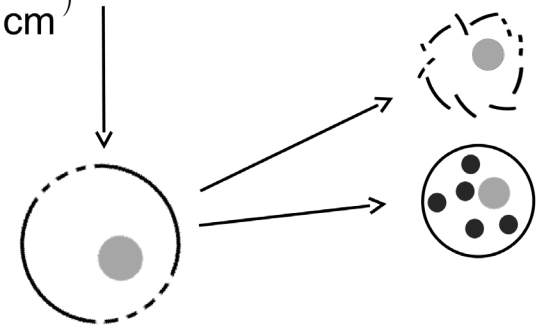
Cell fusion

Based on: Techniques of signal generation required for electropermeabilization Marko Puc, 2004

Background – EP for tumor therapies



$|\vec{E}| \ (\frac{V}{cm})$

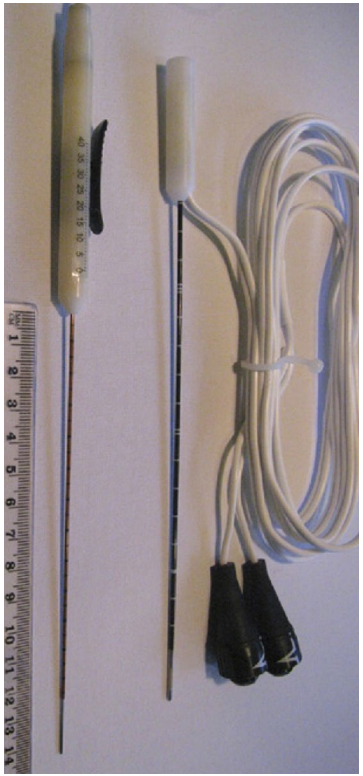


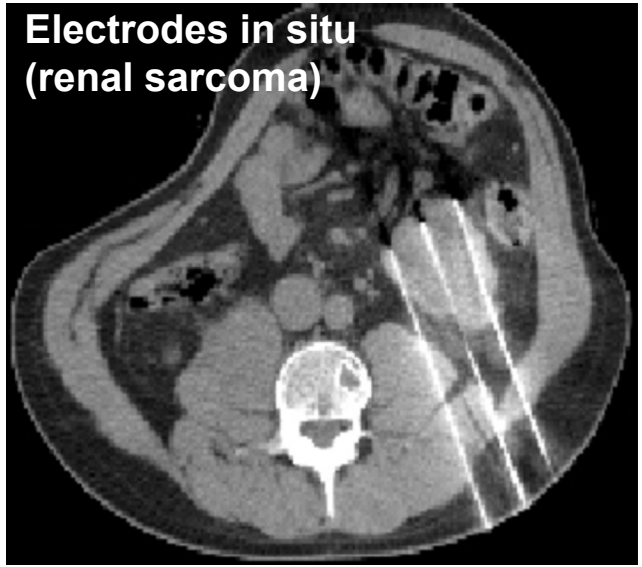
Usage of EP in medicine

1) Irreversible, permanent destruction
   → Irrecoverable defects form (≈ s) [1]
   → Cells continue to die (≈ h) [1]
   → **IRE – Irreversible Electroporation**

[1] A Review of Basic to Clinical Studies of Irreversible EP Therapy, Jiang, Davalos, 2015

Background – EP in medical usage



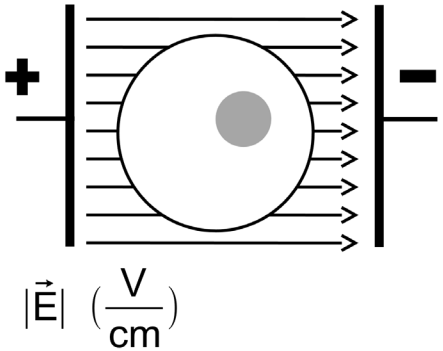


IRE with Nanoknife

- CT guided intervention
- Up to 6 electrodes, but EP with 2 electrodes only

Investigation of the Safety of Irreversible Electroporation in Humans, KR Thomson 2011

