

The Invasive Ablation Paradox: An Advocacy Featuring Histotripsy and the Challenges of Modernisation in Ablation

¹Dr. Sayantan Patra, ²Dr. Soumya Suvra Patra, ³Dr. Reetoja Das,

⁴Mrs.Sima Patra (Bhandari)

¹*Assistant Professor, Radiology MBBS, MD, DNB PGMER and Seth Sukhmal Karnani Memorial Hospital, under West Bengal Medical Education Service*

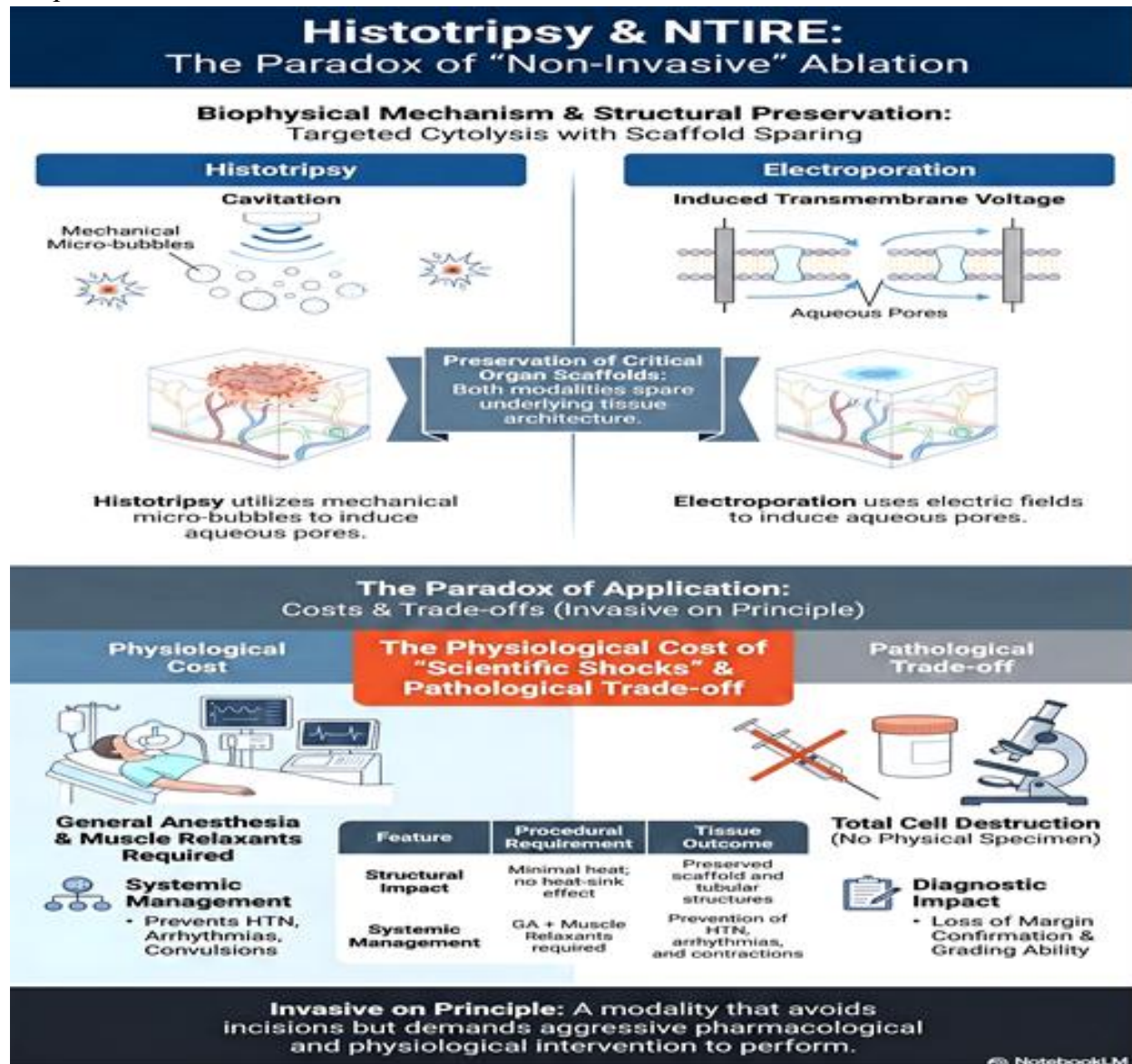
²*Post Graduate Year 2 Resident MBBS PGMER and Seth Sukhmal Karnani Memorial Hospital, under West Bengal Medical Education Service*

