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Commentary

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Cancer: An Electrically Mediated Dysfunction in the Body

Ramesh Singh Chouhan*

International Academy for Medical Sciences, The Regenerate Clinics India, Hyderabad, Telangana, India.

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Cancer is an electrical fault. The voltage across the membrane has to be corrected for the replication of mutating cells to be stopped. The only way to stop cancer is to change the behavior of the cells. Trying to kill cells is a haphazard process with drastic side effects. Like the several systems that exist in the human body, Cancer with its own boundaries may also be considered one such system. Fundamental to this is the cell membrane which separates the internal and external milieu of the cell and interacts with biomechanical, biochemical, and bioelectrical gradients, all of which affect the gene regulatory networks. While the mutation centered models of cancer have dominated our understanding, the importance of the cellular environment is now gaining ground. Cancer is now to be viewed as a developmental disorder of cell regulation, where there is a loss of the organizational capacity of the surrounding environment [1]. That Cancer is a result of bioelectric dysfunction had been proposed by several proponents during the Seventies and Eighties [2, 3]. The membrane potential is critical for many other processes including cell cycle, cell-volume control, proliferation, muscle contraction (even in the absence of an action potential), and wound healing [4] and is highly correlated with mitosis, DNA synthesis, cell cycle progression and overall proliferation in general [5, 6]. Cancer cells exhibit different electrochemical properties and a different distribution of electrical charges than normal tissues [7, 8] as the composition of the membrane proteins become different in cancer cells than normal cells. This directly influences the 'fluidity, permeability and conductivity of the membrane. Lipid peroxidation due to increased production of reactive oxygen species contributes to increased permeability and membrane degeneration which then result in compensatory increase in saturated fatty acids in the membrane [9, 10]. The altered membrane composition and structure of the cancer cells make it more permeable resulting in the moving out of potassium, magnesium and calcium and the corresponding inflow of sodium and

water [11] which produce biochemical changes inside of the cells. The result of these mineral movements, membrane composition changes, energy abnormalities, and membrane charge distribution abnormalities is a drop in the normal membrane potential and a change in membrane capacitance [12, 13, 14, 15]. Regulation of mineral ion concentrations on both sides is an important boundary function of the membrane [16]. The metabolic functions as well as the membrane potential of the cell are affected by the passage of these ions. The dielectric property of the membrane is the key to establish the presence of electric circuits in biological tissues. Membrane potentials play a central role in cellular proliferation. The electrical conductivity and permittivity of cancerous tissue have been found to be greater than that of normal tissue [17]. Most cancers possess an excess of fixed electronegative charges on their surfaces [2]. In fact, tumors were detected based on voltmeter readings [18, 19] and treated to a degree with micro electric currents given directly to the tumor areas [3]. External manipulation of the membrane potentials as possible treatment for cancers led to *in vitro* transformation of cervical squamous cells to pluripotent cells or stem cell like cells [20]. Semiconducting proteins and extracellular matrix proteoglycans and their associated electrical charges contribute to the innate conductivity of a tissue. The degree of tissue acidity, tissue hypoxia, availability of electron donors such as antioxidants, and the presence of electrophilic compounds on the cell membrane and in the extracellular matrix all affect the electrical properties of tissues. The increased conductivity of cancer cells can be attributed to all of the above. Negatively charged molecules such as phosphatidylserine, heparin sulfate and sialic acid are more abundant on cancer cell membrane surfaces compared to normal cells. The negative charge is also augmented because cancer cells have more microvilli creating a larger surface area than normal cells. These charges create an electrical defense shield, provide a protective barrier against the immune system and facilitate migration and invasion [21]. Because immune defense cells such as NK cells and macrophages also have a negative surface charge, these cells are repulsed by the strong negative electrical field of cancer cells when they try to approach and terminate cancer cells [8, 22, 23]. Because cancerous cells demonstrate greater permittivity, which is the ability to resist the formation of an electrical field they will respond to external electrical fields differently from normal cells. Healthy cells have a membrane potential of about -60 to −100mV. When cancer cells begin cell division and DNA synthesis the membrane potential falls to around −15mv. Since the membrane potential in a cancer cell is consistently weaker than the membrane potential of a healthy cell, the electrical field across the membrane of a cancer cell will be reduced. The reduction in membrane electrical field strength will in turn cause alterations in the metabolic functions of the cell. Exposure to electric and electromagnetic fields affect the membrane potentials of cells and depending on the quantity of exposure, the field strength and frequency. The changes can be temporary or permanent to the cell resulting in alteration of the cell membrane composition, the ionic composition, biochemical influx and eflux and metabolic functions. The result is the abnormal cell and the conglomeration of diseases called CANCER.

In conclusion, Antoine Beauchamp "the biological terrain of the being is the cause of disease" is the view to go.

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