Background – EP in medical usage



Advantages IRE vs. RFA

- Non-thermal mechanism
  → No heat sink effect
  → No harms to vessels

- More apoptosis than necrosis
- Pulsed electrical field instead of joule heating
  → Easier to simulate the physics
  → Better plannable Intervention

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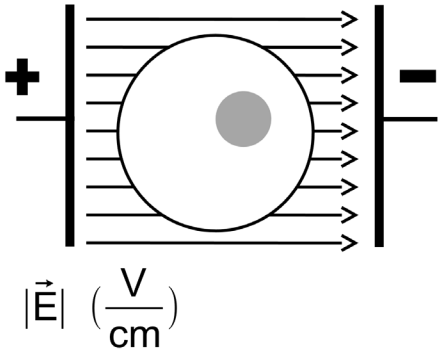

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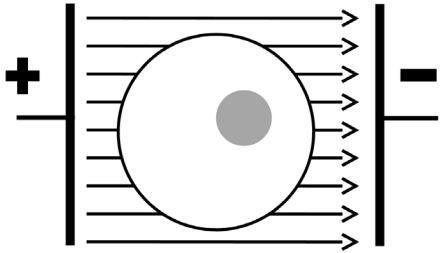
- More Electrodes
  → longer preparation time
- More needle tracts
  → increased risk tract seeding [1]

[1] Increased Risk of Needle Tract Seeding after Irreversible Electroporation (IRE) of Malignant Liver Tumors, M Distelmaier 2016

Background – EP for tumor therapies



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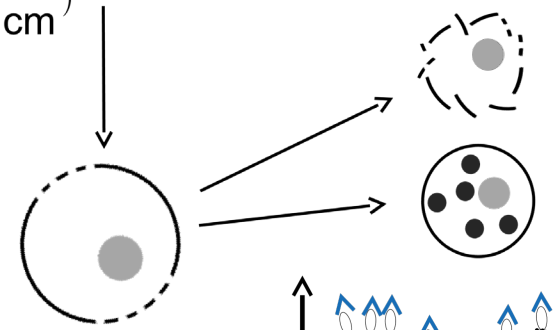
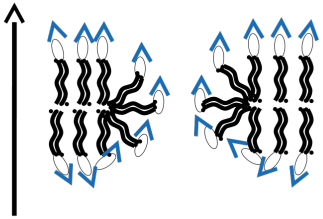
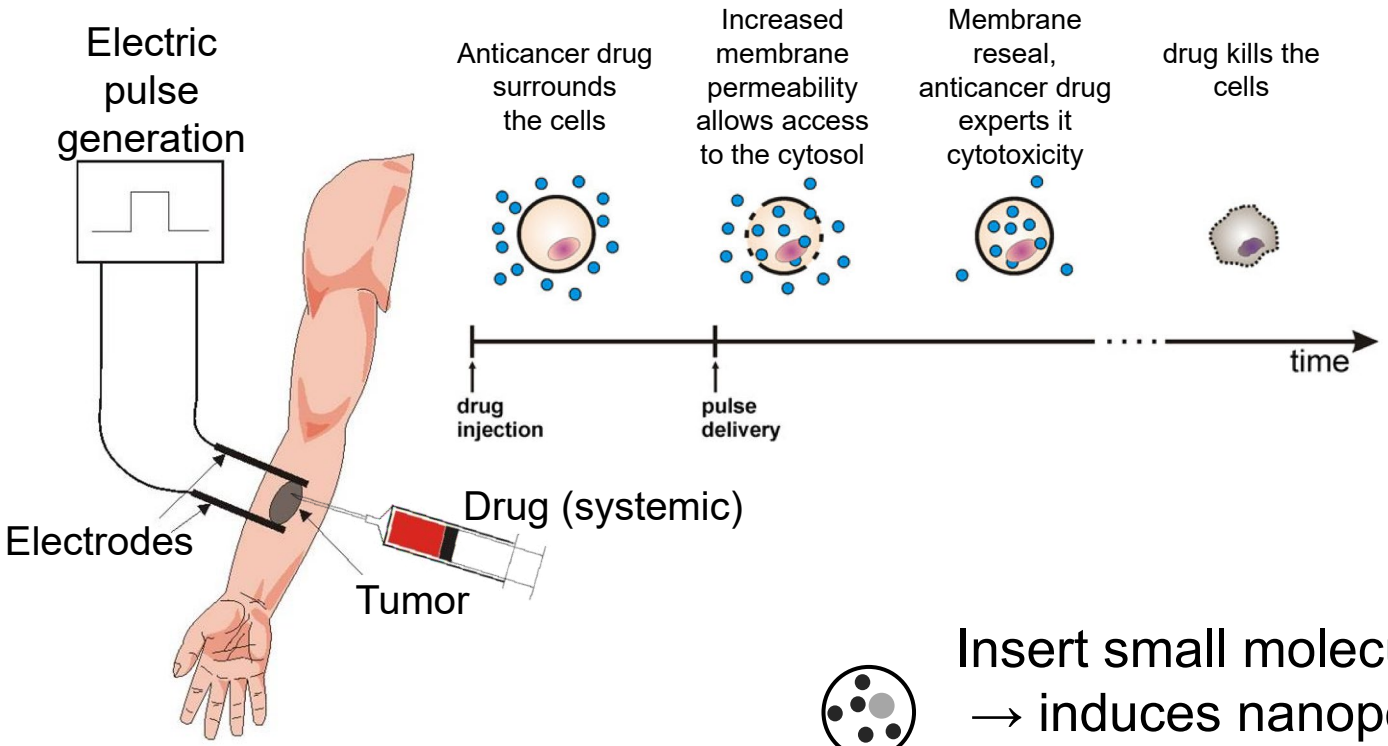




