Diamagnetic Effects of Blood in a Magnetically Levitated Blood Pump

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Magnetic bearings are becoming increasingly popular in ventricular assist devices. In most cases, blood fills a portion of the gap between the magnetic actuators and rotor. Understanding the effects of the operating fluid on magnetic suspension is necessary, particularly when the device geometry features a relatively large gap (typically defined as greater than 150 um and as large as 2 mm in some pumps). A large gap reduces cell damage and allows unrestricted flow, it but increases the distance and amount of material through which magnetic fields must pass. These net effects of the operating fluid on the magnetic suspension can be characterized in terms of a contribution to the overall damping and stiffness of the system. This contribution may be caused by traditional tribological properties (density and viscosity) as well as the magnetic properties of the medium. This research isolates the effects of fluid diamagnetism on a magnetically levitated blood pump. Experimental transient and frequency responses of the system operating at 3000 to 6000 rpm are presented while pumping different liquid media: Blood, water, and fluids with similar densities and viscosities to each, but different magnetic susceptibilities. In order to calculate the stiffness and damping coefficients, a mathematical model of the system is iteratively updated to match experimental transient response. The resulting coefficients are validated in the frequency domain by means of simulations, which agree with experimental frequency response data. The relationship between diamagnetism, damping and stiffness coefficients of the test fluids with known magnetic susceptibility is also used to obtain a quantitative estimate of the magnetic susceptibility of blood.

Pre-Clinical Evaluation of Direct Current Ablation for the Treatment of Benign Prostatic Hyperplasia

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Benign Prostatic Hyperplasia (BPH) is a non-cancerous growth of the prostate gland affecting about 50% of the men over age 50. As men age, the prostate continues to grow leading to increased prostate volume, which may cause lower urinary tract symptoms (LUTS). These symptoms can include the inability to completely empty the bladder, urine retention, and a profound sensation of urgency. Direct Current (DC) ablation may be applied to treat these symptoms as a minimally-invasive alternative to surgery, medication, or thermal ablation, by causing tissue necrosis within the lateral lobes of the prostate. The objective of this study was to evaluate the effects of DC ablation in canine prostates by investigating how the resulting necrosis would change the macrostructure of the prostate for the potential treatment of symptomatic BPH. DC ablation is achieved by passing direct current through two electrodes in tissue, causing the formation of hydrogen ions at the anode and hydroxyl ions at the cathode. These ions diffuse through the tissue causing a pH of ~1 at the anode, and ~13 at the cathode. The extreme anti-physiological pH regions cause cellular necrosis and form in a predictable manner that is directly proportional to the charge delivered. The controlled shape and size of the lesions allow for predictable necrotic zones and enable treatment optimization. Treatment was performed on 6 acute and 8 chronic canine subject by performing a laparotomy and inserting electrodes through the prostate capsule. Acute subjects were sacrificed before recovery, while chronic subjects were sacrificed after 1, 3, 20, 40, and 60 days to investigate the healing cascade of the prostate after treatment. The chronic subjects were monitored for changes in urination or defecation patterns. Urine and blood samples were collected to evaluate the subjects' health throughout the study. Both macro-visual and pathological analyses were done to evaluate tissue response all acute and chronic subjects. Cellular necrosis within the prostate was significant and exhibited a dose response within the range of 0.07 to 0.10 /coulomb for each electrode pair. The does response is defined as the ratio of necrotic tissue created, to charge delivered. Necrotic prostate cells resulted in voids with minimal scar tissue and a visible reduction in prostate mass. The treatment followed tissue planes constraining necrotic zones to the region between the prostate capsule and prostatic urethra. Both normal and hyperplastic tissues were treated and exhibited necrosis. No necrosis was observed outside the prostate. DC ablation has been demonstrated to create well-defined, predictable, and repeatable regions of cellular necrosis and structural changes in canine prostates. This technology may offer promise for the treatment of symptomatic BPH with an appropriately designed delivery system. Other potential applications include other benign and malignant tumors within the body.