³*Senior Resident MBBS, MS, DNB PGMER and Seth Sukhmal Karnani Memorial Hospital, under West Bengal Medical Education Service*

⁴*Principal and Professor Bsc, Msc, PG Dip PGMER and Seth Sukhmal Karnani Memorial Hospital, under West Bengal Medical Education Service*

Abstract—Histotripsy is a mechanical, ultrasound-based ablation technology that utilizes high-pressure pulses to induce acoustic cavitation, liquefying targeted tissue at a sub-cellular level. Similar to non-thermal irreversible electroporation (NTIRE), its clinical philosophy focuses on "scientific shocks" designed to preserve the underlying tissue scaffold and vital structures such as nerves and blood vessels. While marketed as non-invasive, the modality faces significant counterarguments due to its "invasive on principle" nature. Specifically, like NTIRE, the procedure often necessitates general anesthesia and muscle relaxants to prevent complications like muscle convulsions or cardiovascular stress, mirroring the high physiological burden of invasive surgery. Furthermore, the transition to non-invasive destruction removes the possibility of obtaining a physical surgical specimen, leaving clinicians without definitive pathological confirmation of margins or grading. This review evaluates the technical success of such modalities against the clinical and ethical trade-offs regarding their "invasive-on-principle" nature.

Graphical abstract:



I. INTRODUCTION: THE REEMERGENCE OF SCIENTIFICALLY TAILORED SHOCKS

Modern oncology is increasingly moving toward modalities that "preserve organ function". Histotripsy, a mechanical ultrasound-based technology, and NTIRE, an electrical-based technology, represent a shift away from thermal "cook-and-cut" methods. While NTIRE uses extrinsic pulsed electric fields to create transient pores via induced transmembrane voltage (ITV), Histotripsy uses high-pressure ultrasound pulses to create mechanical "micro-bubbles" (cavitation) that liquefy tissue at the sub-cellular level.

II. CLINICAL UTILITY AND TECHNICAL SUCCESS

Both technologies are applied to similar anatomical targets where precision is vital. Evidence from NTIRE demonstrates significant technical success in "blind" or minimally invasive targeting of the liver (86% technical success) and prostate (<0.5% recurrence). These modalities are prized because they preserve the tissue scaffold and vital tubular structures like nerves and blood vessels, which traditional surgery or thermal ablation might destroy.

III. THE COUNTERARGUMENT: THE "INVASIVE ON PRINCIPLE" PARADOX

The core critique of Histotripsy—and non-invasive ablation at large—is that while the *delivery* is non-invasive, the *intent* (tissue destruction) is inherently invasive. This leads to several clinical and philosophical counterarguments:

- **The Loss of Surgical Pathology (Non-source Information):** Unlike surgical resection, non-invasive liquefaction (Histotripsy) or osmolysis (NTIRE) leaves no specimen for a pathologist to re-examine. There is no way to confirm "clear margins" or reassess tumor grading after the fact, potentially leaving "blind spots" in the patient's long-term staging.
- **Physiological Burden of General Anesthesia:** A primary counterargument against the "non-invasive" label is the high physiological cost of these procedures. To prevent complications like cardiac arrhythmias, hypertension, and muscle convulsions, these "non-invasive" treatments often require general anesthesia (GA) and heavy muscle relaxants. From the patient's perspective, the duration of hospital stay is often longer although the site related pain often goes unnoticed.
- **Technical Risks and Major Complications:** The preservation of the scaffold does not eliminate risk. Clinical data on pancreatic NTIRE shows a 10–20% major complication **rate**, including pancreatitis, bile fistulas, and bleeding. The "non-tactile" nature of non-invasive ablation is heavily reliant on imaging, limited by technological know-how and/or human comprehension of technology. The paradigm shift from open to laparoscopic to image guided percutaneous ablation was a justifiable one based on operator experience and advancement of technology. However, these techniques rely more on lesion geometry planning on software which necessitate comprehensive knowledge of software operations rather than hardware. The distinction between ablated and non-ablated area is also very sharp leaving questionable efficacy (at least in terms of time) for adequate A0 margin which remains an inherent drawback.
- **Palliative vs. Curative:** In most cases, these modalities are relegated to palliative intent or downstaging rather than being a primary curative option (contrary to RFA, MWA and Cryoablation, which are considered the primary curative options, even in high Charlson score). The authors can not help but speculate whether the non-invasive nature is a benefit to the patient or a safety valve for the doctor's conscience, upholding the paradigm "something is

better than nothing". Perhaps the best test for these non-invasive techniques would be the test of time.

IV. CONCLUSION: THE FUTURE OF PRECISION BIO-ELECTRIC THERAPY

As technology evolves towards High-Frequency IRE (H-FIRE) eliminating the need for general anaesthesia, the physiological burden on patient (including duration of hospital stay) is expected to decrease. However, the fundamental paradox remains: whether software operation remains the only expertise for the "medicine man" in the not-so-distant future where real-time imaging, real-time needle insertion (conveniently much thinner than an ablation applicator), automated dose calculations and automated multi-session planning becomes a reality. Perhaps its in the best interest of the physicians to embody the "human element", in the best interest of the profession.