1) Irreversible, permanent destruction
   → Irrecoverable defects (≈ s), cell death (≈ h) [1]
   → **IRE – Irreversible Electroporation**
2) Temporary destabilize of cell membrane
   → induces nanopores Ø ≈ 20- 120 nm [2]
   → Insert small molecules: drugs
   → Recovering, membrane still permeabilized (≈ s)
   → Defects recovered, membrane resealed (≈ h) [1]
   → **ECT – Electrochemotherapy**

[1] A Review of Basic to Clinical Studies of Irreversible EP Therapy, Jiang, Davalos, 2015
[2] Single-Cell Electroporation for Gene Transfer In Vivo, Haas, Cline, 2001

Background – EP in medical usage



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Based on: Electrochemotherapy - technological advancements for efficient electroporation-based treatment of internal tumors, D Miklavčič 2012

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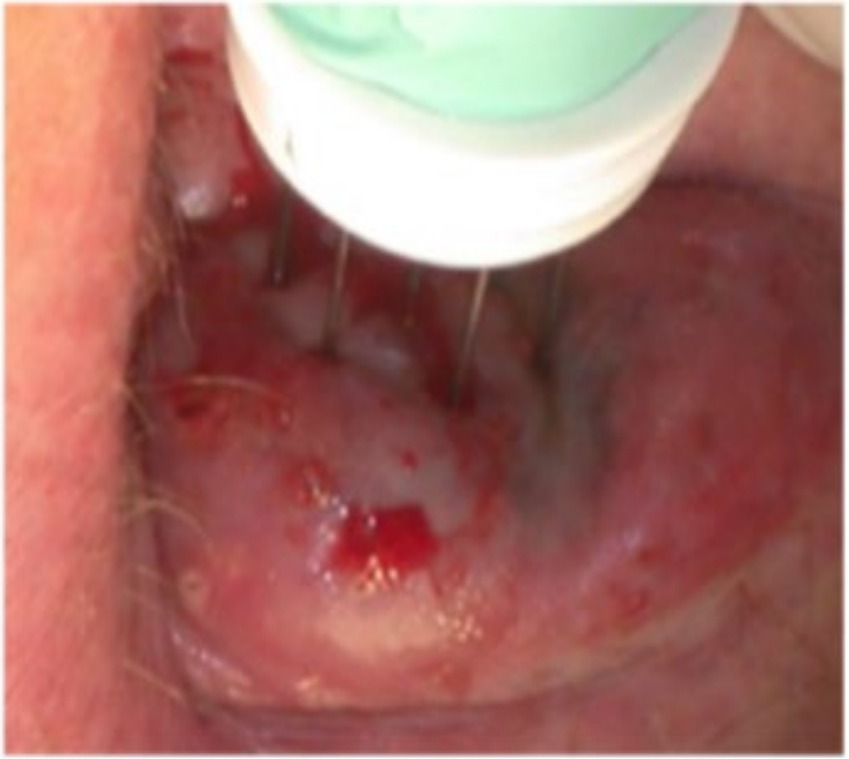

