Visualization and Hemo-Dynamic Evaluation of Edge-to-Edge Mitral Valve Repair Within Reanimated Swine Hearts

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This project aims to investigate the performance of edge-to-edge mitral valve repair (MVR) within reanimated swine hearts. Direct imaging and hemodynamic data of the mitral valve during normal cardiac function (Normal), after an induced prolapse (Prolapse), and post surgical repair (E2E) was obtained. Isolated swine hearts (n=6) were reanimated using a clear Krebs–Henseleit buffer. Mitral prolapse, and regurgitation, in the P2 region was induced by cutting chordae tendinae of the posterior leaflet. An edge-to-edge MVR procedure was performed, suturing the prolapsed P2 region to the A2 region of the anterior leaflet. The mitral valve was imaged using endoscopic cameras in the left atrium and ventricle allowing verification of stitch placement and leaflet coaptation. Analysis of the endoscopic images provided measures of annulus area, orifice area, and regurgitant area. Echocardiography, the standard clinical imaging modality, was used to determine the hemodynamic performance of the valve. Additionally, ECG and left chamber pressures were recorded at a sample rate of 5 kHz. Prolapse of the P2 region was consistently created, and edge-to-edge repair of the mitral leaflet showed full leaflet coaptation. The annulus area of the valve was tracked throughout the procedure and did not show significant variation. The orifice area, defined as the area of the annulus that does not contain leaflets, normalized to the corresponding annulus area for Normal, Prolapse and E2E were: $41 \pm 13\%$, $44 \pm 14\%$ and $21 \pm 13\%$, $p=0.02$. The regurgitant area, normalized to the corresponding annulus area, increased from $2 \pm 2\%$ for Normal to $8 \pm 3\%$ for the Prolapse and then decreased to $1 \pm 1\%$ for the E2E group. The regurgitant fraction, normalized against the maximum observed, for Normal, Prolapse and E2E was $10 \pm 6\%$, $57 \pm 26\%$ and $13 \pm 13\%$, $p<0.01$. Over the course of the experiment the left ventricular (LV) systolic pressure and negative dP/dt reduced from 95 to 54 mm Hg and 743 to 402 mm Hg/s, respectively. Our results show that orifice area was significantly smaller after MVR when compared to Normal and Prolapse periods. There was no significant change in regurgitant area and regurgitant fraction from the Normal to repaired valve as compared to a significant increase in regurgitant area and regurgitant fraction during Prolapse. Low gradients were observed for all three groups, with no indications for symptomatic stenosis. The reduction of LV function was caused by global ischemia and the progressive onset of edema. In this acute assessment of edge-to-edge repair of P2 prolapse, repair does not affect annulus area, decreases orifice area, and successfully eliminates regurgitant area with no evidence of mitral stenosis.

Use of Colloidal Graphite Coating to Reduce Magnetic Resonance Imaging Artifacts Caused by Metallic Objects

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Magnetic susceptibility mismatch, between human tissue and a foreign metallic object, is one of several factors responsible for image distortions in magnetic resonance imaging (MRI). Combining diamagnetic materials such as bismuth or carbon with paramagnetic materials such as nitinol or titanium can reduce the mismatch in bulk susceptibility of a foreign object and the surrounding tissue. Muller-Bierl et al. have succeeded in reducing MRI field distortion by coating titanium wire with bismuth. Wilson et al. used a pyrolytic graphite mouth shim to improve brain functional MRI performance. Conolly et al. have successfully used pyrolytic graphite in foam to reduce image artifacts at air-tissue interfaces. In this study, it was hypothesized that coating a metallic object with carbon particles suspended in a polymer can reduce the size of image artifacts. Four 6Al-4V titanium discs ($2.3\ \text{mm} \times 9.5\ \text{mm} \varnothing$) were encapsulated in an epoxy-graphite mixture. Mixtures of graphite and epoxy were poured around the titanium discs in molds and allowed to cure. A specimen of titanium was encapsulated in plain epoxy to serve as the control sample. Polycrystalline graphite was mixed at mass ratios of 1:2 and 1:1 to epoxy for two of the samples. Pyrolytic graphite flakes were mixed at a 1:2 mass ratio to epoxy. The sample discs were placed in an aqueous solution of copper sulfate and gadolinium contrast agent inside a wrist imaging coil at the isocenter of a 3 Tesla MRI machine; disc axes were perpendicular to the B_0 direction. A T2-weighted gradient echo MRI image was taken in the coronal plane. Echo time, relaxation time, flip angle, and phase encode direction set to 71 ms, 3430 ms, 80 degrees, and right to left respectively. The control sample produced an arrowhead artifact sweeping in the same direction as the static magnetic field vector, B_0. The two samples containing powdered polycrystalline graphite produced arrowhead shaped artifacts. The direction of image distortion, however, was opposite from that of the control sample. The change in direction of the image artifact is attributed to the change in bulk magnetic susceptibility of the sample from paramagnetic behavior of titanium encapsulated in plain epoxy to a diamagnetic behavior from the added carbon powder. The titanium sample encapsulated in the pyrolytic graphite-epoxy mixture produced an artifact with irregular outline and no discernable directional bias relative to B_0. The hypothesized cause for this difference in artifact shape between the polycrystalline and pyrolytic graphite samples is an increase in air bubble entrapment due to the planar structure of the pyrolytic graphite flakes during the epoxy mixing process. Further study is underway to find a specific carbon-polymer mass ratio and coating thickness that will reduce MR image artifacts that would otherwise appear due to the presence of a metallic object in the MRI region of interest. This work is supported by MIMTeC, a National Science Foundation Industry University Collaborative Research Center and by NIH Grant P30NS057091.