V. FIGURES

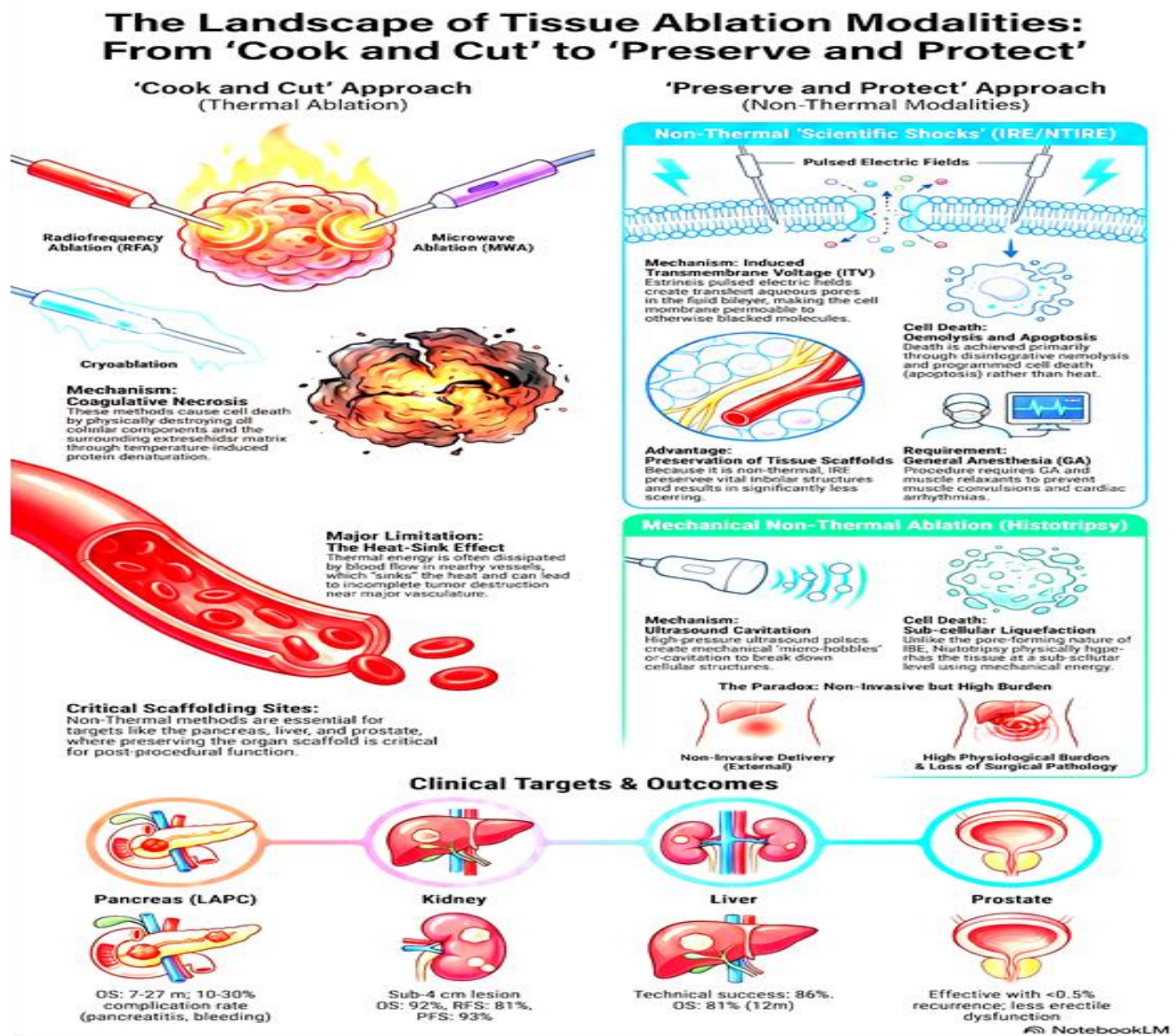


Figure 1: Where does histotripsy stand in the grand scheme of ablations?

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REFERENCES

- [1] Kotnik T, Pucihar G. Induced Transmembrane Voltage—Theory, Modeling, and Experiments. In: Pakhomov AG, Miklavčič D, Markov MS, editors. *Advanced Electroporation Techniques in Biology and Medicine*. Boca Raton (FL): CRC Press/Taylor & Francis Group; 2010. p. 51–70.
- [2] [Internal Document]. *Electroporation: Principles, Applications, and Clinical Perspectives*.
- [3] Pucihar G, Kotnik T, Valič B, Miklavčič D. Numerical determination of the transmembrane voltage induced on irregularly shaped cells. *Ann Biomed Eng*. 2006;34:642-652.
- [4] Schoenbach KH, Beebe SJ, Buescher ES. Intracellular effect of ultrashort electrical pulses. *Bioelectromagnetics*. 2001;22:440-448.
- [5] Kotnik T, Miklavčič D. Second-order model of membrane electric field induced by alternating external electric fields. *IEEE Trans Biomed Eng*. 2000;47(8):1074-1081.
- [6] Pakhomov AG, Pakhomova ON. Nanopores: A distinct transmembrane passageway in electroporated cells. In: Pakhomov AG, Miklavčič D, Markov MS, editors. *Advanced Electroporation Techniques in Biology and Medicine*. Boca Raton (FL): CRC Press/Taylor & Francis Group; 2010.
- [7] Pauly H, Schwan HP. Über die Impedanz einer Suspension von kugelförmigen Teilchen mit einer Schale. *Z Naturforsch*. 1959;14B:125-131.
- [8] Kotnik T, Miklavčič D. Theoretical evaluation of voltage inducement on internal membranes of biological cells exposed to electric fields. *Biophys J*. 2006;90:480-491.