Electrochemotherapy in treatment of tumours
Serša, Snoj, 2008

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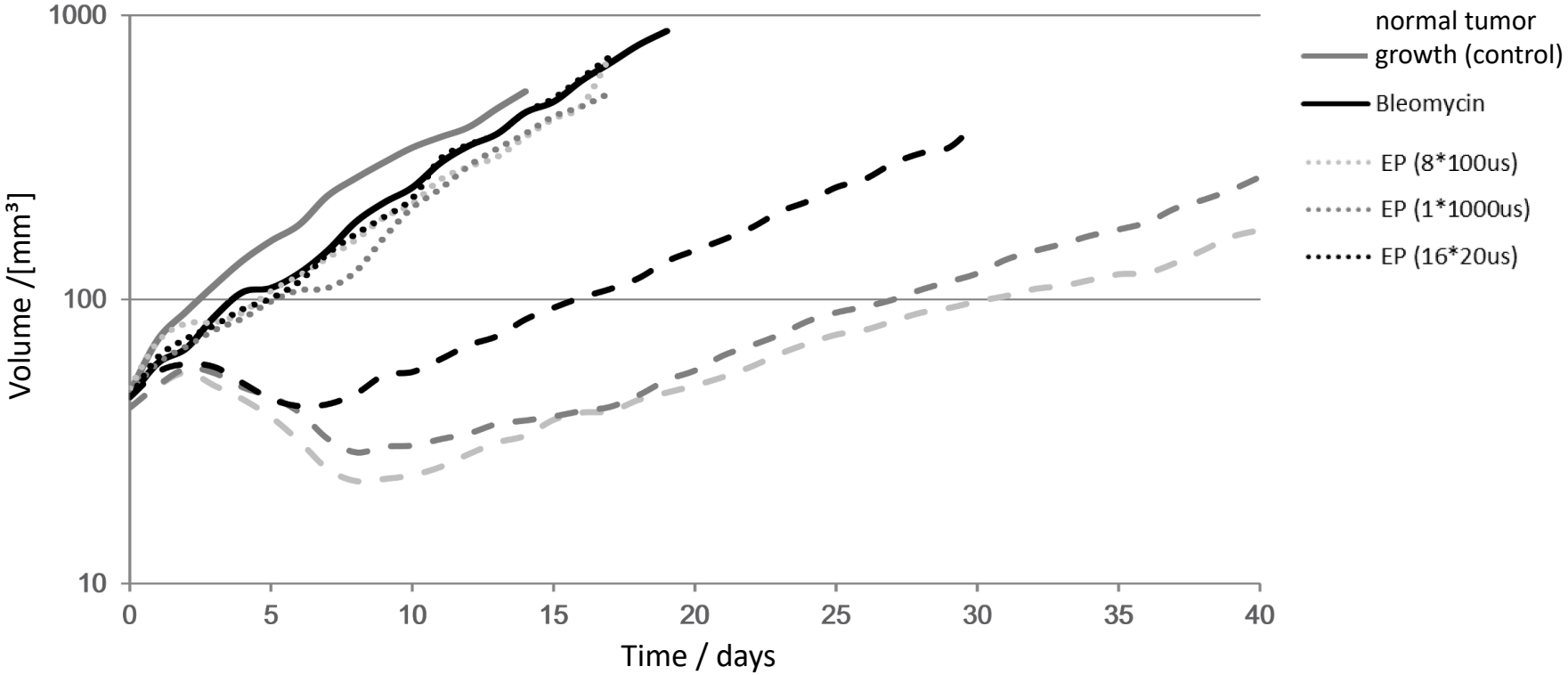

Based on: Optimisation of Pulse Parameters In Vitro for In Vivo Electrochemotherapy, Lebar, Miklavčič, 2002

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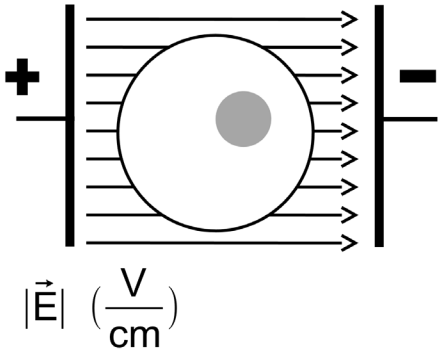

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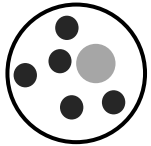

- Apoptosis
- More tumor-specific
- Reduced field strength / bigger ablation areal

[1] Increased Risk of Needle Tract Seeding after Irreversible Electroporation (IRE) of Malignant Liver Tumors, M Distelmaier 2016

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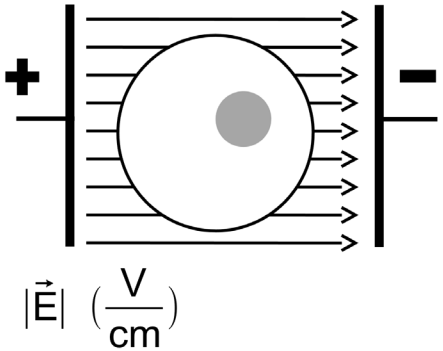

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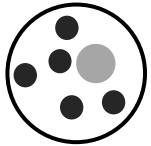

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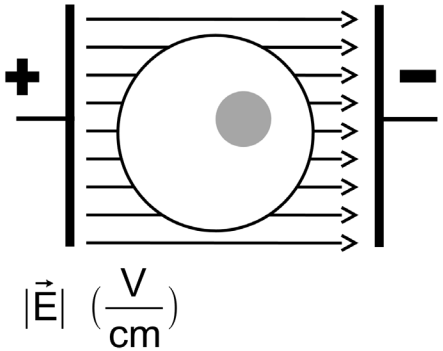

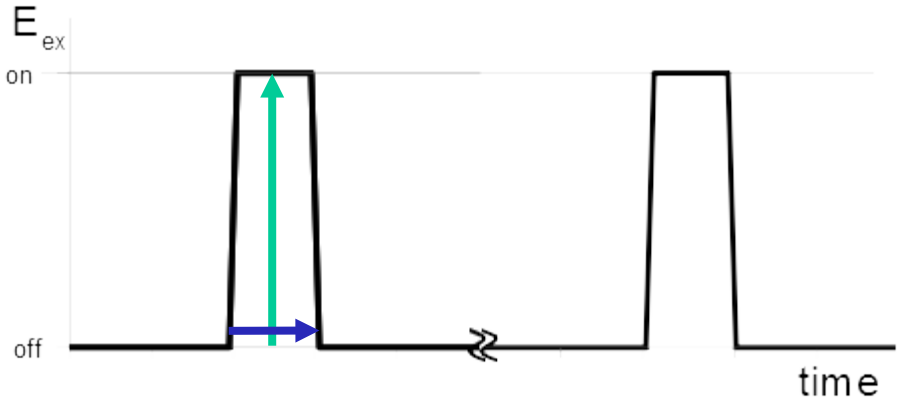

Main parameters: field strength E (Volt / distance), puls width, shape (rect), distance, # of pulses, frequency

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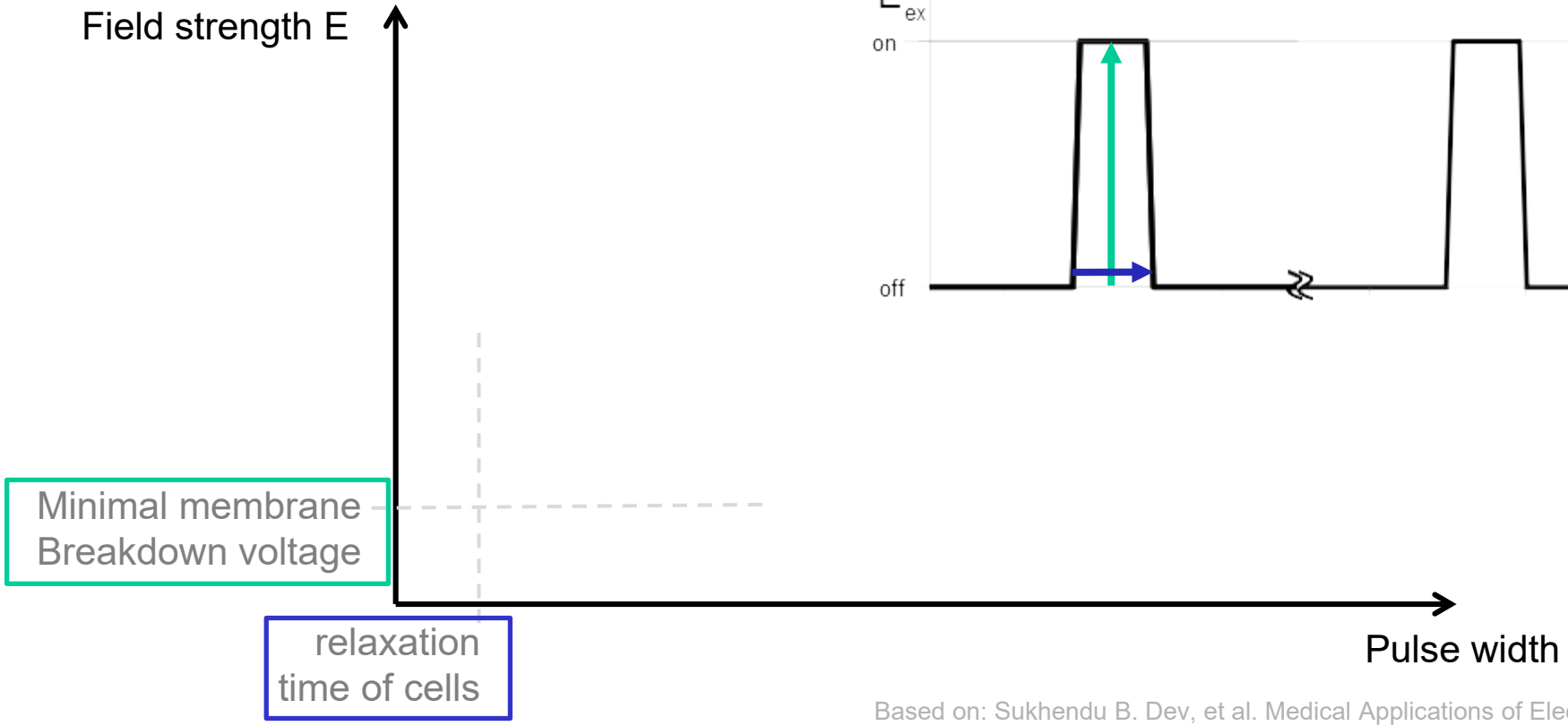

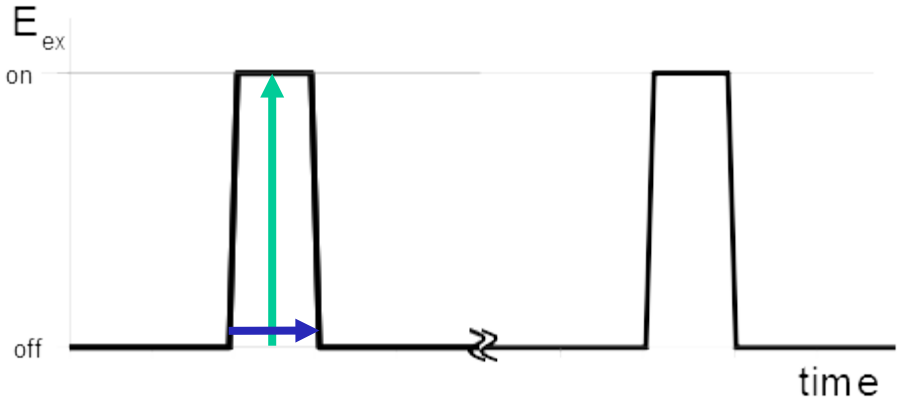

Based on: Sukhendu B. Dev, et al. Medical Applications of Electroporation“
IEEE transactions on Plasma Science 28/1, 2000

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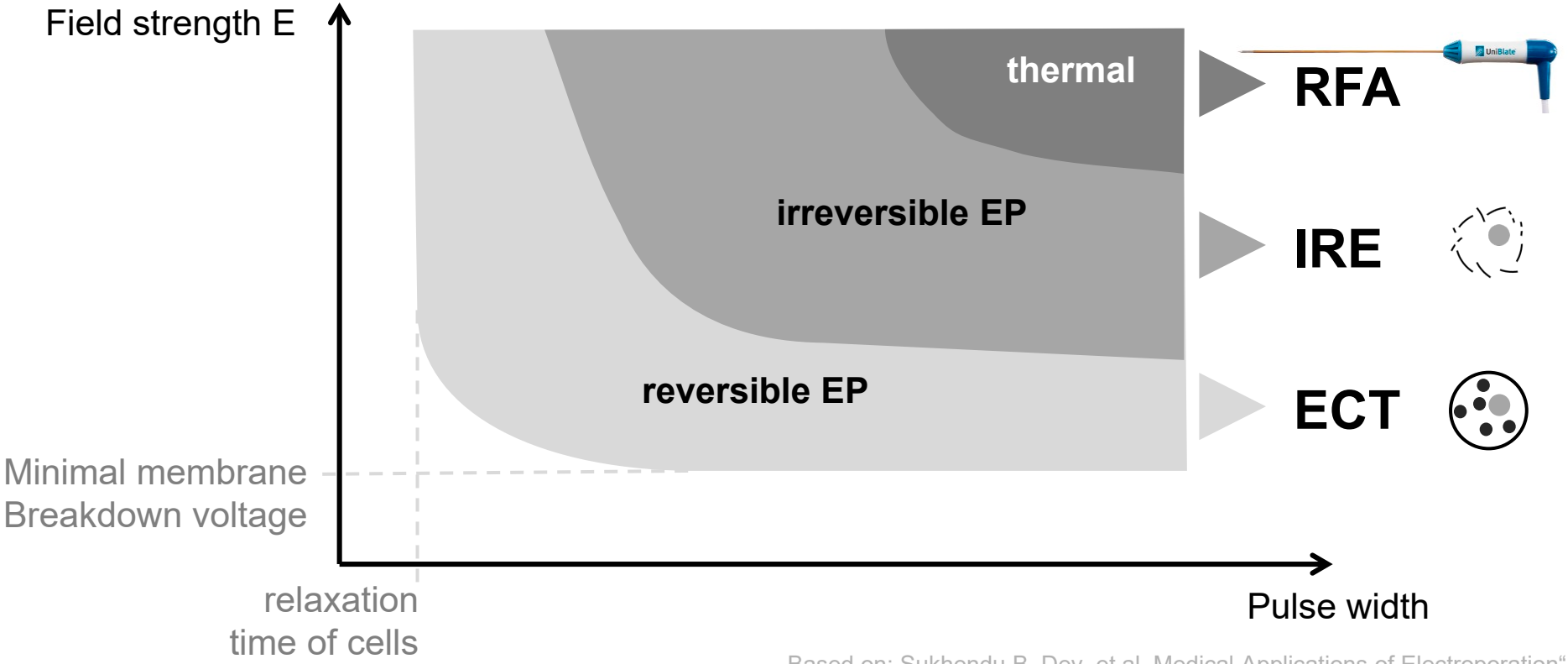

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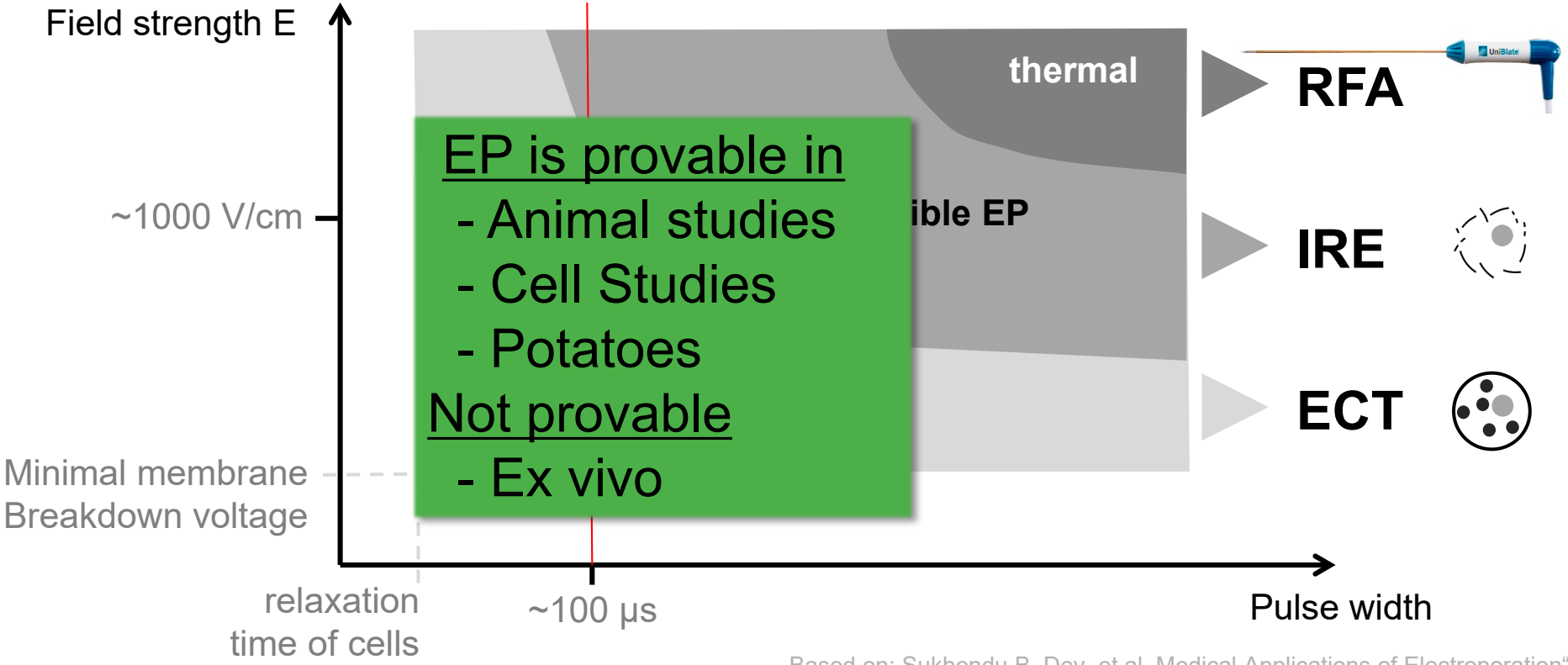

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